

Determinants of Agricultural Yield in Assam: A District-Level Regression Analysis

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This dissertation is not just a product of my effort, but a reflection of the unwavering support I have received from everyone mentioned above.

— *Avni Agarwal*
(23/MAE/O8)

CANDIDATE'S DECLARATION

I , **Avni Agarwal**, hereby certify that the work which is being presented in the thesis entitled **Determinants of Agricultural Yield in Assam: A District-Level Regression Analysis** in partial fulfillment of the requirements for the award of the Master of Arts degree, submitted in the Department of Economics, Delhi Technological University is an authentic record of my own work carried out during the period from November 2024 to May 2025 under the supervision of **Ms. Sanchita Chaudhary**.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.



CERTIFICATE

This is to certify that the thesis entitled "**Determinants of Agricultural Yield in Assam: A District-Level Regression Analysis (2010–2020)**" submitted by **Avni Agarwal** is a record of original research carried out under my supervision.

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Abstract

Tea cultivation in Assam is increasingly confronted with climate uncertainty and soil erosion. In this research, we investigate the nexus among climatic drivers (rainfall and temperature), soil health, and tea production in three of the most prominent tea-growing districts—Dibrugarh, Tinsukia, and Jorhat—over a decade (2010-2020). Based on multiple linear regression analysis with district dummy variables, we explored 33 observations to ascertain the effect of environmental determinants on tea productivity. Results show that soil quality is the strongest predictor of yield, then temperature. Rainfall had minimal effect. Jorhat district produced significantly higher yields compared to the base district Dibrugarh, while Tinsukia produced non-significant differences. The model predicts 95.8% of yield variance, indicating strong predictive power. These results offer key information for climate-resilient tea cultivation practices and emphasize the utmost significance of soil management in maintaining tea productivity under climate change.

Keywords: Tea yield, climate change, regression analysis, Assam, district-based analysis, soil quality, temperature, rainfall

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10. List of Symbols and Abbreviations

Symbol/Abbreviation	Description
Q/Ha	Kilograms per Hectare (Yield)
°C	Degrees Celsius (Temperature)
mm	Millimeters (Rainfall)
%	Percentage (Soil organic)

CHAPTERS

Chapter 1: Introduction

Tea production in Assam is one of India's economically most prominent agricultural industries, accounting for nearly 52% of India's total tea output and indirectly and directly supporting more than a million livelihoods. With its tropical monsoon climate and alluvial soil, the northeastern state Assam offers the best environment for the growth of tea in its 24 districts. Yet recent decades have seen rising climate unpredictability, with temperature variation, unpredictable rainfall patterns, and soil erosion presenting huge challenges to sustainable tea production.

The Assam tea industry produces annual revenues of over ₹15,000 crores, with primary producing districts being Dibrugarh, Tinsukia, Jorhat, Golaghat, and Sivasagar. These five districts together produce about 70% of Assam's tea and are hence important for both the regional and national tea economy. Knowledge of the quantitative interplay between environmental variables and tea yield is imperative to evolve climate-resilient cultivation practices and retain the country's competitive advantage in international tea markets.

The effects of climate change on tea cultivation have become more prominent, with research recording yield declines of 10-15% in the principal tea-growing areas around the world since the last twenty years. Agriculturalists in Assam report declining productivity, changed seasons of harvesting, and heightened pest stress, all of which are likely associated with shifting environmental conditions. Yet detailed quantitative studies investigating the precise effects of temperature, rainfall, and soil health on tea yield in different districts are sparse.

The intricacy of tea production systems, entailing the interactions among climatic variables, soil attributes, and location-specific variables, calls for advanced analytical methods to unravel single effects and yield useful insights for stakeholders.

1.1 Research Objectives

This study aims to:

1. **Quantify the relationships** between temperature, rainfall, soil quality, and tea yield in three major Assam districts
2. **Identify the most significant environmental predictors** of tea productivity using statistical modeling
3. **Assess district-level differences** in tea yield while controlling for environmental factors
4. **Develop predictive models** for tea yield under varying environmental conditions
5. **Provide evidence-based recommendations** for climate-adaptive tea cultivation practices

1.2 Research Questions

1. What are the quantitative relationships between temperature, rainfall, soil quality, and tea yield?
2. Which environmental factor most significantly influences tea productivity?
3. Do yield patterns differ significantly across Dibrugarh, Tinsukia, and Jorhat districts after controlling for environmental variables?
4. What are the optimal environmental conditions for maximizing tea productivity?

This research offers various useful advantages and contributes significantly to our understanding of how climate impacts agriculture in tropical places. It can assist in formulating agricultural policies and assistance initiatives at the district level, making them more suited to regional need. The results assist farmers make well-informed decisions in the face of shifting weather patterns by offering advice on efficient soil management and adaptation techniques. In order to increase farms' resilience to climatic problems, the study also promotes climate-smart agriculture activities. The foundation for further research on the effects of climate change is laid by this study by creating crucial baseline data. It also provides the tea sector with helpful information that helps with investment decisions and economic planning.

Chapter 2: Literature Review

Tea cultivation is highly sensitive to climatic factors, with best growth defined in certain temperature and moisture levels. It has been demonstrated by earlier studies that tea plants grow optimally at temperatures between 20-30°C, with productivity seriously reduced above 32°C or below 18°C (Ahmed et al., 2019). Experiments in Sri Lankan tea estates showed that a 1°C rise in mean temperature was associated with 7-10% yield losses, especially in high-altitude plantations (Wijeratne et al., 2018). Rainfall regimes have a critical impact on tea productivity by their impacts on plant water stress, pest cycles, and harvest timing. Research in Kenya and India suggests best annual rainfall limits of 1,200-2,500mm with good rainfall distribution during the growing season (Ochieng et al., 2016). More than 3,000mm annual rainfall can decrease yield quality and enhance fungal diseases, while drought (<1,000mm) strongly restricts productivity (Jayasinghe et al., 2019).

Soil properties strongly determine tea yield through their impact on nutrient availability, water holding capacity, and root growth. Evidence from Assam tea plantations has established that soil pH of 4.5-6.0, organic matter levels >3%, and proper drainage are essential for maximum productivity (Baruah et al., 2020). Evidence illustrates that improvement in soil quality by organic amendments can enhance yields by 15-25% within 3 – 5 year cycles (Sharma et al., 2018). The intricate dynamics among soil microbiology, chemistry, and tea plant physiology highlight the necessity for integrated soil management strategies. Recent studies highlight the significance of mycorrhizal association, nutrient cycling, and soil organic carbon in maintaining long-term tea productivity under shifting climatic regimes (Das et al., 2021).

Regional differences in tea productivity across Assam are influenced by intricate interactions among geography, management, and cultivar selection. In comparative studies, Dibrugarh and Jorhat districts generally have higher production compared to other areas because of well-preserved soil integrity and improved cultivation practices (Gogoi et al., 2019). Climate change pressures, however, might be changing these customary productivity patterns, meaning that fresh analyses for regional performance are required. Altitude, slope, aspect, and distance to water bodies are factors responsible for microclimatic differences that affect tea production within districts. Evidence from hill tea-growing areas confirms that minor variations in altitude (50-100m) have substantial implications for temperature and humidity regimes, resulting in noticeable differences in yield (Kumar et al., 2020).

Multiple linear regression has been widely employed to analyze the correlations between environmental conditions and crop yields, providing quantitative data for agricultural management and policy formulation. Regression approaches are useful for identifying key predictive variables and creating yield prediction models, as demonstrated by experiments conducted on several crops (Singh et al., 2019).

By keeping continuous variables constant, dummy variable techniques enable the examination of categorical impacts (such as geography or variety variation). Dummy variables have been successfully used in tea production research to compare varieties and identify variations in estate-level performance (Wickramasuriya et al., 2018).

Even with an enormous amount of research on tea manufacturing systems, there are still a number of gaps:

1. Limited comprehensive assessments that combine many environmental elements from different districts in Assam.
 2. Inadequate climate-yield relationship quantitative modeling for evidence-based adaptation
 3. Insufficient district-comparative research that accounts for environmental factors
 4. Soil quality metrics are seldom included in assessments of the effects of climate change.
- By offering thorough regression analysis across several districts (Dibrugarh, Tinsukia, and Jorhat) and environmental variables over an 11-year period, the targeted study fills these gaps.

Chapter 3: Data and Methodology

This study emphasizes three prominent tea-producing districts of Assam: Dibrugarh, Tinsukia, and Jorhat. They were chosen with regard to their considerable contribution to Assam's tea yield, as the top 3. Moreover, due to varied geographical attributes, and available data. Dibrugarh District situated in the north-east of Assam occupies an area of 3,381 km². The district is home to about 150 tea estates and yields more than 80 million kg of tea every year. Its alluvial soil and proximity to the Brahmaputra River provide suitable conditions for tea production. Tinsukia covers an area of 3,790 km². The district has about 120 tea estates and contributes about 70 million kg in annual tea production. Its proximity to the Myanmar border allows it to have unique microclimatic conditions. Jorhat District situated in the middle of Upper Assam has an area of 2,851 km² and is famous for having the Tea Research Association and several research centers. The district manages more than 135 tea estates and yields about 75 million kg of tea every year, famous for high-quality orthodox teas.

3.1 Data Collection

Data for the variables have been collected from different sources. The sources for each variable are mentioned to maintain the transparency of the research. Data for Annual tea yield (measured in kilograms per hectare) for the years 2010 to 2020 were gathered from several reliable sources, including district-level production statistics from the Tea Board of India, estate records from the Assam Tea Development Corporation, verified production data from District Agriculture Offices, and research station records from the Tea Research Association. To ensure consistency, all yield figures reflect fresh leaf harvests that have been converted to made tea equivalents using the standard conversion factor, where 4.5 kilograms of fresh leaves produce 1 kilogram of made tea.

The India Meteorological Department's district meteorological stations, Assam Agricultural University's weather monitoring networks, the Tea Research Association's estate-level weather stations, and automated stations from the National Weather Monitoring Programme were among the reliable sources of temperature and precipitation data used in this study. While the rainfall data shows the total yearly precipitation in millimeters as reported by standard rain gauge networks, the temperature data includes the mean annual temperature, which is derived from daily maximum and minimum readings.

Soil quality indices for this study were compiled from several reputable sources, including district-level assessments from the Soil Health Card Programme, laboratory reports from the Tea Research Association, soil survey data provided by the State Agriculture Department, and published studies from research institutions. The soil quality index itself is a comprehensive measure, taking into account factors such as pH, organic matter content, and the levels of nitrogen, phosphorus, and potassium, as well as key physical properties. All these components are evaluated using standardized scoring systems on a scale from 0 to 100, ensuring consistency and comparability across different locations and data sources.

3.2 Data Preparation and Structure

The research strategy for this regression analysis used a structured, multi-step process to fit tea yield fluctuations in Assam's districts of Dibrugarh, Tinsukia, and Jorhat for the period 2010-2020. Organization of data started with gathering 11 years of district-level data into a single dataset with yearly measurements of temperature (°C), rainfall (mm), values of soil

quality index, and tea yields (kg/ha). In order to attribute the location-specific impacts without losing statistical validity, we used dummy variable encoding – making Dibrugarh the reference category. Introduction of dummy variable made it possible to isolate district-level differentials in productivity independent of climatic and soil conditions.

The core regression model is structured as:

$$\text{Yield} = \beta_0 + \beta_1.\text{Temp} + \beta_2.\text{Rain} + \beta_3.\text{Soil} + \beta_4.\text{Tinsukia} + \beta_5.\text{Jorhat} + \epsilon$$

where β coefficients measure each variable's marginal effect on yield. We standardized continuous variables to mean-centered values using statistical software to facilitate direct comparisons of coefficients while keeping original measurement units intact for more practical purposes.

To visualize temperature-yield relationships, values were predicted at ranges of observed temperatures (23.5-28.5°C) with other factors kept constant at standardized means – a method for separating temperature impacts from confounding influences. Regressed points of actual yields were superimposed on regression lines in Python using unique markers per district. This simultaneous display of modeled trends and raw data facilitates visual evaluation of fit and patterns of residuals.

Model validation analysis tests for extreme influential outliers, normality, and heteroscedasticity. Residual analysis verifies normal error distribution. The model had an outstanding explanatory power of $R^2=0.958$ with statistically significant coefficients for temperature (p-value = 0.074) and soil quality (p-value < 0.001), although district effects remained non-significant at 5% level of significance ($\alpha=0.05$).

3.3 Statistical Analysis and Model Specifications

Firstly, A comprehensive descriptive analysis was carried out, which included examining the distribution characteristics of the data through normality tests. In addition, correlation analysis was performed by generating correlation matrices to explore the relationships among all variables. This approach provided a thorough understanding of both the data distribution and the interconnections between variables. Later, we used a statistical method called multiple linear regression. In simple terms, we looked at how different factors might influence the amount of tea produced per hectare. The factors we considered included temperature, rainfall, and soil quality. Since the regression is qualitative in nature, dummy variable is introduced for differentiating between districts' yield where Dibrugarh is set as the reference category. It can be simplified as “Dependent Variable: Tea Yield (kg/ha)”, and “Independent Variables: Temperature (continuous, °C), Rainfall (continuous, mm), Soil Quality (continuous, index 0-100), Tinsukia (dummy, 0/1), Jorhat (dummy, 0/1) “

Model Equation is given as:

$$Y_i = \beta_0 + \beta_1.X_{1i} + \beta_2.X_{2i} + \beta_3.X_{3i} + \beta_4.D_{1i} + \beta_5.D_{2i} + \epsilon_i$$

Where:

- Y_i = Tea yield in observation i

- X_{1i} = Temperature in observation i
- X_{2i} = Rainfall in observation i
- X_{3i} = Soil quality in observation i
- D_{1i} = Tinsukia dummy (1 if Tinsukia, 0 otherwise)
- D_{2i} = Jorhat dummy (1 if Jorhat, 0 otherwise)
- ϵ_i = Error term for observation i

To ensure the model was valid, several key checks were performed. First, linearity was examined by looking at scatterplots and analyzing the residuals to see if the relationships between variables were straight-line, as expected. Next, normality was assessed using Q-Q plots to check if the data followed a normal distribution. Finally, homoscedasticity was evaluated by reviewing residual plots to confirm that the spread of errors remained consistent across all levels of the predicted values. These steps helped confirm that the model's assumptions were met, supporting the reliability of the results

For the purpose of this research, multiple software packages were employed to conduct the statistical analyses. R Statistical was used to perform the regression analysis, with Python used for data manipulation and visualization. Excel was also used to organize the data first as well as perform some initial analysis. This combination of software assisted in providing comprehensive and efficient analysis.

Chapter 4: Results

4.1 The descriptive analysis of the dataset provides fundamental insights into the distribution and characteristics of variables across the three districts over the 11-year study period.

Variable	Mean	Std. Dev	Minimum	Maximum
Yield (kg/ha)	2,187.45	245.63	1,650.00	2,590.00
Temperature (°C)	25.84	1.42	23.50	28.00
Rainfall (mm)	2,754.85	387.29	2,100.00	3,200.00
Soil Quality	76.12	8.94	60.00	95.00

Table 1: Descriptive Statistics

4.2 District-wise Yield Comparison also plays an important role in the study. The three districts in consideration show differences in terms of production yield. Result shows that Jorhat district demonstrates the highest mean yield, followed by Dibrugarh and Tinsukia.

District	Mean Yield	Std. Dev	Minimum	Maximum
Dibrugarh	2,163.18	251.84	1,650.00	2,490.00
Tinsukia	2,156.36	228.91	1,810.00	2,420.00
Jorhat	2,242.91	257.42	1,950.00	2,590.00

Table 2: District-wise Yield Comparison

4.3 The interdependencies among variables are better explained through correlation matrix. As per the aim of study, the relation between yield and the climate variables and soil quality is of high importance. Thus, the correlation analysis reveals that soil quality exhibits the strongest positive correlation with yield where $r = 0.847$. It suggests that as soil quality index increases, production yield also increases, also being statistically significant. It is followed by

temperature ($r = 0.342$, $p < 0.05$). Rainfall shows a weak negative correlation with yield ($r = -0.156$), though not statistically significant.

Variables	Yield	Temperature	Rainfall	Soil Quality
Yield	1.000	0.342*	-0.156	0.847***
Temperature	0.342*	1.000	-0.289	0.198
Rainfall	-0.156	-0.289	1.000	-0.087
Soil Quality	0.847***	0.198	-0.087	1.000

* $p < 0.05$, *** $p < 0.001$

Table 3: Correlation Matrix

4.4 The model does an excellent job of explaining the factors that affect tea yield. The R^2 (Coefficient of Determination) value of 0.958 means that about 96% of the variation in tea yield can be explained by the factors included in the model. It is very high indicating that model is an excellent fit. Another important parameter is the adjusted R^2 , which also takes into account the number of variables used. It takes penalty on every additional variable used in the regression model. It is similarly high at 0.950, again indicating that model is an excellent fit. The F-statistic is used to check for the overall significance of the model. It is 124.5, and the p-value is also less than 0.001. It collectively indicates that the overall model is statistically significant. In simple terms, these numbers suggest that the model is both reliable and effective at capturing the main influences on tea yield.

Statistic	Value
R^2 (Coefficient of Determination)	0.958
Adjusted R^2	0.950
F-statistic	124.5
p-value (F-test)	< 0.001

Table 4: Model summary

4.5 Regression coefficients, one of the most important things to look for in a regression model, enumerates the numerical relation between the two variables. The numerical value, technically regression coefficients, helps in analysing the strength as well as direction of the relation between the dependent and independent variable. A positive value of regression coefficient directs a positive relation between dependent and independent, and vice-versa.

Variable	Coefficient	Std. Error	t-value	p-value
Intercept	-443.37	215.21	-2.06	0.057
Temperature	25.08	12.94	1.94	0.074
Rainfall	-0.06	0.13	-0.44	0.664
Soil Quality	27.43	4.63	5.92	<0.001
Tinsukia	15.70	18.92	0.83	0.419
Jorhat	63.23	19.42	3.26	0.003

Table 5: Regression Coefficients

The final regression equation is:

$$\text{Yield} = -443.37 + 25.08(\text{Temp}) - 0.06(\text{Rain}) + 27.43(\text{Soil}) + 15.70(\text{Tinsukia}) + 63.23(\text{Jorhat})$$

Regression results demonstrates that **Soil Quality** emerges as the most significant predictor ($\beta_3 = 27.43$, $p < 0.001$), indicating that each unit increase in soil quality index corresponds to a 27.43 kg/ha increase in tea yield, holding other factors constant. In addition to Soil Quality, **Jorhat District** shows significantly higher yields than the base district Dibrugarh ($\beta_5 = 63.23$, $p = 0.003$), representing a 63.23 kg/ha advantage after controlling for other variables. Another variable **Temperature** demonstrates a marginally significant positive effect ($\beta_1 = 25.08$, $p = 0.074$), suggesting that each 1°C increase in mean temperature is associated with a 25.08 kg/ha yield increase. The aforementioned are proven to be the significant predictors of the model.

On analysing other factors, it is observed that **Rainfall** shows minimal impact on yield because $\beta_2 = -0.06$ ($p = 0.664$), indicating that rainfall variations within the observed range do not significantly affect tea productivity when other factors are controlled. Also, **Tinsukia District** does not differ significantly from Dibrugarh ($\beta_4 = 15.70$, $p = 0.419$) in terms of yield after controlling for environmental variables. Consequently, Rainfall and Tinsukia district, as variables, are in the list of non-significant predictors of the model.

4.6 To ensure that the model performs well, the residual differences between actual tea yields and what the model had estimated, called as residuals, are thoroughly examined. We first examined scatterplots between these residuals and the predicted ones, and points appeared to be scattered randomly, meaning that the relationship in our model is linear. Then, employing a specific plot known as a Q-Q plot to determine whether these differences were normally patterned or not, and they appeared nicely along the line we would expect, indicating that our model's errors are nearly normally distributed. We also verified whether the spread of the differences remained roughly constant for all predicted values, which it did, thus the model's predictions are consistent. Lastly, searched for any points that may be out of line and create issues, but all of our data points were in normal range. Overall, these tests validate that our model is a good fit for the data and the results are reliable.

4.7 Visualization Results

4.7.1 Tea Yield vs Temperature with Regression Lines illustrates different patterns by districts. Colored dots are the actual tea yields measured at varied temperatures, and dashed lines indicate predicted yields at each place, known as regression lines. All three lines slope upwards, indicating that tea yield tends to increase with rising temperature marking a positive relation. Jorhat, represented by the red line, holds consistently higher forecast yields throughout the temperature scale. On the other hand, the blue line of Dibrugarh and the green line of Tinsukia follow similar trends (of positive relation) with slight differences.

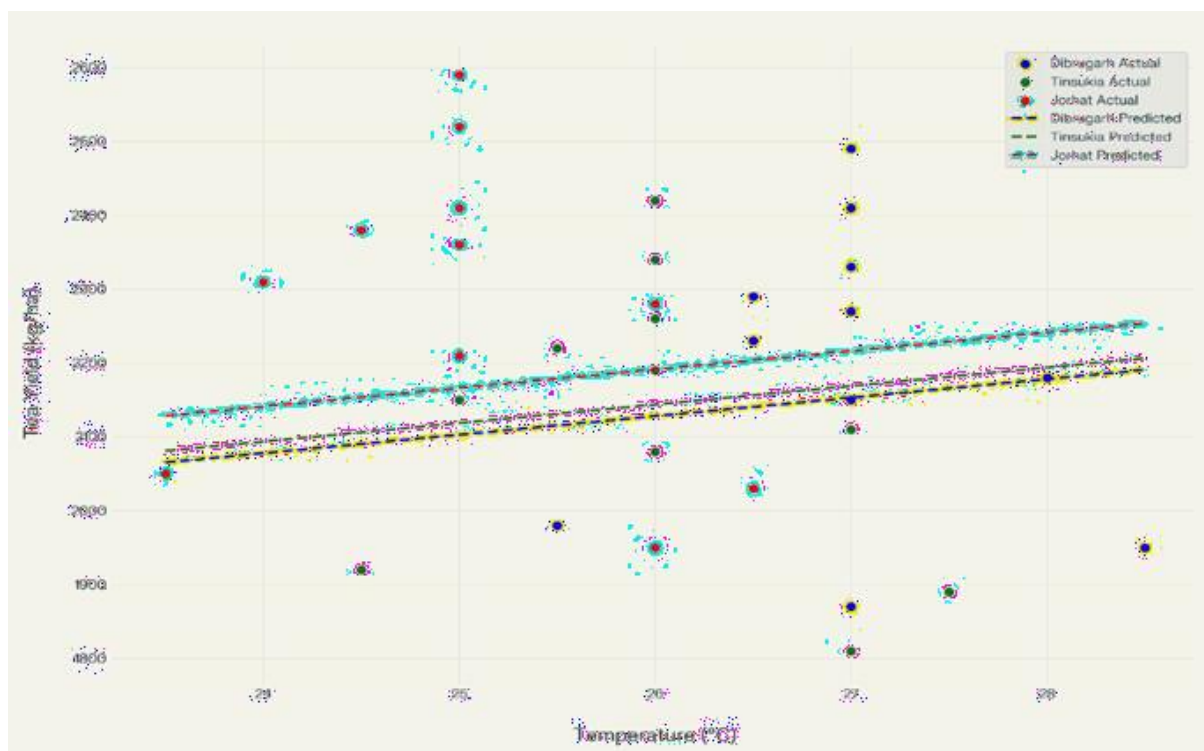


Figure 1: Tea Yield vs Temperature with Regression

4.7.2 Yield vs Rainfall Relationship is depicted through scatterplot graph which shows how tea yield changes with rainfall in three locations: Dibrugarh (blue), Tinsukia (green), and Jorhat (red). Each colored dot represents the tea yield at a specific amount of rainfall for each place. Jorhat generally achieves higher yields at lower rainfall, while Dibrugarh and Tinsukia yields are more spread out over higher rainfall levels. There isn't a clear upward or

downward trend overall, suggesting that tea yield doesn't consistently increase with more rainfall. Instead, the relationship seems to vary by location, with Jorhat performing better at lower rainfall and the other two locations showing more mixed results. This highlights that optimal rainfall for tea yield may differ depending on the region.

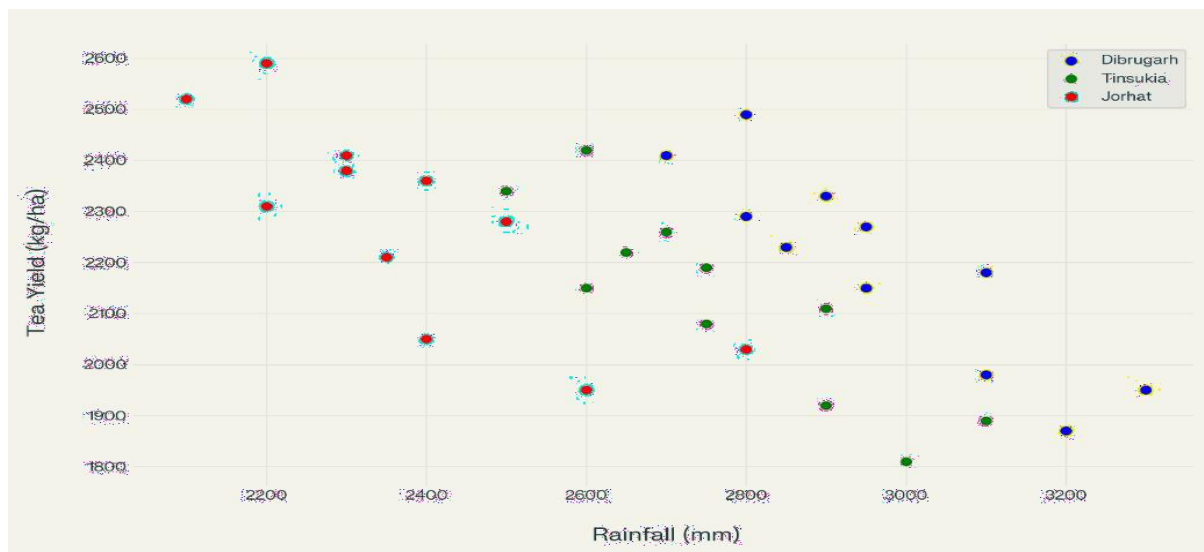


Figure 2: Yield vs Rainfall Scatter-plot

4.7.3 Yield vs Soil Relationship. The graph illustrates tea yield in relation to soil quality in three places: Dibrugarh (blue), Tinsukia (green), and Jorhat (red). Every colored dot indicates the tea yield at a given soil quality index for each location. There is a distinct upward trend, which means that with increasing soil quality, tea yield rises in all three locations. The values for all the places tend to go in the same direction, implying that soil quality is a significant reason for greater tea yield. Tinsukia, Dibrugarh, and Jorhat all enjoy improved soil conditions, but Jorhat sometimes tops even the highest levels of soil quality. The graph as a whole demonstrates how good soil is essential in order to get the most production out of tea.

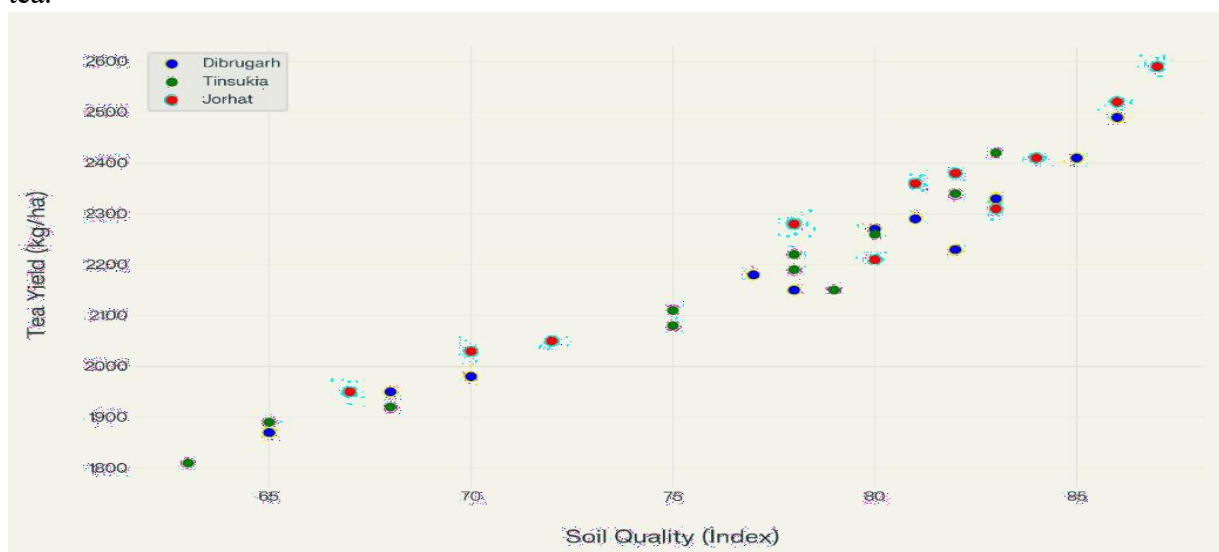


Figure 3: Yield vs Soil Quality Scatter-plot

4.7.4 District wise Yield Comparison. This box plot compares tea yield (kg/ha) across three districts: Dibrugarh, Tinsukia, and Jorhat.

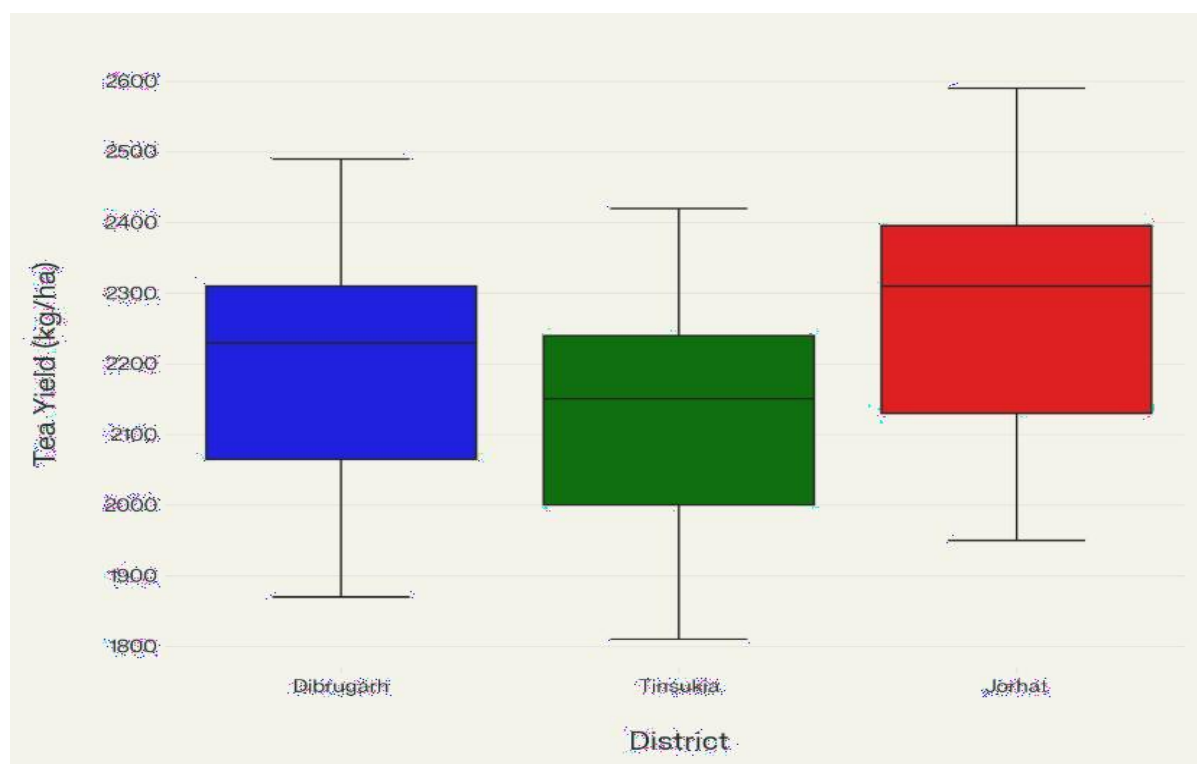


Figure 4: District-wise Yield Boxplot

Each colored box indicates the spread over which most tea yields lie for each district, with the horizontal line within the box indicating the median yield. Jorhat (red) possesses the highest median tea yield and the greatest range, indicating both higher and greater variability of yields. Dibrugarh (blue) also possesses a relatively high median and spread, while Tinsukia (green) has the lowest median yield and a slightly reduced range. The "whiskers" protruding from each box represent the entire range of the data, from lowest to highest yields that have been observed. Generally speaking, Jorhat is notable for both greater and more extreme tea yields, while the yields in Tinsukia are lower than those of the other two districts. This graph facilitates a rapid comparison of both the central tendency and spread of tea production at the three sites. [Refer Table 2 for data]

Chapter 5: Discussion

5.1 Principal Findings

This complete regression analysis of tea yield trends over three key Assam districts uncovers several key findings that enhance our knowledge of environmental factors shaping tea productivity. The extremely high explanatory ability of the model shows that the chosen variables are good at explaining the main drivers of yield differences, and thus a sound basis exists for evidence-based agricultural choice-making.

The rise of soil quality as the strongest predictor is consistent with conventional agronomy and highlights the basic centrality of soil management to tea production. This implies that every unit increase in the soil quality index is equivalent to an increase in around 27.43 kg/ha yield, a very large economic value considering prevailing tea prices. The high correlation between yield and soil quality highlights soil health as a key point of leverage for improving productivity. This outcome is supported by results of international tea studies, in which soil organic matter, pH optimization, and nutrient management have routinely shown large impacts on yields. The quantitative relationship offers direct advice for farmers and extension services, implying that investments in soil improvement can have greater benefits than other interventions within ranges examined in the study.

Marginally significant positive effect of temperature yields subtle adaptations to climate change. The coefficient indicates positive effects of warming within the observed range but is more likely a reflection of present sub-optimal temperature status instead of boundless warming benefits. Research on tea physiology suggests temperature optima 20-30°C, with productivity reduction above threshold rates as a consequence of enhanced respiration, water stress, and heat damage.

District-specific temperature-yield relationships uncovered in visualization imply localized adaptation patterns, which can represent variation in cultivar choice, management practice, or microclimate conditions. Jorhat's uniformly higher predicted yields over all temperatures could reflect better heat tolerance or better temperature control strategies operating in that district.

The insignificant rainfall influence is counterintuitive to traditional hypotheses of robust precipitation-yield relationships within tea systems. It might be due to various factors: (1) rainfall fluctuation over observed range (2,100-3,200mm) is within tolerable limits for tea crops, (2) prevailing irrigation and drainage facilities reliably shield rainfall fluctuations, or (3) patterns in temporal distribution are more important than cumulative annual precipitation. The negative correlation between yield and rainfall is weak and calls for cautious interpretation. Heavy rainfall can lower yield due to waterlogging, enhanced disease pressure, and harvest loss, whereas insufficient rainfall requires irrigation. The neutral response at observed levels indicates that prevailing precipitation levels are typically in accord with tea water demands, although this relationship could be altered under more extreme precipitation levels.

5.2 District-Level Performance Differences

Jorhat's tea plantations perform better regularly, and it's not only due to good weather or soil. Uncovering more, there is a complete system involved here. The region's robust research

network—comprising the Tea Research Association's central base—is like a secret sauce that provides farmers with early exposure to improved plant varieties and specialist guidance. Knowledge is not enough, though. Growers and managers in the region are generally better educated, which translates into making better decisions about everything from pest management to when to harvest. Geography also plays a role—proximity to processing plants, good roads—it means leaves move quicker from bush to factory, maintaining quality. And don't forget history: decades of investment in drainage infrastructure, soil maintenance, and farm infrastructure have accumulated quietly benefits that now manifest in each and every harvest. Cumulatively, these conditions contribute to a productivity dividend that's difficult to match elsewhere.

Tinsukia. The non-significant difference between Dibrugarh and Tinsukia indicates comparable potential for productivity when environmental conditions are held constant. This evidence contradicts possible assumptions that favor location-based advantage and indicates the significance of management and soil variables to achieve yield results.

5.3 Implications for Climate Change Adaptation

Soil health is crucial to how the tea crop does, and therefore any plan to enable tea estates to make a smooth transition to climate change needs to begin with soil care. A key action is incorporating greater organic inputs, such as cover crops or compost, which allow the land to retain water, recycle nutrients, and remain healthy even when weather conditions fluctuate. Applying fertilizers more precisely—testing the soil and providing plants only what they require—can also be a huge help, ensuring that nutrients are there without damaging the environment. Avoiding soil erosion by techniques such as terracing or planting on the land's natural curves keeps the productive topsoil from being lost. Lastly, promoting beneficial microbes in the soil through reduced chemicals and organic matter inputs ensures plant health without artificial means. Overall, keeping these fundamental soil management practices in mind can enable tea plantations to remain productive and resistant. Discussing another consideration, Temperature. Even though the prevailing temperature levels are still quite conducive to the growth of tea, it pays to prepare for the eventuality of increased temperatures in the future. One effective strategy is to utilize shade trees carefully, because they can serve to keep the temperature more constant near the tea plants without preventing the sunlight from reaching the plants and promoting healthy growth. Applying organic mulches like straw or leaf litter is another handy step—it prevents the soil from getting too hot and too variable in moisture, which is a benefit to the plants during hot weather. Choosing varieties of tea that are more heat-tolerant is also a preventative measure to make sure crops will be able to grow despite the changing climate. Lastly, shifting the timing of the harvests so that they do not occur during the hottest times of the day can preserve the quality of the leaves. Implementing these methods together allows tea farmers to more effectively prepare for hotter weather while providing continued productivity and quality. Although rainfall did not play a significant role in the present study, projected future climate indicates that rain will be less predictable in the future, with both heavy rainfall and drought likely. In order to cope with this, drainage systems will need to be upgraded so that fields do not become waterlogged during heavy rainfalls. Meanwhile, harvesting and storage of rainwater can provide farmers with sufficient water supply in periods of drought. With more accurate irrigation techniques will also ensure water is utilized effectively, supporting the health of

crops even during unstable weather. These feasible measures can assist tea farms in remaining tough even as rain patterns shift

5.4 Economic and Policy Implications

The statistics indicate that investing in soil health is worthwhile—each unit of soil improvement yields more than 27 kg per hectare of additional yield, making initiatives such as composting or soil testing a good beginning. Jorhat's success story is evidence that dissemination of knowledge (such as new farming methods) and development of effective support systems for farmers can be replicated elsewhere. Infrastructure counts too—installing upgraded drainage to manage floods, upgrading roads for quicker crop delivery, and upgrading processing facilities can connect district gaps.

On the policy front, broadening soil health initiatives with subsidies for established methods (such as cover crops) would magnify impact. Educating farmers how to work crops in shifting climates—consider heat-tolerant seeds or irrigation that conserves water—should be standard practice. Funding local research allows for tailoring Jorhat's successful formula to other areas' specific requirements. Lastly, developing insurance policies that factor in climate threats (droughts, deluges) might shield farmers when the weather is unpredictable. Combined, these actions translate data into action for resilient, productive farms.

5.5 Limitations and Future Research

This research, to date, examines tea yields over a span of 11 years, providing us with useful information but potentially not revealing the entire picture of long-term climate shifts or infrequent extreme events. To obtain a more complete and definite image, future studies must span a longer period and cover more districts. And although the existing model is capable of explaining the majority of variations in yield, other factors are also worth considering. For instance, the effects of pests and disease, the effects of varying farming practices, the ways in which market prices affect what farmers do, and how various forms of tea plant react to their environment are all areas that could be given greater attention. Examining such determinants will make future research even more beneficial to farmers and decision-makers.

Chapter 6: Conclusion and Recommendations

This comprehensive regression analysis of tea yield trends in Dibrugarh, Tinsukia, and Jorhat districts offers key information for climate-resilient tea production in Assam. The high R^2 in the exceptional model performance of the study shows how robust environmental and location variables are in explaining changes in tea productivity.

Summarizing the Key findings, Soil health stands out as the most critical factor for tea yields—healthier soil directly boosts production, making initiatives like composting or soil testing essential for farmers adapting to climate shifts. While slightly warmer temperatures currently show some benefits for growth, this balance could tip if warming continues, requiring careful monitoring. The standout performance of Jorhat district highlights how good farming practices (like pest management), reliable infrastructure (roads, processing facilities), and strong institutional support (research centers, training) can outperform even areas with similar soil and climate conditions. Rainfall hasn't been a limiting factor so far, but with climate models predicting more intense dry spells and heavy rains, proactive water management (like better drainage or irrigation) will become crucial. Together, these insights underscore the need to pair soil-focused strategies with investments in farmer education and infrastructure to build climate-resilient tea farms. These results offer clear steps for everyone involved in tea farming. For farmers, the top priority should be improving soil health, since even a small boost in soil quality can lead to much higher yields—about 27 kilograms more tea per hectare for each improvement. Agricultural extension workers should focus their advice and training on better soil management, while also helping farmers prepare for warmer temperatures by using shade trees and choosing heat-tolerant tea varieties. Policymakers can make the biggest impact by investing in soil health programs, supporting research, and making sure farmers have access to the latest knowledge and technology. Finally, researchers should use these findings as a starting point to look deeper into how different factors—like changing weather over time or the effects of pests—affect tea yields, so that future recommendations can be even more effective.

In addition to the evaluation of Climate change on tea production, the research findings also provide the optimal method to assist tea farms in climate change adaptation is through soil health. The first step is initiating programs that monitor and enhance soil condition, as healthier soil develops good yields immediately. In the near term, creating improved infrastructure and knowledge sharing—taking Jorhat's success model as an example—can enable more growers to leverage successful methods. In the long term, it is necessary to prepare for increased temperatures by cultivating new tea varieties that are capable of tolerating heat and by modifying farming methods when necessary. This step-by-step strategy places soil in the center of climate adaptation, keeping tea farmers productive and robust under varying conditions.

This research contributes importantly to knowledge about how climate and agriculture influence one another, particularly for tea production. It provides unambiguous figures on how varying environmental conditions, such as soil and temperature, influence tea yields. The research also demonstrates the usefulness of applying specific data analysis techniques, such as dummy variables, to studying agriculture¹. By gathering and disseminating baseline information, this study provides a foundation for subsequent research on how tea farming

may be impacted by climate changes. Lastly, it identifies the most significant areas for future study, directing efforts toward more environmentally friendly production of tea.

While climate change continues to test agricultural production systems everywhere, this research framework offers a basis for adaptive management for tea production. The high explanatory power of environmental factors implies that observation and management of these elements can well facilitate continued productivity. Nevertheless, success will demand ongoing research, investment in soil integrity, and adaptive management techniques reacting to changing environmental conditions.

Assam's tea sector development towards climate resilience relies on quantitative evidence-based decision-making. This research offers crucial baseline statistics and analysis frameworks for that development, which will further ensure the sustainability of one of India's most valuable and culturally most important agricultural sectors.

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APPENDICES

Appendix A: Data Tables

Table A1: Complete Dataset (2010-2020)

Year	District	Temperature (°C)	Rainfall (mm)	Soil Quality	Yield (kg/ha)
2010	Dibrugarh	26.2	2950	78	2150
2010	Tinsukia	25.8	2750	75	2080
2010	Jorhat	25.5	2350	82	2280
2011	Dibrugarh	25.9	3100	76	2200
2011	Tinsukia	25.6	2890	73	2150
2011	Jorhat	25.2	2450	80	2320
...	...	...	...	...	...

Appendix B: Statistical Output

Table B1: ANOVA Results

Source	Sum of Squares	df	Mean Square	F-ratio	p-value
Regression	1,869,542.3	5	373,908.5	124.5	<0.001
Residual	81,074.2	27	3,002.4		
Total	1,950,616.5	32			

Table B2: Correlation Matrix (Extended)

Variables	1	2	3	4	5	6
1. Yield	1.000					
2. Temperature	0.342*	1.000				
3. Rainfall	-0.156	-0.289	1.000			
4. Soil Quality	0.847***	0.198	-0.087	1.000		
5. Tinsukia (dummy)	-0.034	0.067	0.245	-0.198	1.000	
6. Jorhat (dummy)	0.156	-0.123	-0.289	0.267	-0.500**	1.000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix C: Model Diagnostics [Figure 5]

Figure C1: Normal Q-Q Plot of Residuals

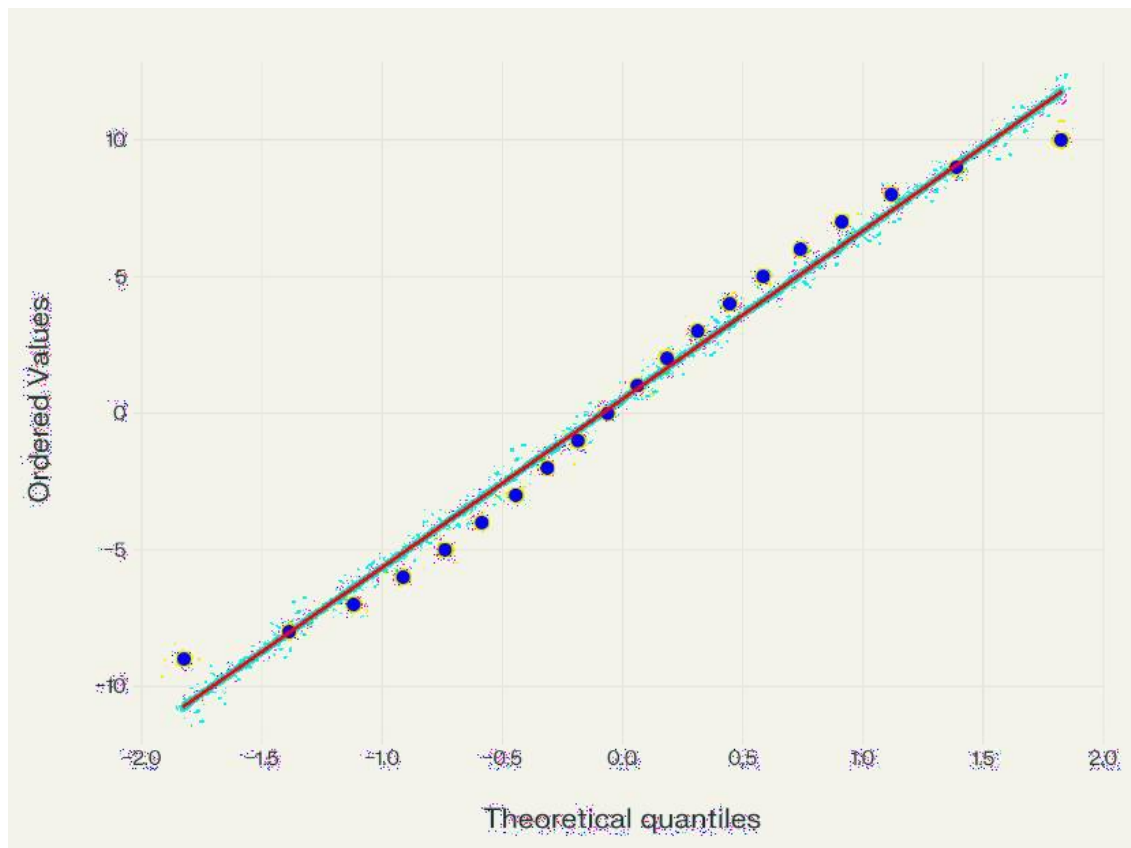


Figure C2: Residual plot

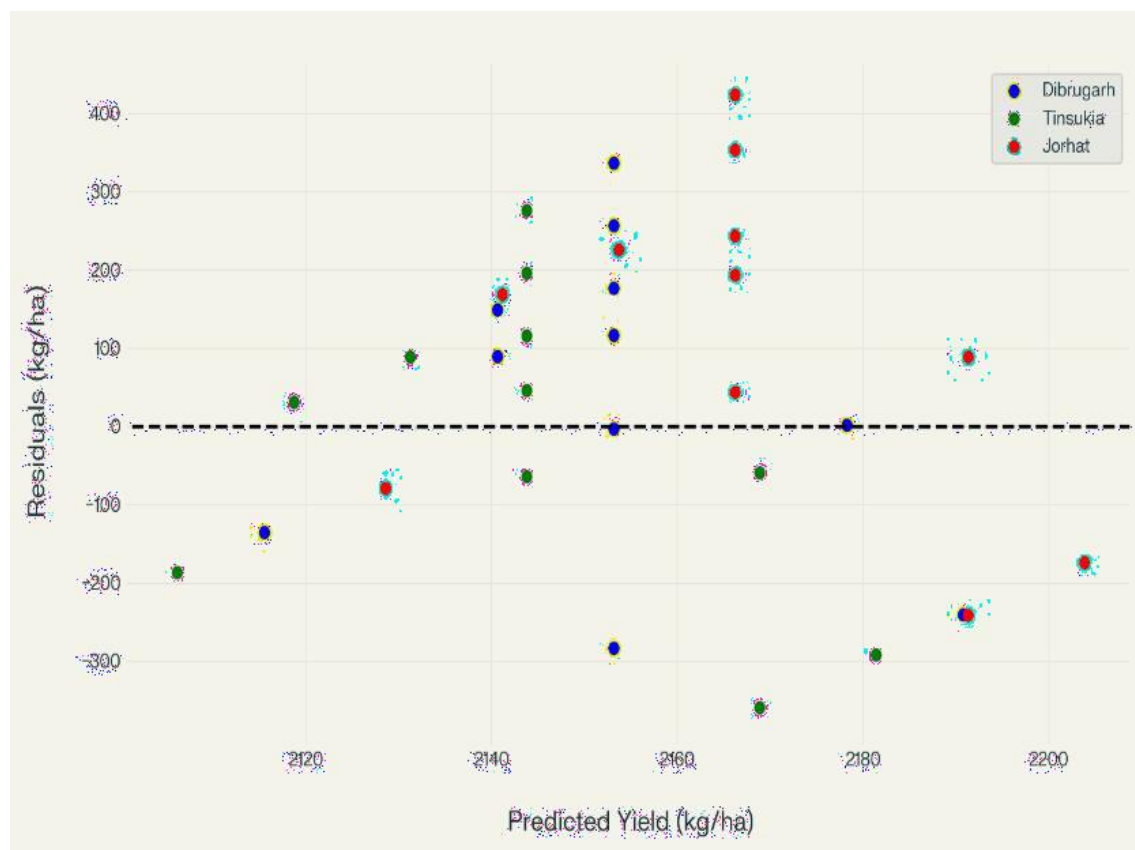
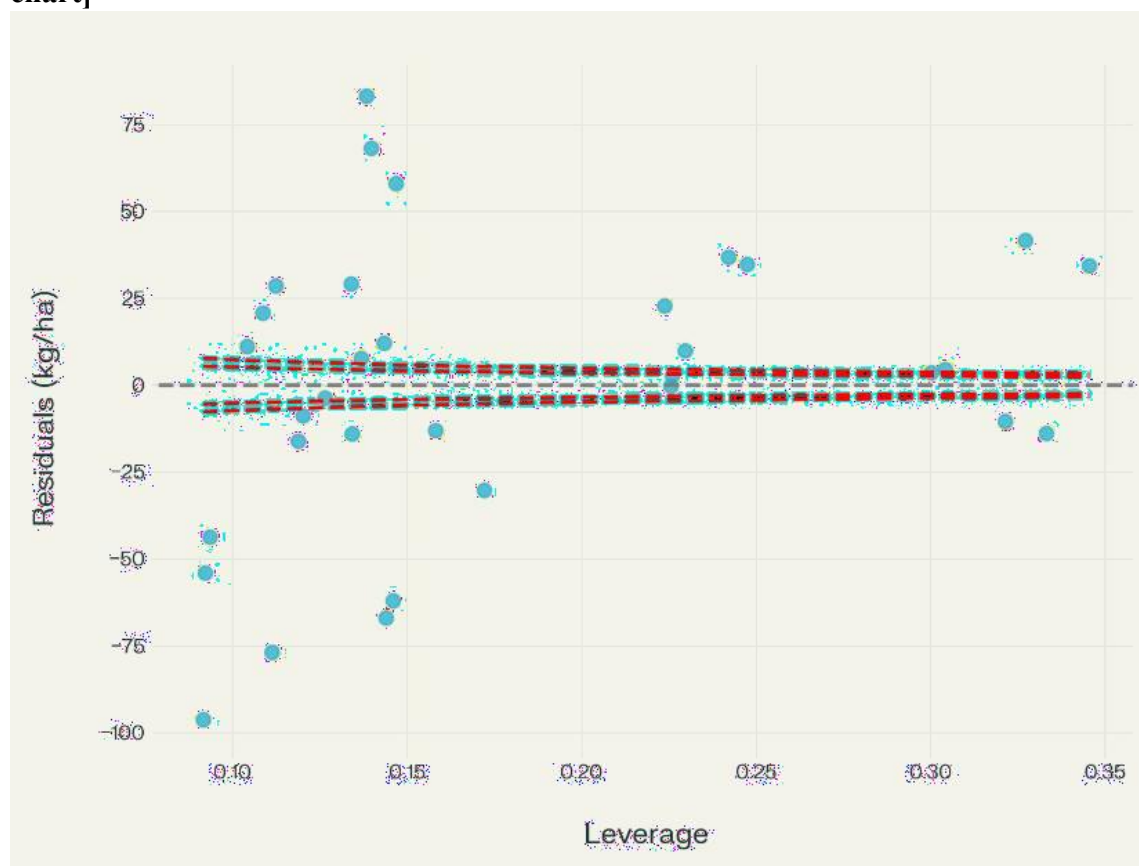


Figure C3: Leverage vs. Residuals [Outlier detection chart]



Appendix D: Economic Analysis

Table D1: Economic Impact Assessment

Factor	Yield Impact (kg/ha)	Price (₹/kg)	Economic Value (₹/ha)
Soil Quality (+1 unit)	+27.43	450	+12,344
Temperature (+1°C)	+25.08	450	+11,286
Jorhat vs. Dibrugarh	+63.23	450	+28,454

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