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Growth Patterns of Area, Yield, and Productivity of Major Fruit Crops in Assam: An Analysis Using Vector Autoregression

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Abstract

Fruit cultivation holds a crucial place in Assam's agricultural economy, supporting both rural livelihoods and nutritional needs. The research work analyses the growth dynamics of area, production, and productivity of nine major fruit crops, viz., banana, pineapple, papaya, orange, guava, Assam lemon, litchi, jackfruit, and mango, over the period 2010 to 2024. Using secondary data from the Statistical Handbook of Assam, the study applies the Compound Annual Growth Rate (CAGR) analysis to trace growth patterns, and the Vector Autoregression (VAR) model to identify key determinants influencing fruit crop productivity. The CAGR results reveal considerable variability in the area, production, and productivity of fruit crops in Assam from 2010 to 2024. While guava demonstrated significant increases in both cultivable area and productivity, mango exhibited the maximum growth in production. Furthermore, the results of the VAR model show that cropping intensity and fertiliser consumption have a positive and significant impact on productivity, while irrigation intensity affects it negatively, indicating a bias towards rice-focused irrigation practices in the state. The scope of the study is far-reaching, offering valuable insights for enhancing productivity, promoting sustainable agricultural practices, and strengthening the role of horticulture in Assam's rural development.

Keywords: Fruit cultivation, panel data, CAGR, VAR model

1 Introduction

Agriculture is the cornerstone of Assam's economy, providing support for the livelihoods of many rural residents and significantly contributing to the socio-economic framework of the state. (Upadhyaya, 2022). Within this domain, fruit cultivation emerges as a critical sub-sector, distinguished by its economic significance, nutritional value, and potential for both domestic consumption, and export markets (Egorov *et al.*, 2021; Szymańska *et al.*, 2021). Assam is renowned for its diverse fruit crops, including bananas, pineapples, citrus fruits, guavas, and papayas, which collectively contribute substantially to the state's agricultural gross domestic product. These crops not only provide a steady income source for thousands of smallholder farmers but also address nutritional deficiencies prevalent among the population, making them indispensable to the region's food security and public health (Sarma *et al.*, 2025). The impetus for this paper stems from the necessity to comprehensively examine the area under cultivation, total production, and productivity per hectare of these major fruit crops. Such an analysis is vital for mapping their current status and tracing growth trajectories. Productivity and profitability in this sector are increasingly threatened by a range of factors, including climate change, soil degradation, pest and disease pressures, limited access to modern agricultural technologies, and inefficiencies in market infrastructure. These issues underscore the urgency of adopting sustainable practices to safeguard and enhance fruit cultivation in Assam. Therefore, the aims of the study are: (a) to analyse the recent growth dynamics of nine major fruit crops in Assam; (b) to identify the determinants of fruit crop productivity in Assam. The document is structured into five parts, starting with the introduction. The second part offers a concise review of relevant literature concerning how fruit crop farming contributes to increasing the income of agricultural communities. The third part presents the specifics of the data sources and methodologies employed in the research. The study's results are discussed in the fourth part. Finally, the fifth part emphasises a conclusion of the key findings. This study is expected to offer valuable insights for policymakers, agricultural scientists, and farmers, facilitating improved crop management, technology adoption, and market integration. Hence, the research is both timely and essential for fostering sustainable agricultural development and economic resilience in the state.

2 Review of literature

Cultivation of fruits can significantly raise the farmers' income and bring them above the poverty line. Moreover, fruit cultivation also improves the nutritional status of the people and reduces the gap between health and efficient use of natural sources of nutrients (Navia *et al.*, 2020; Oladele, 2011). Although India has achieved the goal of food security, the nutritional security or the mitigating the hidden hunger is yet to fulfil. The rural part of India suffers from nutrition and micronutrient deficiencies, poverty, and unemployment. Agriculture, being traditional in the country, suffers from several agricultural distress. The agricultural sector is characterised by inadequate irrigation facilities, lack of power supply, lack of research and extension facilities, lack of working capital, poor management, post-harvest loss, irrupted market condition, limited access to credit, and adoption of improper technology. As a result, the farmers, particularly marginal and small farmers, incur either low profits or even losses from cultivation and remain in mass poverty. Nandal and Bhardwaj (2014) have used the term 'underutilised horticultural crops', which includes various tropical fruit trees in India that are high in nutrition but neither grown commercially on a large scale nor traded extensively. These underutilised fruit crops can essentially help in solving the problems related to health and nutrition, poverty and unemployment perceived in rural India. India is a vast country characterised by various agro-ecological situations that are suitable for numerous fruits. These fruits are whole of micronutrient. Further, as the country's per-capita income grows, people shift their consumption preference toward highly nutritious horticultural crops rather than only demand cereals and pulses. Fruits have a high scope of value addition activities, particularly for micro and small enterprises based on food processing activities. Therefore, fruit cultivation, along with adopting suitable modern technology, can ensure food and nutritional security and improve the livelihood of the farming communities (Aworh, 2015). In addition, the North-East Region of India is rich in various types of fruit crops. The region mostly follows the pure organic method of cultivation of fruits. However, the region's productivity lags well behind the national average, which can be improved by implementing appropriate agro-techniques. The primary importance should be given to preserve the nutrient properties of these underutilised fruit crops (Bhattacharyya & Das, 2018).

3 Data and methodology

3.1 Data source

The present study is based on secondary data collected from the Statistical Handbook of Assam from 2010 to 2024. Data on various aspects such as area, production, yield of major fruit crops in Assam, as well as irrigated area, rural road length, institutional rural credit, and fertiliser consumption have been compiled for the analysis.

3.2 Methodology

3.2.1 Methodology to assess the growth trends of area, production and yield of fruit crops

The Compound Annual Growth Rates (CAGR) has been estimated to analyse the growth trends of area, production and productivity of nine major fruits crops in Assam, viz., banana, pineapple, papaya, orange, guava, assam lemon, litchi, jackfruit, and mango. Following (Das *et al.*, 2007), the CAGR is calculated as:

$$Y_t = Y_0(1+r)^t \qquad (1)$$

Where, Y_t is area or production or yield in the current year, Y_0 is area or production or yield in the base year, r is percentage growth rate of area or production or yield, and t is time period. Taking the natural logarithm of the equation (1), r is evaluated.

3.2.2 Methodology to determine the factors that impact the fruit crop productivity

To ascertain the factors influencing fruit crop productivity, a multivariate panel data model, viz., the Vector Autoregression (VAR) is used in the study. The VAR model with k endogenous variables and p lags in matrix notation is specified as

$$y_t = V + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \varepsilon_t \qquad (2)$$

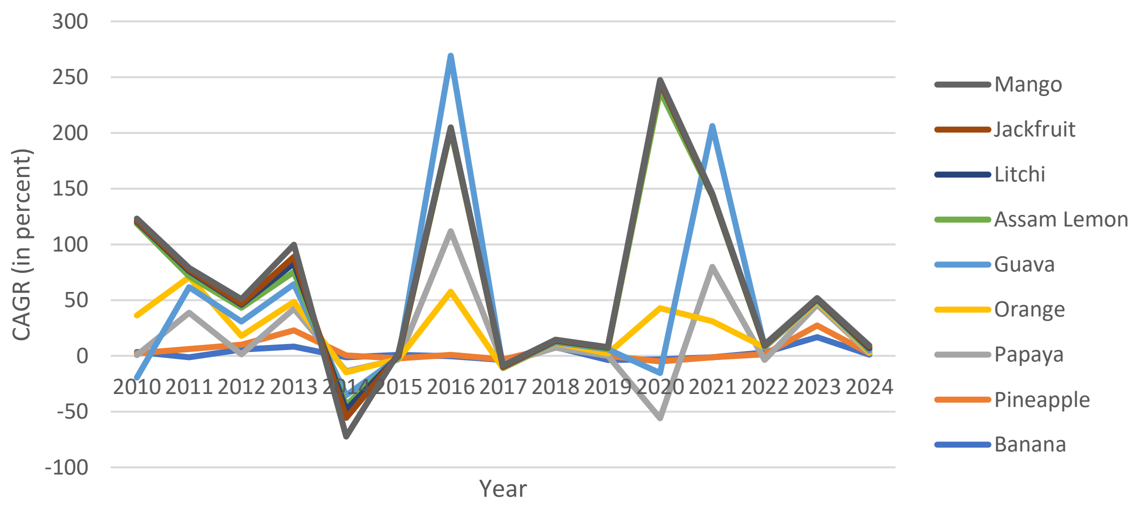
Where, y_t is the vector of dependent variable at time t, and y_{t-1}, y_{t-2},…., y_{t-p} are its lagged and ε_t are $k \times 1$ vectors. $A_1, A_2, \dots, A_p$ are $k \times k$ coefficient matrices. In this model, we use the fruit crop productivity as the dependent variable and independent variables are cropping intensity, irrigation intensity, road intensity, institutional rural credit, and fertiliser consumption.

4 Results and Discussion

4.1 Growth trend analysis of nine major fruit crops in Assam: The CAGR assessment

The primary objective of the study is to assess the growth dynamics of area, yield, and productivity of major fruit crops in Assam between 2010 and 2024. Figure 1 shows the Compound Annual Growth Rate (CAGR) of the area under cultivation for nine major fruit crops in Assam from 2010 to 2024. The figure presents how the land area for each crop has expanded or fluctuated over the period. It is seen that during the period 2015 to 2017, guava registered the highest growth in cultivated area, followed by mango, papaya, and orange, all of which exhibited strong positive growth trends. A subsequent rise has been observed between 2019 and 2022, when mango, guava, papaya, and orange reached a notable peak in acreage expansion, indicating a clear shift in farmer preference and increasing market demand across Assam. In contrast, other fruit crops such as banana, pineapple, Assam lemon, litchi, and jackfruit recorded only moderate positive growth in area under cultivation. The plausible reasons for these observations are the growing popularity of guava, mango, papaya, and orange may be linked to their shorter time to harvest, greater yield capacity, and enhanced adaptability to the region's agro-climatic environment. Additionally, these fruits enjoy strong consumer demand in both local and regional markets, offering farmers better price realisation compared to traditional crops like banana and jackfruit. Government initiatives promoting horticultural diversification, improved access to quality planting material, and the rising interest in orchard-based farming systems may have further encouraged farmers to expand the cultivation of these crops. On the other hand, fruits like banana and pineapple, though important in the state's fruit sector, often face constraints such as post-harvest losses, fluctuating market prices, and high perishability, which may have limited their expansion relative to guava, mango, papaya, and orange.

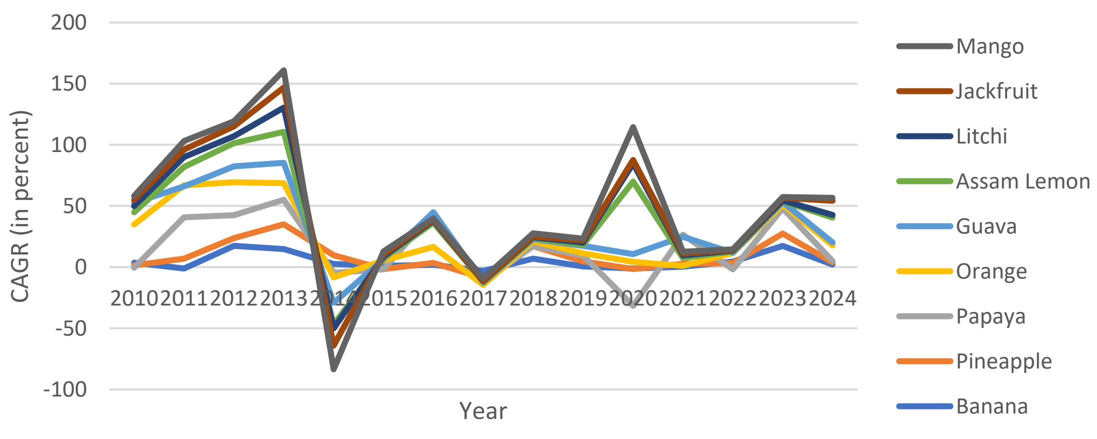
Fig. 1: CAGR trend of area under nine selected fruit crops in Assam, 2010 to 2024



Source: Statistical Handbook of Assam, Directorate of Statistics and Economics, Assam, 2010-2024

Figure 2 presents the Compound Annual Growth Rate (CAGR) of production for nine major fruit crops in Assam from 2010 to 2024, highlighting the dynamic shifts in fruit crop performance over time. Between 2010 and 2013, all selected fruit crops recorded a positive growth trajectory, with mango leading the growth rate, followed by jackfruit, litchi, Assam lemon, guava, orange, papaya, pineapple, and banana. This reflects the growing importance of fruit-based farming systems in Assam's agrarian economy, largely supported by favourable climatic conditions, increasing farmer participation in horticultural schemes, and expanding consumer demand in both domestic and cross-border markets. However, the period 2014 to 2016 witnessed a downturn, with most crops showing negative growth in production, the steepest decline being in mango. This stagnation could be attributed to several agricultural economic factors, such as erratic rainfall patterns, pest infestations, and limited access to post-harvest infrastructure. Additionally, fluctuating market prices and inadequate marketing channels during this period may have discouraged farmers from maintaining large-scale orchard management, thereby depressing growth trends. Interestingly, between 2019 and 2021, production of mango, jackfruit, litchi, and Assam lemon rebounded strongly, showing a peak in growth. This recovery may be explained by targeted government interventions under horticultural development programs (such as Horti Vision 2020), improvements in input delivery systems, and rising market linkages with neighbouring states, viz., Mizoram, Manipur, Kolkata, and Maharashtra. Mango and litchi, in particular, benefit from high consumer demand and favourable price realisation, encouraging farmers to reinvest in orchard management. Jackfruit and Assam lemon have also gained commercial momentum due to their growing use in food processing and value addition, enhancing their economic viability. In contrast, guava, orange, pineapple, and banana registered only marginal growth, while papaya experienced a negative growth rate during this same period. These trends may be linked to crop-specific vulnerabilities. Papaya, being highly sensitive to unpredictable weather fluctuations and pests, faces greater production risks. Similarly, pineapple and banana suffer from high post-harvest losses and weak storage and transport facilities, limiting their competitiveness despite steady consumer demand. For orange, issues of declining orchard productivity and soil related challenges in certain parts of Assam may have constrained growth.

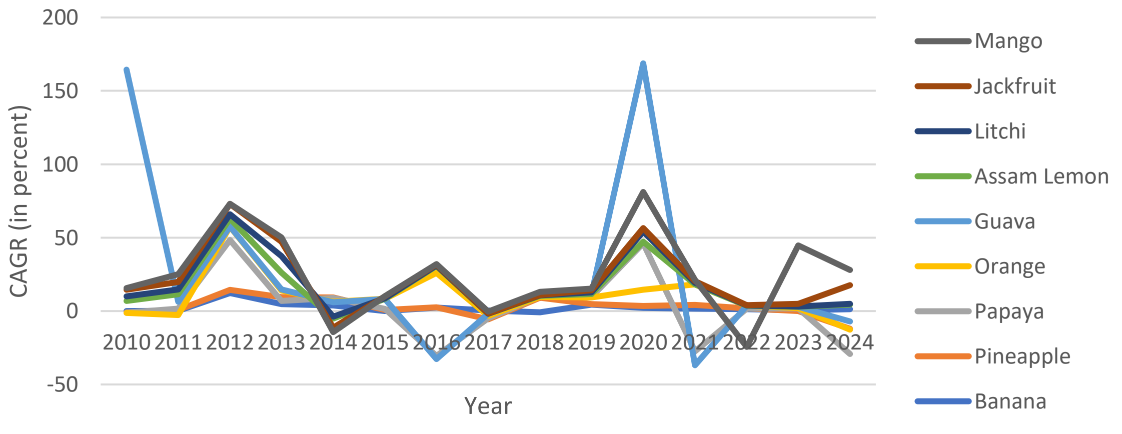
Fig. 2: CAGR trend of production of nine selected fruit crops in Assam, 2010 to 2024



Source: Statistical Handbook of Assam, Directorate of Statistics and Economics, Assam, 2010-2024

Figure 3 presents the Compound Annual Growth Rate (CAGR) of productivity for nine major fruit crops in Assam from 2010 to 2024, illustrating the changes in yield per hectare over time. The analysis reveals that, although productivity trends across most fruit crops exhibited frequent fluctuations during this period, guava stands out with particularly sharp variations. Its productivity declined significantly between 2010 and 2011, and it even recorded a negative growth rate in 2016. This was followed by a sharp increase in 2019 and 2020, before falling steeply again in 2021 and 2022. Post-2022, guava productivity has shown only a marginal recovery. The probable explanation of such volatility in guava productivity can be attributed to a combination of biotic, climatic, and market related factors. The sharp declines in productivity during 2010 to 2011 and 2016 may be linked to pest infestations, fruit fly attacks, and disease outbreaks, which are common challenges for guava cultivation in Assam. Moreover, inadequate extension support and poor adoption of scientific orchard management practices among smallholder farmers might have aggravated yield losses. The sharp rise in productivity during 2019 and 2020 could reflect favourable climatic conditions, improved use of high yielding varieties, and increasing farmer awareness of plant protection measures under horticultural development schemes. However, the subsequent fall in 2021 and 2022 may have been influenced by extreme weather variability, such as heavy rainfall and flooding in key guava growing areas, which often damage fruit bearing trees and reduce productivity. The marginal recovery after 2022 suggests that while guava cultivation continues to hold economic significance in Assam, its productivity remains highly unstable compared to other fruit crops. This underlines the need for strengthening crop management practices, promoting resilient varieties, and improving post-harvest handling to stabilise yields and enhance the profitability of guava cultivation in the state.

Fig. 3: CAGR trend of productivity of nine selected fruit crops in Assam, 2010 to 2024



Source: Statistical Handbook of Assam, Directorate of Statistics and Economics, Assam, 2010-2024

4.2 Factors determining fruit crop productivity in Assam: The VAR model estimation

An additional important objective of the research is to evaluate the factors that influence fruit crop productivity in Assam. To achieve this goal, the VAR model has been employed. The methodology is described in detail in the previous section of the paper. Additionally, Table 1 provides an overview of the variables used in the VAR model.

Table 1: Description of the variables used in the VAR model	
Variables	Description
FCP	Fruit crop productivity (dependent variable) measured as the ratio of Total fruit production (in metric tonnes) to Gross Cropped Area (in hectare)

CI	Cropping intensity measured as the ratio of Gross Cropped Area (in hectare) to Net Sown Area (in hectare), multiplied by 100.
II	Irrigation intensity measured as percentage share of irrigated area to Gross Cropped Area.
RI	Road intensity measured by length of rural roads (in km) to per hectare Gross Cropped Area.
ICr	Institutional rural credit (Scheduled Commercial Bank and Regional Rural Bank taken together) measured by bank credit (in INR crore) per hectare of Gross Cropped Area.
FERT	Fertiliser consumption measured by consumption of fertiliser (in kg) per hectare of Gross Cropped Area.
Source: Author	

Before estimating the Vector Autoregression (VAR), it is helpful to understand the statistical characteristics of the variables incorporated in the model. Table 2 presents the descriptive statistics for the variables used in the VAR model. It shows that the average productivity of fruit crops per hectare of gross cropped area is 0.51, implying that for each hectare of farmland, the yield of fruit crops is 0.51 metric tonnes, during a period of 15 years between 2010 and 2024. This relatively low figure suggests there is significant potential for improving fruit cultivation in Assam. Furthermore, the mean cropping intensity is 145.35 percent, meaning that the gross cropped area is about 1.45 times the net sown area. In simple terms, on average, each hectare of cultivable land is cropped about 1.45 times in a year. These results illustrate a reasonably effective use of land and the implementation of multiple cropping practices, which contribute to enhancing production and creating job opportunities. The average irrigation intensity is found to be 4.80 percent, signifying low irrigation coverage and dependence on rain-fed agriculture, making the sector vulnerable to climate variability and erratic monsoons. Additionally, the mean road intensity is 1.01 km per hectare of gross cropped area, suggesting strong rural connectivity, which is generally favourable for agricultural development. It can lead to higher efficiency, profitability, and rural welfare, provided it does not excessively reduce cultivable land. On average, the institutional rural credit provided is INR 0.02 crore for each hectare of gross cropped area, indicating that farmers can access around INR 2 lakhs for every hectare they cultivate. These results imply a reasonable influx of formal credit into agriculture, which promotes modernisation, reduces reliance on informal sources, and may enhance profitability and efficiency. Nevertheless, the actual effect hinges on fair distribution, proper usage, and the repayment ability of farmers. Moreover, the average fertiliser consumption is 0.06 kg per hectare of gross cropped area, implying very low adoption of chemical inputs, which constrains productivity and keeps agriculture at a subsistence level. While this may have environmental benefits, it also underscores the need for policy interventions to encourage balanced nutrient use and modernisation of farming practices in Assam.

Table 2: Descriptive statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
FCP	0.51	0.09	0.36	0.67
CI	145.35	2.76	139.44	148.59
II	4.80	0.99	3.55	6.47
RI	1.01	0.18	0.75	1.34
ICr	0.02	0.01	0.01	0.03
FERT	0.06	0.01	0.05	0.07
Source: Statistical Handbook of Assam, Directorate of Statistics and Economics, Assam, 2010-2024				

It is important to mention that prior to estimating the VAR model, the Augmented Dickey-Fuller test is applied to assess the non-stationarity of the model, and a differencing technique is used to ensure the series is stationary. The study employs the Akaike Information Criterion (AIC) to identify the optimal lag length. Additionally, to diagnose the model, the Durbin-Watson statistic is used to check for the presence of autocorrelation, while the Granger Causality Wald test is conducted to analyse variations in the dependent variable. The result of the VAR estimation is shown in table 3. It is seen that the cropping intensity (CI) has a positive and significant impact on the fruit crop productivity at 1 percent level of significance. This indicates that an increase in cropping intensity correlates with an increase in the productivity of fruit crops in the state of Assam. The rationale behind this observation is that greater cropping intensity results in more output per hectare and enhances resource utilisation for producing various crops, which, in turn, increases the likelihood of diversifying crop production toward high-value fruit crops. However, irrigation intensity (II) has a significant negative coefficient at the 1 percent level. This suggests that increased irrigation intensity associates with diminished productivity in fruit crops. These results imply that irrigation facilities are primarily concentrated in rice fields within the state, leading farmers to focus more on rice production and to diversify less into fruit crops. Lastly, fertiliser consumption (FERT) has a positive and significant coefficient at a 1 percent level of significance. This indicates that as fertiliser consumption per hectare increases, the productivity of fruit crops also rises. This outcome is anticipated, as an additional unit of fertiliser contributes to greater incremental yield, thereby boosting the overall productivity of fruit crops. Adequate fertiliser application guarantees a balanced supply of nutrients, which encourages improved quality and increased yield, making output per hectare more effective and profitable. In addition, fertiliser application not only improves productivity but also raises market value and profitability.

Table 3: Results of the Vector Autoregression (VAR) model				
Variables	Coefficient	Standard error	z	P>|z|
CI	0.004^{***}	0.001	3.590	0.000
II	-0.030^{***}	0.003	-8.940	0.000
RI	0.008	0.021	0.400	0.691
Icr	0.199	2.734	0.070	0.942
FERT	1.190^{***}	0.320	3.710	0.000
CONS	-0.684	0.175	-3.900	0.000
Durbin-Watson d-statistic = 2.4				

Granger Causality Wald test (all variables) =131.13***
Note: *** denotes significant at 1 percent level of significance *Source:* Statistical Handbook of Assam, Directorate of Statistics and Economics, Assam, 2010-2024

It is also seen from Table 6 that the Durbin-Watson d-statistic approaches to 2, suggesting that there is no autocorrelation in the estimated model. Moreover, the Granger Causality Wald test (considering all variables) shows significance, which implies that the estimated model is robust and a good fit for prediction.

5 Conclusion

Agriculture serves as the bedrock of Assam's economy, underpinning the livelihoods of a vast majority of its rural populace and playing a pivotal role in the state's socio-economic framework. Analysis of the growth trends in area, production, and productivity of nine crucial fruit crops in Assam from 2010 to 2024 reveals notable fluctuations driven by the interaction of agro-climatic conditions, market dynamics, and support systems, which influence the performance of crops in Assam's horticultural sector. Crops such as mango, jackfruit, litchi, and Assam lemon stand out as more resilient and financially viable choices for farmers, while others are hindered by production uncertainties and marketing challenges. Furthermore, the findings of the study depict Assam's agricultural economy with balanced land use (cropping intensity near national norms) and strong infrastructure (high road intensity), but hampered by critical bottlenecks in water (low irrigation) and inputs (minimal fertiliser, below-average credit). This setup likely results in low to moderate productivity, weather dependent incomes, and limited scalability, contributing to rural economic stagnation or migration. Positively, good roads could catalyse growth if paired with irrigation and input improvements, potentially raising farmers' income and economic growth in the state. Policy intervention might include targeted subsidies, micro-irrigation projects, and digital credit platforms to build resilience against climate change and market shocks. If these metrics stem from a drought prone or marginal area, they underscore the need for region-specific interventions to align with national goals like doubling farmer incomes.

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