FORECASTING OF RICE YIELD BASED ON BIOMETRICAL CHARACTERS AND ANALYSE THE PERFORMANCE OF PRADHAN MANTRI FASAL BIMA YOJANA IN WEST GODAVARI DISTRICT OF ANDHRA PRADESH

By

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MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL STATISTICS)
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This is to certify that the work recorded in this thesis entitled **"Forecasting of Rice yield based on biometrical characters and analyse the performance of Pradhan Mantri Fasal Bima Yojana in West Godavari district of Andhra Pradesh"** submitted in partial fulfilment of requirements for the award of degree **Master of Science (Agriculture)** in **Agricultural Statistics** of the College of Basic Sciences and Humanities, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar is a genuine record of the bona fide research work carried out by **Mr. Gajjarapu Jaya Krishna** under my guidance and supervision.

The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma. The assistance and help received during course of this investigation and sources of literature have been duly acknowledged.

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We, the undersigned, members of the Advisory committee of **Mr. Gajjarapu Jaya Krishna**, a candidate for the degree of Master of Science in Agriculture (Agricultural Statistics) has gone through manuscript of thesis and agree that the thesis entitled **"Forecasting of Rice yield based on biometrical characters and analyse the performance of Pradhan Mantri Fasal Bima Yojana in West Godavari district of Andhra Pradesh"** may be submitted by him in partial fulfilment of the requirements for the award of the degree.

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Abstract

This study, conducted in West Godavari district, Andhra Pradesh, a prominent rice-producing region, employs biometrical characteristics to forecast rice yield and assesses the performance of the Pradhan Mantri Fasal Bima Yojana (PMFBY) program. Time series analysis reveals stable rice-growing area but increasing production and yield.

The study identifies ten biometrical characteristics affecting rice yield, including plant population(X1), plant height(X2), tiller count(X3), panicle length(X4), nitrogen(X5), phosphorus(X6), potassium levels(X7), irrigation frequency(X8), disease infestation(X9), and plant condition(X10). Multiple regression analyses were conducted using these variables, resulting in a model selection process which includes R-square, adjusted R-square, Root Mean Square Error (RMSE), Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Coefficient of Variation (CV) based on these 5 models are selected from overall possible models. Residual

analysis of these 5 models favoured a third model of the selected five models for forecasting rice yield. The chosen model ($\hat{Y} = 46.08838 + 0.80226X_1 + 0.14708X_2 - 0.36854X_3 - 0.02404X_5 + 0.02418X_7 + 1.28461X_8$) having yield affecting characters such as plant population, plant height, tiller count, nitrogen application, potassium application and irrigation frequency adeptly forecasts rice yield (94.01 quintals/ha) and accounts for 52.6% of yield variation. These models were rigorously assessed for validity. The final selection was based on residual analysis, with a preference for models demonstrating the least Mean Absolute Percentage Error (MAPE), ensuring robust predictive performance.

Furthermore, the study highlights the robust growth of PMFBY insurance scheme metrics, emphasizing higher Compound Annual Growth Rates (CAGRs) during Rabi seasons. In the 2022 Kharif season, 604,529 farmers were insured, covering 180.5 thousand hectares, with a gross premium of 105.07 crores and a sum insured of 1,756 crores.

In conclusion, this research contributes significantly to precise rice yield prediction and showcases the effectiveness of PMFBY in West Godavari district, crucial for enhancing food security and economic stability.

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ABBREVIATIONS

%	=	Percentage
e	=	error
RMSE	=	Root Mean Square Error
AIC	=	Akaike Information Criterion
BIC	=	Bayesian Information Criterion
CV	=	Coefficient of Variation
MAE	=	Mean Absolute Error
MAPE	=	Mean Absolute Percentage Error
CAGR	=	Compound Annual Growth Rates
GPS	=	Global Positioning Systems
PMFBY	=	Pradhan Mantri Fasal Bima Yojana
MSP	=	Minimum Support Price
LGR	=	Linear growth rate
LASSO	=	Least absolute shrinkage and selection operator
ANN	=	Artificial neural network
SMLR	=	stepwise multiple linear regression
PCA	=	principal components analysis
SSE	=	Error sum of squares
MSE	=	Mean Square Error
ANOVA	=	Analysis of Variance
SSR	=	Explained sum of squares
FM	=	Full model
RM	=	Reduced model
VIC	=	Variance Inflation Factor
FE	=	Forecast Error
PE	=	Percentage Error
Kg	=	Kilogram
Ha	=	Hectare

CHAPTER - I

INTRODUCTION

INTRODUCTION

Forecasting stands as a pivotal element in contemporary decision-making processes, carrying immense importance across a spectrum of industries and sectors. The capacity to anticipate forthcoming events, trends, and results through the analysis of available data and analytical methods has brought about a transformative shift in the way societies and organizations plan, allocate resources, and address challenges. In the realm of agriculture, the significance of forecasting becomes particularly pronounced, offering essential insights for sustainable production, resource management, and risk mitigation.

In recent times, the global agricultural landscape has been marked by a series of intricate and interconnected challenges. Factors such as population expansion, evolving dietary preferences, climate irregularities, and resource limitations have collectively intensified the pressures faced by the agricultural sector. Amidst these complexities, the true value of precise and timely forecasting becomes evident.

Forecasts emerge as indispensable tools for a diverse range of stakeholders, including policymakers, agricultural practitioners, and decision-makers at various levels. On a macroeconomic scale, accurate agricultural forecasts contribute to the formulation of informed policies and strategic decisions. Governments and international entities rely on such forecasts to proactively anticipate potential food scarcities, allowing for pre-emptive measures to stabilize markets and ensure food security. Additionally, the operational choices of agribusinesses, traders, and food processors hinge on dependable production projections, enabling them to streamline supply chains and manage fluctuations in pricing.

Rice, a vital crop that feeds many worldwide, plays a huge role in keeping our food supply steady, supporting people's lives, and keeping economies balanced. As the world's population keeps growing and the effects of climate change become clearer, making sure we have enough rice that's reliable has become extremely important. Being able to predict how much rice we'll get accurately could help us avoid not having enough to eat, plan how to grow crops better, and lessen the problems that come with changing weather patterns.

The changing weather patterns and the increasing demands on farming resources have shown that we need better ways to grow crops. The old-fashioned methods we used to manage crops and guess how much they'll produce aren't good enough for today's tough farming problems. So, combining details about plants (like how they grow and their features) with smart ways of guessing the future could be a really good way to improve how we predict how much rice we'll get.

Forecasting rice yield comes with a range of benefits that go beyond just farming. Looking at the bigger picture, accurate predictions can provide valuable information to policymakers, investors, and global food organizations. This information helps them make well-informed choices about how much rice to produce, how to distribute it, and what prices to set. This knowledge empowers governments to take action early to prevent potential food shortages. They can create strategies to keep markets stable and ensure that everyone in society can have access to food.

Rice stands out as India's top food crop, growing on nearly a quarter of the entire cultivated land and feeding almost half of the country's population. This grain is the mainstay for people in the eastern and southern regions, especially in places getting more than 150 cm of rain each year. In the year 2021, it covered an extensive land area of 46.2 million hectares, resulting in a significant production of 129.4 million metric tons and a productivity of 2.79 metric tons per hectare (**INDIASTAT,2021**). In the Andhra Pradesh, west Godavari and east Godavari districts are considered as rice bowl of Andhra Pradesh. In the region of West Godavari, rice takes the lead as the primary food crop.

Numerous organizations in both India and other countries are actively involved in devising methodologies for predicting crop yield and production prior to harvest, utilizing a range of approaches. One approach involves incorporating multiple influencing factors into the forecast model. Alternatively, another approach employs measurements of plant characteristics collected during the plant's growth cycle. It can be reasonably assumed that plant characteristics encompass the combined effects of all variables impacting production. With these principles in mind, the current study aims to develop a forecast model for rice yield in West Godavari district, Andhra Pradesh, leveraging both biometric attributes and input from farmers' assessments.

Building on the earlier conversation about forecasting, it's clear that the world of agriculture is open to various unknowns, especially when it comes to crop losses due to things like bad weather, pests, and diseases. These uncertainties can seriously impact farmers' earnings, often causing money problems and a lack of stability. Crop losses, whether big or small, can upset the careful equation between the money invested, costs incurred, and the money farmers expect to make – something they really depend on for their livelihoods.

The financial aftermath of these kinds of crop losses is complex. Farmers don't just face immediate losses from getting less yield; they also have to deal with higher costs for things like replanting or growing new crops. These money problems can create a cycle where farmers end up owing more and more, as they might have to borrow money to pay for their needs or make up for what they've lost. Often, farmers have few options but to sell off what they own or use up their savings just to manage, putting their future financial stability at risk.

Agricultural insurance plans come up as a sensible way to stop this pattern of uncertainty and weakness. These insurance schemes act like a safety net when there are crop losses, giving farmers some financial defence that really helps reduce the effects of sudden surprises. The money they get from insurance can help balance out the costs caused by crop failures, so farmers don't have to take extreme steps to deal with the situation.

The importance of agricultural insurance becomes clearer when we think about how it affects farmers' lives as a whole. Farming usually brings in money during certain times of the year, so it's tough for farmers to handle their money well and make smart plans. Insurance adds a dose of predictability to this mix, letting farmers expect and handle risks while keeping their income steadier over the long run. This steadiness gives farmers more control to make smart choices about investing, updating their methods, and growing their businesses overall.

Moreover, agricultural insurance fits in well with the bigger aim of making farming sustainable. When farmers are protected from the big problems that come with crop losses, they tend to try out new and smart methods and use better quality materials. This change towards modern and sustainable farming doesn't just help each farmer but also adds to the strength and efficiency of the whole farming sector.

To wrap up, the significance of agricultural insurance schemes comes from their power to lessen the harmful impacts of crop losses on farmers' earnings and ways of life. By giving financial protection and stability in uncertain times, these insurance plans are crucial in helping farmers handle difficulties, make smart choices, and add to the lasting health of agriculture. As farming keeps changing, the role of insurance becomes even more essential in creating strong and successful farming communities.

Since gaining independence, concerted efforts have been undertaken both at the central and state levels in India to establish a crop insurance program for the benefit of farmers. The initial pilot crop insurance program was initiated in 1972, albeit with limited coverage. Subsequently, in 1978, this was replaced by the Pilot Crop Insurance Scheme. In 1985, a nation-wide initiative, the Comprehensive Crop Insurance Scheme, was launched, employing an area-based approach. This scheme was succeeded by the National Agriculture Insurance Scheme in 1999, which was later adapted into the Modified National Agriculture Insurance Scheme. Alongside these, the Indian government introduced various other pilot projects and initiatives, including the Pilot Scheme on Crop Insurance (2000), the Farm Insurance Scheme (2003), and the Weather-Based Crop Insurance Scheme (2007). The recurrent alterations to these insurance programs were implemented with the aim of achieving improved outcomes in terms of claims processing, premium rates, and other pertinent factors (Gulati et al., 2018). At present, two active crop insurance schemes—the Pradhan Mantri Fasal Bima Yojana and the Restricted Weather-Based Crop Insurance Scheme—are in operation.

In 2016, the government introduced the Pradhan Mantri Fasal Bima Yojana (PMFBY) with innovative features, allocating an initial sum of Rs. 5500 crore in the 2016–2017 union budget (Rai, 2019). This initiative offers a comprehensive risk management solution through a uniformly low premium rate applied nationwide. PMFBY was designed to supplant earlier crop insurance schemes, notably the National Agriculture Insurance Scheme and the Modified National Agriculture Insurance Scheme, which exhibited certain inherent limitations. Operating on an area-based methodology, this insurance scheme extends coverage to all categories of farmers, including those with loans, without loans, tenants, and sharecroppers. Initially, the program mandated participation for farmers with outstanding loans from financial institutions, while being voluntary for those without loans. However, as of the kharif season in 2020, the scheme's participation became optional even for farmers with loans (Government of India, 2020).

The Pradhan Mantri Fasal Bima Yojana (PMFBY) is executed by both public and private insurance companies, operating under the overarching supervision of the Ministry of Agriculture and Farmers' Welfare. A distinctive feature of this scheme is its "one premium, one season" structure. It provides coverage for agricultural risks spanning the period from pre-sowing to post-harvest, and it encourages the adoption of modern technologies like global positioning systems (GPS), remote sensing, smartphones, and drones to accurately assess crop yields and losses, thereby expediting the claims settlement process. PMFBY encompasses a wide range of crops including kharif and rabi crops, as well as annual horticultural and commercial crops. Farmers are subject to a uniform premium rate: 2.0 percent for kharif crops, 1.50 percent for rabi crops, and 5.0 percent for annual horticultural and commercial crops. The remaining portion of the premium is split equally between the central and state governments.

Due to its geographical location as a delta region with numerous canals and its coastal proximity, West Godavari is highly susceptible to flooding during the monsoon season and frequently experiences the impacts of cyclones. Consequently, agricultural insurance schemes play a crucial role in providing stability to farmers' income in the event of crop losses. So, the study is carried out to analyse the performance of PMFBY insurance scheme in this district

In this way an attempt is made by this study to examine "**Forecasting of Rice yield based on biometrical characters and analyse the performance of Pradhan Mantri Fasal Bima Yojana (PMFBY) in West Godavari district of Andhra Pradesh.**"

OBJECTIVES

(i) To study the trend in area, production and productivity of rice yield in West Godavari district of Andhra Pradesh.

(ii) To forecast the rice yield in West Godavari district of Andhra Pradesh based on Biometrical characters.

(iii) To analyze the performance of Pradhan Mantri Fasal Bima Yojana in West Godavari district of Andhra Pradesh.

In Chapter II, a brief review of the literature focused on trend analysis, forecasting rice yield through biometrical characters, and the effectiveness of insurance schemes. Chapter III detailed the methods and approaches used to attain various objectives. Moving on to Chapter IV, outcomes and discussions were showcased using tables and figures accompanied by concise explanations. Chapter V encapsulates the study's wrap-up and conclusion. The conclusion is followed by a compilation of essential references.

CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Numerous investigations were carried out to identify the most reliable forecasting methods for various crops. The forecasting of Rice yield in the West Godavari district of Andhra Pradesh is based on multiple linear regression models in the current study. Brief reviews of local, national, and international literature are explained in this chapter in relation to the current investigation. Considering the goal of the study, opinions are offered for,

2.1 Trend analysis of crops in different region.

2.2 Forecasting of yield based on biometrical characters.

2.3 To analyse the performance of crop insurance schemes.

2.1 Trend analysis of crops in different region

In their research**, Mahto *et al* (2023)** utilized existing data to examine the patterns and Compound Annual Growth Rate of Ragi crop cultivated area, production, and yield in India. Their findings indicated a consistent rise in the Minimum Support Price (MSP) over time. However, they observed fluctuations in the area under cultivation and production, with an average annual decrease of 2.65% and 1.76% respectively. Notably, the MSP for finger millet exhibited a significant CAGR increase of 9.4%.

In their investigation, **Wasnik *et al.* (2022)** examined the growth patterns, instability, and the impact of area, yield, and their interaction on the production of key staple commodities: paddy, wheat, and gram. The study relied solely on secondary data spanning from 2000-01 to 2019-20. The findings revealed a consistent increase in both the area and production of paddy and wheat over the years. However, it was observed that the increase in production of gram was more substantial. The analysis of gram production growth indicated that the primary factor contributing to this increase was the larger cultivated area for gram in India**.**

Mainuddin *et al* (2022) A research was carried out in Bangladesh utilizing the non-parametric Mann-Kendall test and Theil-Sen slope estimator methods. The study incorporated data from all accessible weather stations across the country. The findings indicated a noteworthy downward trend in both wet season and dry season rainfall, which consequently affects rice cultivation. Additionally, the maximum temperatures recorded during both the wet and dry seasons exceeded the optimal temperature ranges required for rice production. Such temperature deviations are expected to have detrimental effects on crop yield in light of climate change, as rising temperatures continue to pose challenges.

K N, U., & Paul, H. (2022) conducted a study to examine the trends in the cultivation area, production, and productivity of cashew nuts in India, with a specific focus on the state of Kerala. Secondary data spanning a 20-year period from 2000 to 2020 were collected for analysis. Out of the total area of cashew cultivation in India (1,125,000 hectares) and the total production (703,000 metric tons), Kerala contributed only 8.5 percent of the cultivation area and 12.37 percent of the production in the most recent year of 2020. The analysis of the trends in area, production, and productivity revealed a negative Compound Annual Growth Rate (CAGR) throughout the study period.

Madhukar *et al* (2020) conducted a study to investigate the trends in crop yield for three significant food crops, namely wheat, rice, and maize, across various states in India. Annual yield data from all 29 Indian states were collected and analysed for the period spanning from 1967 to 2017. Different types of regression models were used for the application, and the selection of the best-fit statistical models was based on the AIC. The findings indicated that wheat yields in 13 states, rice yields in eleven states and maize yields in six states of India did not exhibit improvement over the study period.

Sunandini *et al* (2020) The aim of this study was to examine the trends, growth patterns, and fluctuations in the area, production, and yield of rice crop in the state of Andhra Pradesh over a span of fifty-five years, from 1959 to 2013. The annual growth rate and instability were calculated using the Compound Growth Rate and Coefficient of Variation methods. The findings of the study indicated that during this period, there was a 25% increase in the cultivated area, a 201% increase in production, and a 138% increase in productivity of rice in Andhra Pradesh.

Shafeer, K. B. *et al* (2021) In this study, an analysis was conducted to examine the trends and instability in the area, productivity, and production of paddy crops across various districts in Andhra Pradesh. The data used for the analysis spanning from 1991-92 to 2018-19, district-wise data from this period were assessed, revealing that the overall growth rate of paddy cultivation area in Andhra Pradesh exhibited a decline of 0.5%. Conversely, the growth rate of paddy productivity showed a positive trend of 1.31%, while the production increase was recorded at 0.74%. These observations can be attributed to the adverse effects resulting from changing weather patterns**.**

Unjia *et al* (2021) A research was conducted to analyse the trends in the cultivation area, production, and productivity of maize in India. Second-party data regarding the area, production, and productivity of maize were collected spanning the years from 1990-91 to 2018-19. The collected data was subjected to analysis using descriptive statistics and linear growth rates, specifically the Compound Annual Growth Rate (CAGR). The findings of the study indicated that both the area and production of maize have shown a consistent increase over the specified time period.

Atla *et al* (2021) This study aimed to estimate the annual compound growth rates of area, production, and productivity of paddy across different states in India. The analysis employed an exponential growth function to examine the pre-WTO period (1970-71 to 1994-95), the post-WTO period (1995-96 to 2017-18), and the overall period (1970-71 to 2017-18). The results revealed that in states such as Uttar Pradesh, West Bengal, Karnataka, Maharashtra, Punjab, and Assam, there were positive and significant growth rates in area, production, and productivity. Conversely, in Andhra Pradesh and Tamil Nadu, the growth rate in area exhibited a negative and significant trend, while production and productivity showed positive and significant trends throughout the entire period.

Lalitonjam *et al* (2018) A study was conducted to assess the contributions of the area, yield, and their interaction to the growth in rice production in India, as well as to determine the compound annual growth rates of area, production, and yield of rice. Secondary data from the years 1980 to 2014 were collected and analysed. The findings of the study indicated that during the period from 1980 to 2014, the yield effect had the highest contribution to the changes observed in rice production in India. Additionally, both the production and yield of rice exhibited compound annual growth rates of approximately 5% and 4% per annum, respectively.

Gayatri *et al* (2018) The aim of this study was to assess the current situation of groundnut cultivation in India, focusing on the area, production, and yield. The researchers collected secondary data from the Directorate of Economics and Statistics for their analysis. The findings revealed that, except for the area under cultivation, both production and yield of groundnut displayed an increasing trend. The compound growth rate for the groundnut cultivation area exhibited a negative trend, while production and yield demonstrated positive trends at rates of 1% and 3.26% respectively. These results indicate that the increase in yield has a greater impact on overall production than changes in the cultivated area.

Sunitha, *et al* (2018) The research aimed to analyse the growth rates of rice production using a time series data spanning from 1986-87 to 2015-16 for ten districts in Telangana State. The data was divided into two periods, each consisting of fifteen years. The growth patterns were examined through compound growth rate (CGR) and linear growth rate (LGR). CGR was fitted on an exponential model ($Yt = \beta_0+\beta_t+ \varepsilon_t$), while LGR was fitted on a linear model ($Y_t = \beta_0 + \beta_1 +\epsilon$). Results revealed an overall upward trend in the area, production, and productivity of rice at both the state level and within each period. During the second period, the linear growth rate and compound growth rates of the area and production of rice were higher compared to the first period, while productivity was highest in the first period. In terms of the state as a whole, the growth rates of production were higher than those of the area and productivity. Notably, production exhibited the highest growth rate during the second period, surpassing the growth rates of both the area and productivity in all periods. Regarding area, the growth rates showed positive but non-significant trends in both periods. However, for production and productivity, the growth rates were positive and significant at the 5% and 1% probability levels, respectively, in both periods.

Kumrawat and Yadav (2018) A study was conducted to evaluate the patterns in the area, production, and yield of mustard crop in the Bharatpur region of Rajasthan. To accomplish this, secondary data were collected from multiple published sources and websites, covering the period from 2001-02 to 2014-15. The findings indicated a consistent upward trend in the area, production, and yield of mustard crop in the Bharatpur region from 2001 to 2013. However, from 2013 to 2015, there was a decline observed in all three factors, primarily attributed to unfavourable weather conditions during that period.

Jain (2018) The study involved an analysis of 41 years' worth of data, spanning from 1970-71 to 2011-12, to examine the variations and fluctuations in the area, production, and yield of rice in India. The results indicated that, at the national level, the compound annual growth rate of rice's area, production, and yield remained positive, albeit gradually declining over the study periods. However, in the most recent decade (2000-01 to 2011-12), there was a noticeable increase in instability observed across all three factors—area, production, and yield—pertaining to rice cultivation in India.

Parmar *et al* (2017) The researchers conducted an analysis of the area, production, and productivity trends as well as growth rates of maize crop in the Panchmahal region of Gujarat from 1949-50 to 2007-08. They employed both parametric and nonparametric regression models for their study. The findings indicated that the production of maize experienced an annual increase of 0.49 percent. This growth was attributed to the combined effect of an increase in both the cultivated area and productivity, which exhibited annual growth rates of 0.30 percent and 0.21 percent, respectively.

Shruthi *et al* (2017) conducted an investigation to examine the growth rates of area, production, and productivity of groundnut crop in Telangana, specifically focusing on the period from 2000-01 to 2014-15. The researchers utilized an Exponential function to analyse the data. The findings of the study revealed that during the specified study period, there was an increase observed in the area, production, and productivity of groundnut in Mahabubnagar district of Telangana.

Greeshma *et al* (2017) A study was conducted to analyse the growth models and trends pertaining to the area, production, and productivity of sugarcane crop in the Coastal Andhra region of Andhra Pradesh State. The researchers found that the quadratic function provided the best fit for both area and production, while a linear function was most suitable for measuring productivity. The results of the study indicated an upward trend in the area, production, and productivity of sugarcane crop throughout the specified study period.

Akhter *et al* (2016) A comprehensive study was conducted to analyse the growth and trends in the area, production, and yield of major crops in Bangladesh, including rice, wheat, pulse, rapeseed and mustard, jute, sugarcane, and tea. Data were collected over a 40-year period from 1969-74 to 2004-2009. The compound growth rate and trend analysis revealed that the production of rice increased during this period, primarily due to the corresponding increase in per-hectare yield of rice crops in Bangladesh. The study also demonstrated an overall increase in the area, production, and yield of wheat over time, with the exception of the years 2004-2009. Additionally, it was observed that the area, production, and yield of pulses showed an increasing trend. Specifically, the area, production, and yield of rapeseed and mustard crops increased at rates of 1.21%, 2.33%, and 1.11% per annum, respectively. On the other hand, there was a decrease in the area, production, and yield of jute. Interestingly the analysis revealed that the trend coefficients for the area, production, and yield of sugarcane and tea were positive, indicating an overall growth in these crops over time.

Sihmar (2014) The study observed that the production of crops like rice and wheat in Haryana exhibited satisfactory performance during three distinct periods: 1980-81 to 1989-90, 1990-91 to 1999-2000, and 2000-01 to 2006-07. However, crops such as Gram, Massar, Maize, Sesamum, and groundnut experienced negative growth rates. The research also indicated that the instability in production was low and declined over time for wheat and rice crops. Furthermore, the study highlighted the positive impact of the Green Revolution and new economic reforms on the overall production of food grains.

Bhatt *et al* (2014) An investigation was conducted to compare the production of food grain crops in Jammu & Kashmir and Haryana, revealing that Haryana had higher levels of production, cultivated area, and yield in comparison to Jammu & Kashmir. The study identified yield and its interaction with the cultivated area as the primary factors contributing to food grain production in Haryana during the period from 1979 to 2009.

Sharma (2012) A study was conducted to examine the productivity, production and area trends of food grains in the northeast states. Various functional forms including linear, quadratic, and exponential were employed to analyse the trend, and the linear form was chosen due to its higher value of goodness of fit. The coefficients of variation for the area, production, and productivity of food grain crops were found to be below 0.551 percent. Furthermore, the instability indices for the area, production, and productivity of food grain crops in the northeastern states were positive, suggesting a lower risk associated with cultivating food grains in the region.

2.2 Forecasting of crop yield based on biometrical characters.

Kumar *et al* (2023) A study was conducted to develop a regression model for predicting rice yield before the harvest in Banka district of Bihar for the year 2019-20. Ten variables, including nine biometrical characters and one farmers' appraisal variable (crop condition), were considered in the analysis. Among these variables, five independent variables were found to play a significant role in the model development: X1 (Average of plant height), X3 (Average of effective number of tillers), X6 (potassium Applied), X7 (level of Irrigation), and X9 (plant condition). The developed model was expressed as $\hat{Y} = 31.897 - 0.709X1 + 0.700X3 + 0.233X6 + 1.382X7 + 18.696X9$. After conducting a model validation test, the average value of mean absolute percentage error (MAPE) closely matched the selected model, indicating a good fit for forecasting. Based on this model, the estimated rice yield in Banka district for the year 2019-20 is approximately 41.25 q/ha.

Singh *et al* (2020) The researchers aimed to develop a potato yield forecasting model at the individual farmer level using plant biometrical characters that can be recorded well in advance of the crop harvest. The study findings indicated that the optimal time for forecasting potato yield from farmers' fields is approximately 60 days after the sowing date. At this recommended time, the forecast model was identified as $Y= 0.19X1 + 0.09X2$, where the yield per plot (Y) is significantly influenced by two variables: plant population (X1) and number of leaves (X2).

Basso et al (2019) This study conducts an extensive evaluation of contemporary approaches to seasonal crop yield forecasting, addressing an enduring challenge within agriculture. Acknowledging the pivotal significance of such forecasts for a wide array of stakeholders, including farmers, policymakers, governments, and traders, the chapter scrutinizes diverse techniques delineated in scientific literature. It places particular emphasis on major crops like wheat, maize, rice, barley, and soybean. These methodologies encompass field surveys, statistical correlations between historical yields and in-season variables (such as agrometeorological or remotely sensed data), crop simulation models, and integrated strategies that amalgamate statistical modelling with dynamic process-based crop simulation models. Although some investigations give prominence to field surveys, particularly in countries like the USA, this review imparts insights into the comprehensive spectrum of research outcomes across crops, methodologies, geographic contexts, and prediction accuracies. It concludes by providing a critical evaluation of the strengths and limitations associated with the various methods utilized by researchers and stakeholders in the realm of crop yield forecasting.

Singh *et al* (2019) In this study, a statistical model was employed to forecast the crop yield of wheat at different growth stages. The model utilized various weather parameters, including maximum and minimum temperature, rainfall, morning and evening relative humidity, during the crop's growing period. Weather indices generated from these parameters were used as predictors in the forecast model. To determine the significant weather variables influencing crop yield, the least absolute shrinkage and selection operator (LASSO) and stepwise regression methodologies were applied. The results revealed that LASSO outperformed stepwise regression, with an R-squared value of 0.84 compared to 0.85. Furthermore, the mean square error (MSE) and root mean square error (RMSE) of LASSO regression were superior to those of stepwise regression, resulting in improved crop yield forecasting. Based on the findings, it can be concluded that, for the specific data considered in this study, LASSO is more effective than stepwise regression for variable selection.

Kumar *et al* (2019) A statistical model was developed to estimate rice yield prior to harvest in the year 2018-19. The study incorporated plant biometrical characteristics and farmers' assessments. A sample survey was conducted on farmers' fields using a multistage stratified random sampling method, recording fourteen parameters. Regression analysis was performed, leading to the selection of the best-fitting model ($\bar{Y}$ = 27.07355-1.69966X1 + 0.25058X2 + 0.24110X4 + 1.28741X5-0.45193X6 + 1.17152X13) based on important statistical indicators such as RMSE, R^2, Adj.R^2, C.V, Residual, and Cook's D statistic. The findings indicate that the estimated rice yield in Arwal district for the year 2018-19 is approximately 33.28 q/ha.

Rocha *et al* (2019) The study aimed to investigate the potential of integrating biometric variables and canopy reflectance data to develop models for early-stage prediction of sugarcane biomass. To evaluate this, four sugarcane farms were examined using an crop canopy sensor, and sampling plots of 30 were selected for manual measurements of chlorophyll content, stalk number, plant height and aboveground biomass. The results indicated that both Random Forest model and Multiple Linear Regression models performed similarly in predicting biomass. Furthermore, incorporating biometric variables such as stalk number and plant height with data improved the performance of the models, although the specific attributes selected played a crucial role. These findings suggest that by estimating biomass in the initial stages, sugarcane cultivators can implement essential management practices to enhance yield and minimize input usage.

Bholanath *et al* (2018) A study was conducted to examine the relationship between yield and various plant biometrical characters. Regression models were developed, with yield as the dependent variable and biometrical characters as the independent variables. Among the five selected regression models with the minimum root mean square error (RMSE), all were found to be highly significant. Model-V specifically demonstrated the lowest Standard Error of Mean Predicted value, at 1.08670. Using this model, a pre-harvest forecast for rice yield in Bhagalpur for the year 2016-17, based on biometrical characters, is estimated to be approximately 43.80967 (q/ha).

Das *et al* (2018) An investigation was conducted to analyze the use of different statistical models for predicting rice yield based on long-term weather data. The models examined were stepwise multiple linear regression (SMLR), artificial neural network (ANN), as well as combinations of ANN with principal components analysis (PCA) and penalized regression models like least absolute shrinkage and selection operator (LASSO) or elastic net (ENET). To evaluate the performance of these models across multiple locations, several statistical measures such as R^2 and RMSE for calibration, and RMSE and nRMSE for validation were calculated. Additionally, a non-parametric Friedman test was employed to determine if there were any significant differences among the models.

Sisodia *et al* (2017) The researchers developed several statistical models to forecast rice yield before the harvest, utilizing data from varietal experiments. Through various statistical measures to compare and validate the models, it was determined that model-I of multiple linear regression was the most appropriate, followed by model-III, for accurately predicting rice yield prior to the harvest.

Annu *et al* (2016) This paper focuses on the application of principal component analysis (PCA) to develop statistical models for predicting rice yield before the harvest based on biometrical characters. The models were developed using data from two rice experiments. The forecasted yields from these models were compared to the actual yields, with experiment-I yielding forecasts of 24.25, 22.60, and 21.10 q/ha against actual yields of 28.00, 23.56, and 21.85 q/ha. In experiment-II, the forecasted yields were 24.62, 28.06, and 29.43 q/ha compared to actual yields of 28.82, 29.31, and 26.59 q/ha. The forecasted yields were subject to a maximum standard error of approximately 10 percent. In most cases, the forecasted yields closely matched the actual yields, with only a few exceptions. The models were found to be valid with R2 values of 79.80 and 72.60 for experiment-I and II, respectively. Notably, this study represents the first application of PCA as a statistical tool to develop pre-harvest forecast models based on experimental data.

Kumar *et al* (2014) Using the multiple linear regression technique, yield forecasting models were created for wheat, sugarcane, and paddy crops in two districts of Gujarat: Navsari and Bharuch. By selecting weather variables with the highest R^2 value and significant P-value, significant predictors were identified. The multiple regression analysis was conducted using a trial-and-error approach. To assess the accuracy of the models, validation was performed using independent data sets spanning four years (2007 to 2010) specifically for these two districts.

Aneja and rai (2013) A statistical model was proposed to estimate cotton yield before harvest based on growth indices. These growth indices represent the weighted accumulations of observations on plant biometrical characteristics during different periods, with weights determined by their correlation coefficients with yield. The study utilized pooled data from four years (2003-06), including seven characteristics such as height, girth, total bolls, opened and unopened bolls, as well as yields from various pickings obtained through a pilot survey. Through regression analysis, it was concluded that the number of unopened bolls, girth, and yield obtained five months after sowing are sufficiently indicative for developing advanced estimates of cotton yield.

Verma et al (2013) Crop yield models were developed for cotton hybrids RCH 134BG-I, RCH 134BG-II, Bio seeds 6488BG-I, and Bio seeds 6488BG-II during the kharif season of 2011-12 in Hisar district, Haryana state. The models were based on biometrical characters observed at five-six consecutive stages throughout the growth period of the cotton crop. In the case of hybrid RCH 134BG-I, the total number of bolls at the 3rd and 4th stages emerged as the most effective predictors. On the other hand, for hybrid RCH 134BG-II, the number of unopened bolls at the 1st stage, along with the total number of bolls at the 3rd and 4th stages, were found to be the significant contributing factors. Regarding the hybrid Bio seeds 6488BG-I, the opened bolls at the 3rd stage, total number of bolls at the 4th stage, and the yield from the first picking played crucial roles in predicting crop yield. Similarly, for the hybrid Bio seeds 6488BG-II, the height at the 3rd stage, opened bolls, total bolls at the 4th stage, and the yield from the first picking were identified as the most reliable predictors.

Annu (2013) Crop yield forecast models were developed based on plant biometric characteristics. Various statistical tools and techniques, including multiple regression analysis, discriminating function analysis, principal component analysis, growth indices, and composite forecast, were employed for this purpose.

Zhuo et al (2013) In this study, a novel approach is introduced to boost the precision of regional winter wheat yield predictions using the WOFOST model. Through the assimilation of MODIS LAI data and the application of advanced optimization techniques, the research showcases substantial enhancements in prediction accuracy, as indicated by improved correlation coefficients, a more favourable coefficient of concordance, and diminished relative errors compared to unassimilated outcomes. This interdisciplinary method underscores the potential of incorporating remote sensing data, crop modelling, and weather forecasts for in-season crop yield forecasting, underscoring its practical significance for regional and national agricultural management strategies.

2.3 To analyse the performance of crop insurance scheme

Kaur et al (2021) In a study based on cumulative data, researchers utilized regression analysis to develop a regression model that estimated the impact of insurance characteristics on farmer coverage during the years 2017-2018 and 2018-2019. The study revealed that the agricultural insurance coverage provided by the PMFBY scheme remained relatively low in terms of the number of farmers enrolled in the scheme, area insured, claims paid~~,~~ and overall benefits to farmers. When compared to other schemes, the beneficiary and ratio claim premium ratios were significantly lower for the PMFBY. The analysis indicated that farmers' premiums had a significant influence on the number of farmers insured over time, while subsidies did not play a significant role in farmers' participation in the insurance program. Weaknesses of the PMFBY were identified as late claim settlement, complexity of the system, and limited awareness among farmers.

To address these challenges, the study suggested leveraging digital media platforms to enhance awareness and knowledge about the insurance schemes among farmers.

Reddy *et al* (2021) This research focuses on understanding the factors that influence non-loanee insured farmers' participation in the Pradhan Mantri Fasal Bima Yojana (PMFBY) crop insurance program in Telangana state. The study specifically selected two districts based on their high number of farmers covered under PMFBY. Districts and villages were chosen randomly for data collection purposes. The collected data was then analysed using a logit regression model. The findings revealed that factors such as production risk, interaction with extension agencies, positive feedback from experienced farmers, social group participation, and farmers' income were significant variables that influenced farmers' decision to participate in the crop insurance program.

Singh *et al* (2020) I conducted a study to evaluate the effectiveness of crop insurance schemes implemented in the state of Haryana. I analysed the Economic Survey of Haryana stand reviewed the yearly reports of the Agriculture Insurance Company (AIC) for various periods. The findings of the study revealed that Haryana has implemented a limited number of schemes compared to other states in India. However, the Pradhan Mantri Fasal Bima Yojana consistently demonstrates superior performance and proves advantageous for the farmers in Haryana.

Prasuna *et al* (2019) conducted a study aimed at analysing the current crop insurance scheme, commonly referred to as PMFBY, in Andhra Pradesh. The study utilized a case study approach to examine the practical implementation of PMFBY in three chosen districts of A.P. Secondary data sources were used to gather relevant information. The findings of this study indicate that a majority of small and marginal farmers are unable to avail the advantages of PMFBY due to insufficient awareness and limited promotion of the scheme.

Roy *et al* (2018) This study aims to assess the effectiveness of the scheme in West Bengal, focusing on aspects such as governance, implementation, and farmer participation. Additionally, the study aims to provide policy recommendations for enhancing the scheme's performance. The findings indicate that the scheme has been highly successful in promoting crop insurance among farmers in West Bengal, with over 4.1 million farmers enrolling in PMFBY/BFBY during its initial year of implementation. Moreover, the performance in terms of governance and implementation under PMFBY/BFBY is deemed satisfactory.

Dey, k., Maitra, D. (2017) conducted a study that examined the Pradhan Mantri Fasal Bima Yojana (during the kharif season of 2016) and the Weather-based Crop Insurance Scheme (from the kharif season of 2007 to the kharif season of 2014). The study evaluated the performance of these schemes based on various indicators, including the average sum insured per insured cropped area, the percentage of loanee and non-loanee farmers covered, the average area insured per farmer, the total claim ratio, the farmer claim ratio, the premium as a percentage of the sum insured, and the gross profit to insurance agencies. The findings suggest that increasing the claim payout can enhance farmers' coverage under PMFBY, while factors such as subsidies and actuarial premium rates significantly impact farmers' coverage under WBCIS.

Deshmukh *et al* (2017) I conducted a research study with the following objectives: (1) to assess the performance of the National Agricultural Insurance Scheme in Amravati division, (2) to examine the effectiveness of alternative insurance schemes in the same division, and (3) to identify the underlying reasons for the limited adoption of Agricultural Insurance Schemes. The research primarily focused on analysing the crop insurance scheme for the Gram crop during the Rabi season of 2014-15 in Amravati division. Data for this study were collected through surveys conducted with farmers and banks. The study identified that delayed payment of claims and insufficient awareness about the crop insurance scheme were the main factors contributing to the low coverage of agricultural insurance schemes, as reported by 44 percent of the farmers.

Yasmin and Hazarika (2015) Based on the study conducted in Kamrup district of Assam, it can be observed that the Modified National Agricultural Insurance Scheme (MNAIS) has shown a declining trend over the past three years. This decline is evident in various aspects, including the reduction in the area covered, the number of farmers covered, the sum insured provided to farmers, the premium paid, and the number of farmers who have benefitted from the scheme.

Swain (2014) The research findings highlight a significant concern regarding the low adoption rate of the National Agricultural Insurance Scheme (NAIS) among non-loanee farmers. A closer analysis based on different regions reveals that non-loanee farmers in agriculturally disadvantaged areas such as the northern plateau and central table land exhibit higher participation in NAIS, likely due to the higher agricultural risks prevalent in these regions. On the other hand, the coastal region, known for its agricultural advancement, shows a minimal percentage of area covered by non-loanee farmers, with only 0.3 percent. In contrast, the most agriculturally backward region of the northern plateau demonstrates a substantial 12 percent coverage by non-loanee farmers. These findings indicate that farmers who did not take loan are more inclined to take crop insurance in areas with higher agricultural risks.

Tsikirayi et al. (2013) Research in Zimbabwe has revealed that insurance participation within the agricultural sector remains notably low. Farmers appear to lack a comprehensive understanding of the insurance products available from providers, as well as the inherent benefits of agricultural insurance policies. This is partly attributable to the perception that insurance is typically acquired when a farming enterprise is thriving, with the unfortunate realization of its utility only occurring when a farmer experiences a significant loss.

Patwardhan and Narwade (2013) study illuminated an interesting trend in Maharashtra's agricultural landscape during the kharif season. According to their findings, the number of farmers enrolled in the National Agricultural Insurance Scheme (NAIS) exhibited a modest growth rate of 1.50 percent over the studied period. However, a notable contrast emerged in the statistics for the area covered and the farmers who derived benefits from the scheme. The study revealed a decline of 6.05 percent in the area covered and a 4.14 percent decrease in the number of farmers who reaped the advantages of the NAIS between 2000 and 2010.

Namdev et al (2013) In his research arrived at a conclusive observation regarding the National Agricultural Insurance Scheme (NAIS). Their study emphasized that the NAIS's coverage, including aspects such as the area covered, premium collection, and claim settlement, remains relatively limited. As such, the study underscores the necessity for enhancing the current level of coverage to more effectively address agricultural risk management.

Mani et al (2012) In their study, noted a significant shift in the number of non-loanee farmers participated in the National Agricultural Insurance Scheme (NAIS) in Tamil Nadu. Their findings revealed that in the year 2000, only 0.81 percent of the total farmers covered in the state were non-loanee farmers under the NAIS. However, by 2007, this figure had surged dramatically to 64.42 percent. Over the period from 2000 to 2008, non-loanee farmers constituted 45 percent of the total farmers covered under NAIS in Tamil Nadu. These observations highlight a noteworthy increase in the involvement of non-loanee farmers in the crop insurance scheme during this period.

Suresh Kumar et al (2011) In his research in presented compelling evidence of the substantial growth in the coverage of the National Agricultural Insurance Scheme (NAIS). Their findings indicated a noteworthy expansion, with the area covered under the NAIS scheme increasing significantly from 2.32 lakh hectares in 2000 to 11.09 lakh hectares in 2009. When assessed in terms of net sown area, this coverage witnessed a substantial rise, soaring from 4.24 percent to 22 percent. Likewise, in the context of the gross cropped area, the coverage expanded from 3.6 percent to 19 percent over the same period, showcasing a remarkable increase in the reach and impact of the NAIS scheme.

Gosh and Yadav (2008) observations shed light on the growing acceptance and utility of the agricultural insurance scheme within Indian agriculture. Their findings highlighted a remarkable trend, with an approximate 30 percent increase in the number of farmers opting for coverage, and a substantial 57 percent expansion in the covered area during the year 2004-05. The provided data highlights significant advancements made by the National Agricultural Insurance Scheme (NAIS) in terms of its outreach to farmers, the extent of coverage, and the insured amount. Additionally, the enthusiastic involvement of farmers in the program, combined with the effective efforts of NAIS and its collaborators in efficiently spreading crucial information and advantages throughout a large nation, serves as a strong testament to its achievements.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study is being conducted in order to investigate the growth trend of area, production, and yield, forecasting of Rice yield based on biometrical characters, as well as to analyse the performance of PMFBY in the west Godavari district of Andhra Pradesh. The brief description of material and methods provided here serves as the foundation for this study.

The methodology is outlined below;

3.1 Information of study area

3.2 Source of the data

3.3 Statistical methodology used for the analysis

3.1 Information of study area

West Godavari district is one of the 26 districts of the Andhra Pradesh state, India. It lies between the latitudes of 16°-15'-00" and 17°-35'-00" North and the longitudes of 80°-00'-00" and 81°-30'-00" East. West Godavari district is Situated in the coastal region and known for its fertile lands and proximity to the Godavari River. Covering an area of approximately 7,742 square kilometres, West Godavari district constitutes a significant part of the state's total geographical area. It is located in the eastern part of the state and experiences a subtropical climate. West Godavari experiences a tropical climate which is same for the rest of the coastal Andhra region. The West Godavari district experiences a stark contrast between its hot and dry summers (March-June) and cooler winters. During the summer months, temperatures can soar, often exceeding 50 °C during the day, making it a challenging time of the year. The rainy season is widely regarded as the optimal time for tourists to roam in West Godavari. This period showcases the district's picturesque landscapes as the fields flourish in vibrant shades of green with thriving paddy crops. The rivers, rejuvenated by monsoon rainfall, flow gracefully, and the overall climate tends to be relatively cool and pleasant. The district's climate is influenced by its coastal location and the nearby Eastern Ghats. The district experiences an average of 52.5 rainy days per year, with precipitation total approximately 976 mm. The monsoon season, typically from June to September, brings the majority of the rainfall to the region. The district's agricultural sector benefits greatly from these seasonal rains, contributing to its agricultural productivity. Located at an elevation of approximately 78.74 feet above sea level, West Godavari district enjoys the advantages of being situated in a coastal plain region. The fertile lands and proximity to the Godavari River make it suitable for various agricultural activities, including the cultivation of rice, sugarcane, and other cash crops. Overall, West Godavari district boasts a favourable climate for agriculture, with abundant rainfall and fertile soil. Its geographical features and proximity to the Bay of Bengal make it a significant agricultural region in Andhra Pradesh, contributing to the state's agricultural output.

3.2 Source and description of data

The study was based on first hand data and secondary data which have been obtained from the following sources:

3.2.1 Time series data: Time-series data on area, production, yield for rice crop of West Godavari district pertaining from 1966 to 2017 has been obtained from ICRISAT Hyderabad. (http://data.icrisat.org/dld/src/crops.html)

3.2.2 Biometrical characters data: First hand data (primary data) on biometrical characters of rice is collected directly from the farmer fields.

3.2.3 PMFBY insurance scheme data: Secondary data is obtained from PMFBY portal.

3.3 Statistical methodology used for the analysis

The data derived related to rice from the authenticated sources were used for the analysis as follow.

3.3.1 Method to analyse growth trend of area, production and yield of Rice

3.3.1.1 Graphical Method

Data analysis of time series data of Rice area, production, and yield trend values. After a graphical analysis, the trend in Rice area, production, and yield were calculated at various points along the trend.

3.3.1.2 Compound Annual Growth Rate

Compound Annual Growth Rate (CAGR) could be calculated to study interstate disparities. The student t- test can be used to determine the significance of the growth rate. Sendhil (2012) proposed the formula, which is as follows:

CAGR = (antilog of b -1) x 100

where, b = slope of the regression model fitted with area, production or yield taking time as independent variable

3.3.1.3 Accuracy Measure

Measure of accuracy could be utilized in this research topic;

Coefficient of determination (R^2)

R-squared (R^2) is a widely favoured metric for assessing the quality of a linear statistical model. R^2 assumes values within the range of 0 to 1, with 0 suggesting that the model lacks predictive power, while 1 signifies a perfect fit. The model that boasts the highest R^2 is typically regarded as the most suitable option when determining the best-fitting model. Consequently, this preferred model is expected to yield the lowest forecast error, making it a practical choice for optimizing predictive accuracy in statistical modelling.

3.3.2 Method to develop models for forecasting of rice yield

3.3.2.1 Identification of measurable and non-measurable characters

Crop yield is influenced by various characteristics of the plants. Some of these traits have a direct impact on crop yield, such as the count of plants in each area, the number of ear-heads each plant produces, the quantity of kernels on each ear-head, and the weight of each individual kernel. Other factors, like the height of the plants, have an indirect effect on crop yield. To determine which plant characteristics should be considered as explanatory variables in predictive models for crop yield, it's common to consult with experts in crop physiology, agronomy, and soil science. These specialists can provide insights into how specific traits affect the yield of rice.

The data required for these forecast models would typically be gathered through collaboration with experts in the fields of crop physiology, agronomy, and soil science. These professionals can provide guidance on which characteristics to measure. The collected data would encompass both qualitative and quantitative attributes. For instance, it would include metrics like the average plant population, the average height of plants, the average count of effective tillers, the average length of ear-heads, and details about the presence of nutrients like Nitrogen (N), Phosphorous (P_2O_5), and Potash (K_20), as well as factors like the number of irrigation cycles, the extent of damage caused by pests and diseases, and a subjective assessment of the average health of plants (estimated visually).

Table 3.1: List of qualitative and quantitative characters of rice

S.no	Variables	Variables code	Measurement Unit	Type of characters
1	Yield of field	Y	q/ha	Measurable
2	Average plant population	X1	Per m^2	Measurable
3	Average plant height	X2	Cm	Measurable
4	Average number of tillers	X3	Per m^2	Measurable
5	Average length of panicle	X4	Cm	Measurable
6	Nitrogen(N_2)	X5	Kg/ha	Measurable
7	Phosphorus(P_20_5)	X6	Kg/ha	Measurable
8	Potassium(K_2O)	X7	Kg/ha	Measurable
9	Number of irrigations	X8	Numbers	Measurable
10	Disease infestation	X9	Percentage	Measurable
11	Average plant condition	X10	Eye estimate	Non-measurable

The final character is inherently non-measurable as it relies on subjective human judgment and evaluation.

3.3.2.2 Obtaining data on rice after selection of villages and farmer fields

A structured sampling plan was devised to gather observational data within the West Godavari district of Andhra Pradesh. The selection process involved a multi-stage random sampling approach, commencing with villages as the initial stage, followed by the farmer's field as the second stage, and finally, individual plot as the third stage. This three-stage random sampling was based on the stratification of sampling units by block or mandal. The first stage units consisted of villages, the second stage units were farmer fields, and the third stage units were individual plots.

To ensure a representative dataset, the following sampling protocol was employed: Five villages were randomly chosen, each containing five randomly selected farmers. Within each farmer's field, one plot was designated for observation. This meticulous process resulted in a total sample size of 50 plots across the West Godavari district. Each selected plot was standardized to one square meter for consistency in crop measurements.

Furthermore, to validate the model, 10 percent of the observations were set aside for modal validation purposes, while the remaining 90 percent of the observations were utilized in the development of the model. This rigorous sampling strategy ensures the collection of reliable data and the creation of a robust model for the study area.

3.3.2.3 Fit the best combination of yield attributing characters using least square technique

From a sample of 50 observations, 10 percent of the recorded data was set aside for the purpose of model validation, while the remaining 90 percent of the observations were utilized in the development of the forecasting model.

Statistical tools for model development

Multiple regression

Variations in the independent variables, denoted as X's, lead to variations in the dependent variable, y. To address and model this relationship, we utilize multiple regression, denoted as multiple regression of y on X's.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + e$$

In this context, the symbol β0 represents the intercept term, while the symbols βi (where i takes values from 1 to p) represent the partial regression coefficients. Additionally, the random error is denoted as "e".

Multiple regression equation fitting

Consider a scenario where we gather n observations on both the dependent variable y and the set of independent variables denoted as X's. For each of these observations, there exists an unobserved error term, denoted as e_i. We establish the following assumptions pertaining to these error terms, which are essentially random variables:

1. The errors are independent from one another.

2. The errors possess a mean of zero and maintain a consistent variance (σ^2).

These assumptions can also be written as

$$E(e_i) = 0, V(e_i) = \sigma^2 \text{ for all } i = 1,2, \ldots, n.$$

$$Cov.\left(e_i, e_j\right) = 0$$

Estimation of Parameter

To estimate the unknown parameters $\beta_0, \beta_1, \beta_2, \ldots, \beta_P$, we employ the method of least squares, which involves minimizing the sum of squares of errors. This sum of squares of errors is expressed as:

$$S = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n}\left(Y_i - \beta_0 - \beta_1 X_{1i} - \beta_2 X_{2i} \ldots . -\beta_p X_{pi}\right)^2$$

By differentiating the sum of squares of errors, denoted as S, with respect to the parameters β0, $\beta_1, \beta_2, \ldots, \beta_p$, and setting these derivatives to zero, we obtain a system of P + 1 equations involving P + 1 unknowns, which can be represented as follows:

$$\sum Y_i \quad = n\beta_0 + \beta_1 \sum X_{1i} + \beta_2 \sum X_{2i} + . \; . \; . + \beta_p \sum X_{pi}$$

$$\sum X_{1i}Y_i = \beta_0 \sum X_{1i} + \beta_1 \sum X_{1i}^2 + \beta_2 \sum X_{1i}X_{2i} + . \; . \; . + \beta_3 \sum X_{1i}X_{3i}$$

$$\sum X_{2i}Y_i = \beta_0 \sum X_{2i} + \beta_1 \sum X_{1i}X_{2i} + \beta_2 \sum X_{2i}^2 + . . . + \beta_p \sum X_{1i}X_{pi}$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\sum X_{pi}Y_i = \beta_0 \sum X_{pi} + \beta_1 \sum X_{pi}X_{2i} + \beta_2 \sum X_{pi}X_{2i} + . . . + \beta_p \sum X_{pi}^2$$

To find the values of the P + 1 unknowns, we can solve these normal equations simultaneously. However, it is often more advantageous to solve these equations by inverting the matrix of coefficients on the right-hand side. This approach not only provides the parameter estimates but also facilitates straightforward significance testing of the β's.The equations can be expressed in matrix notation as follows:

$$\begin{vmatrix} n & \sum X_{1i} & \sum X2i & . . . & \sum Xpi \\ \sum X1i & \sum X1i2 & \sum X1iX2i & . . . & \sum X1ipi \\ \sum X_{2i} & \sum X_{1i}X2i & \sum X_{2i}^2 & . . . & \sum X_{2i}Xpi \\ \sum X_{pi} & \sum X_{1i}X_{pi} & \sum X_{2i}X_{pi} & . . . & \sum X_{pi}^2 \end{vmatrix} \begin{vmatrix} \beta 0 \\ \beta 1 \\ \beta 2 \\ \beta p \end{vmatrix} \qquad \begin{vmatrix} \sum yi \\ \sum X1iYi \\ \sum X_{2i}Yi \\ \sum X_{pi}Yi \end{vmatrix}$$

Therefore,

$$\begin{vmatrix} b_0 \\ b1 \\ b2 \\ bp \end{vmatrix} = \begin{vmatrix} n & \sum X_{1i} & \sum X_{2i} & . . . & \sum X_{pi} \\ \sum X_{1i} & \sum X_{1i}^2 & \sum X_{1i}X_{2i} & . . . & \sum X_{1i}X_{pi} \\ \sum X_{2i} & \sum X_{1i}X_{2i} & \sum X_{2i}^2 & . . . & \sum X_{2i}X_{pi} \\ \sum X_{pi} & \sum X_{pi}X_{2i} & \sum X_{2i}X_{pi} & . . . & \sum X_{pi}^2 \end{vmatrix}^{-1} \begin{vmatrix} \sum Y_i \\ \sum X_{1i}Y_i \\ \sum X_{2i}Y_i \\ \sum X_{pi}Y_i \end{vmatrix}$$

Inverse of the matrix is denoted by

$$C = \begin{vmatrix} C_{00} & C_{01} & C_{02} & \cdots & C_{0p} \\ & C_{11} & C_{12} & \cdots & C_{1p} \\ & & C_{22} & \cdots & C_{2p} \\ & & & & C_{pp} \end{vmatrix}$$

Then, $V(b_i) = C_{ii}\sigma^2$, i=0,1,2,.........P

$$Cov(b_i b_j) = C_{ij}\sigma^2$$

Estimation of σ^2

However, in situations where the aforementioned approach is not applicable, the estimate of σ^2 is obtained from the residual or error sum of squares. The residual sum of squares (SSE) is calculated by summing the squared differences between the observed values of y and the corresponding predicted values from the fitted model

$$SSE = \sum_{i=1}^{n} ei^2 = \sum_{i=1}^{n} (y_i - \hat{Y}_i)^2$$

A convenient computing formula for SSE may be substituting $\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_pX_p$ and on simplifying

$$SSE = \sum Y_I^2 - b_0 \sum Y_i - b_1 \sum X_{1i}Y_i - b_2 \sum X_{2i}Y_i \ldots - b_p \sum X_{pi}Y_i$$

Substituting $b_0 = \hat{Y} - b_1X_1 - b_2X_2 - \ldots - b_pX_p$

We get $SSE = S_{yy} - b_1S_{X1y} - b_2S_{X2y} - \ldots - b_3S_{Xpy}$

The residual sum of squares has (n-p-1) degrees of freedom, because P+1 degrees are associated with the estimates β"s involved in obtaining ī . Now the expected value of SSE is E (SSE) = (n-p-1)σ^2 so an unbiased estimator of σ^2 is

$$\hat{\sigma}^2 = S^2 = \frac{SSE}{n-p-1} = MSE$$

The quantity MSE, also known as the error mean square or residual mean square, serves as an important measure in regression analysis. The square root of MSE is sometimes referred to as the standard error of regression, and its unit is the same as that of the response variable y.The accuracy of the estimate of σ^2 (variance of the errors) depends on the residual sum of squares (SSE). However, any violation of the assumptions on the model errors or misspecification of the model form can seriously affect the reliability of MSE as an estimate of σ^2.

In an Analysis of Variance (ANOVA) table, the total sum of squares due to y can be formally split into two components, the explained sum of squares (SSR) and the residual sum of squares (SSE), as follows:

Total Sum of Squares (SST) = Explained Sum of Squares (SSR) + Residual Sum of Squares (SSE)The explained sum of squares (SSR) is associated with the variation in y that can be explained by the regression model, while the residual sum of squares (SSE) captures the unexplained variation or errors. This ANOVA table partitioning allows for a formal statistical analysis of the contribution of the model and the residuals to the total variation in the response variable y. It also helps in assessing the goodness of fit of the regression model and the significance of the regression coefficients.

Table 3.2: Analysis of Variance

Source of variation	d.f.	S.S.	M.S.
Regression	P	$\sum b_i SX_{iy}$	MSR
Deviation from Regression (Residual)	n-p-1	SSE	S^2 = SSE/(n-p-1) = MSE
Total (Corrected Mean)	n-1	Syy	

Estimate of σ^2 in this case works out to

$$S^2 = \frac{S_{yy} - \sum_{i=1}^{p} b_i Sx_{iy}}{n-p-1} = MSE$$

Significance test of β's

May be one is interested in testing the hypothesis Ho: $\beta_i = 0$ against $H_i : \beta_i \neq 0$ for some i. The test statistic for testing this

$$t = \frac{|b_i|}{SE(b_i)} = \frac{|b_i|}{\sqrt{C_{is}^2}} \quad as\ V(b_i) = C_{ii}S^2$$

Which follows under the hypothesis, a t distribution with (n-p-1) d.f., if H_0 is true, Reject H_0 if t > t_a/2, n-p-1.

Tests for subset of regression coefficients are Zero/equal

The full model (FM) is represented as $y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_p X_p + e$. On the other hand, the reduced model (RM) is derived when certain specified values for some regression coefficients are substituted into the full model. The reduced model typically contains fewer distinct parameters to be estimated than the full model.

In hypothesis testing, we assess the adequacy of fit achieved by the complete model against the data by contrasting it with the fit obtained from the simplified model outlined in the null hypothesis. If the reduced model exhibits a comparable level of fit to the data as the full model, then we do not reject the null hypothesis, which defines the model by specifying particular values for $\beta_{i.}$ In other words, the null hypothesis is considered consistent with the data, indicating that the specific parameter values specified in the null hypothesis are plausible explanations for the observed relationships in the model.

To test whether the reduced model is adequate, we calculate the F-statistic using the residual sums of squares (SSE) from the full model (SSE_FM) and the reduced model (SSE_RM). The degrees of freedom for SSE_FM and SSE_RM are denoted as df_FM and df_RM, respectively.

The F-statistic is calculated as:

$$F_e = \frac{[SSE\ (RM) - SSE\ (FM)]/(P+1-K)}{SSE\ (FM)/(n-p-1)}$$

Thus, Fe follows F distribution with (P+1-K) and (n-p-1) d.f. If Fe> table value of F, then reduced model is unsatisfactory.

Forecasting and its variance

We can predict the mean response at a particular point by substituting the value of X‟s in the model.

Let the particular point be $X_{01}, X_{02}, \ldots, X_{OP}$,

Then,

$\widehat{Y_o}=b_0 + b_1X_{01} + b_2X_{02} + \cdots + b_pX_{0p}$

$V(\hat{Y}) = [C_{00} + 2\sum_{i=1}^{p} C_{0i}X_{0i} + \sum_{i=1}^{p} C_{ij}X_{0i}^2 + 2\sum_{i\neq j}^{p} C_{ij}X_{0i}X_{0j}]\sigma^2$

Therefore, a 100 (1-α) per cent confidence interval on the mean response at that point is

$y_o \pm \left(\frac{t\propto}{2}, n-p-1\right) V(\widehat{Y_o})$

When $\widehat{Y_o}$ is used as predictor for some observation, then

$$V(\hat{Y}) = [1 + C_{00} + 2\sum_{i=1}^{p} C_{0i}X_{0i} + \sum_{i=1}^{p} C_{ij}X_{0i}^2 + 2\sum_{i\neq j}^{p} C_{ij}X_{0i}X_{0j}]\sigma^2$$

Relative importance of X's

The β's, as they are, cannot be utilized to assess the relative importance of the X's since their values depend on the units of measurement used. However, the standardized partial regression coefficients (B's) provide a solution to this limitation. By definition, the B's are dimensionless, which makes them independent of any specific unit of measurement. Therefore, B's can be effectively employed to determine the relative importance of the X's in the model, allowing for fair and unbiased comparisons among variables.

$$B_i = \frac{\sqrt{SX_{ixi}}}{\sqrt{S_{yy}}}$$

Selection of best subset of regression analysis

The selection of variables through step-up and step-down procedures does not yield a unique result, as it depends on the order of variable inclusion or exclusion. On the other hand, using all possible regression equations for variable selection requires significant computational resources and is feasible only with high-speed computing facilities.

To choose the best subset of variables, several criteria can be employed. Some common criteria include:

i. R^2 criteria

ii. Adj R^2 criteria

iii. Root Mean square Error

iv. AICc

v. BIC

vi. Cook's D

vii. Variance inflating factor

i. R^2 criteria

R^2 define as

$$R^2 = 1 - \frac{\sum(Y_i - \widehat{Y_i})^2}{\sum(y_i - y)^2}$$

Where,

In the context of observed yield (y_i), predicted yield ($\hat{Y}_i$), and the mean of observed yield ($\bar{y}$), R-squared (R^2) can be interpreted as the proportion of total variability in Y, which is explained by the independent variables. When R^2 is close to one, it indicates that the independent variables account for a substantial portion of the variation in y.

ii. Adj R^2 Criteria

$$AdjR_p^2 = 1 - [1 - R_p^2][\frac{n}{n-p}]$$

Where,

p is the number of parameters, i.e. number of regressors + 1

iii. **RMSE (Root mean square error)**

$$RMSE = \sqrt{\frac{RSS}{n-p}}$$

Where,

RSS in the Residual SS

iv. **AIC (Akaike information criterion):**

In the general case, the Akaike Information Criterion (AIC) is calculated using the formula:

AIC = 2K - 2ln(L)

Where:

- K represents the number of parameters in the statistical model.
- L is the maximized value of the likelihood function for the estimated model.

Lower AIC values indicate a better trade-off between model fit and complexity, making them preferable in model selection processes.

v. **BIC (Bayesian information criterion)**

BIC =2log L + n log T,

Lower the values of these statistics, better is the fitted model.

vi. **Cook's D**

Cook's distance is a statistical measure used to assess the influence of individual observations on the coefficient estimates in a regression analysis. Specifically, it quantifies how much the estimated coefficients would change if a particular observation were removed from the dataset.

vii. **Variance inflating factor:-**

The Variance Inflation Factor (VIF) for the predictor variable Xi is defined as VIFi = 1/TOLi and serves as an indicator of the extent to which multicollinearity inflates the variance of the standardized regression coefficient. Typically, when TOL is less than 0.1 or equivalently, when VIF > 10, it is considered a signal of multicollinearity concerning that specific predictor variable. Similarly, if the average TOL or VIF displays similar behaviour across the entire model, it indicates the presence of multicollinearity in the overall model.

In this data said it is evident that there is not multicollinearity on all counts because

VIF is < 10.

TOL = Tolerance of Xi is defined to be $TOL_i = 1 - R_i^2$

$$R^2 = \frac{Regression\ sum\ of\ squares}{Total\ sum\ of\ squares}$$

Where total sum of square = Regression sum of square + Residual sum of square

$$R^2 = \frac{1 - Residaul\ sum\ of\ squares}{Total\ sum\ of\ squares}$$

R 2 gives the percentage of variation explained by the predictor and hence is an useful indicator of the usefulness of the fitted regression.

Validity test for forecast model

Using the used and unused 10%observations of biometrical data of rice, we calculate the following parameters. These are used for validation of the model.

1. Forecast error (FE)
2. Percentage error (PE)
3. Mean absolute percentage error (MAPE)

1.Forecast Error (FE)

$$FE = Y - \hat{Y}$$

Where, Y=Actual yield

$\hat{Y}$=Predicted yield

2. Percentage Error (PE)

$$PE = \frac{Y - \hat{Y}}{\hat{Y}} \times 100$$

Where, Y=Actual yield

$\hat{Y}$=Predicted yield

3. Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{1}{n}\sum\left|\frac{Y - \hat{Y}}{\hat{Y}}\right| \times 100$$

Where n is the number of observations

PE is the percentage error

Residual analysis

Evaluating the adequacy and validity of a model involves two crucial aspects: residual analysis and examination of predicted values.

Residual s define as

$$e_i = y_i - \widehat{Y_i} \qquad \text{i=1,2,….n.}$$

When considering an observed value, y_i and its corresponding fitted value, $\hat{Y}_i$, analyzing the residuals proves to be a valuable approach for identifying various types of model deficiencies**.**

Residuals have zero mean and approximate average variance as

$$\sum_{i=1}^{n}\frac{(e_i - e)^2}{(n-2)} = \frac{S_{ei}^2}{(n-2)} = \frac{SSE}{(n-2)} = MSE$$

The residuals, numbering n, are not independent, given that they possess (n-2) degrees of freedom. Although this lack of independence might have minimal impact on their utility for assessing model adequacy, it becomes less significant as long as n is not small.

Standardized residuals

Sometimes it is useful to work with the standardized residuals

$$t_i = \frac{e_i}{MSE}, \quad i=1,2\ldots,n$$

The standardized residuals possess a mean of zero and a standard deviation of one. In the case of normally distributed errors, approximately 95 percent of the residuals are expected to fall within the range of -2 and +2.

Residual plots

Residual plots are useful for detecting validity of assumptions on errors and model inadequacy. Some important residual plots for detecting model inadequacies are

(i) Normal probability plot

The normal probability plot exhibits the cumulative normal distribution as a straight line, where the slope indicates the standard deviation and the intercept represents the mean. Therefore, if the residuals deviate from normal distribution, it will typically manifest as a departure of the cumulative residual plot from the straight line pattern.

(ii) Plot of residuals against fitted values $\hat{Y}_i$

The plot of residuals against the fitted values $\hat{Y}_i$ is highly valuable. Whenever there is asymmetry in the distribution of residuals around zero, it indicates potential issues with the model or its underlying assumptions.

(iii)Plot of residuals against independent variable

Standardized residuals are depicted against the independent variable, offering insight into model mis-specification. A lack of trend in the plot is indicative of a correctly specified model.

(iv) Residuals in time sequence

Standardized residuals are graphed against the time sequence (if available). Such a plot can reveal potential correlations between errors at different time periods, termed auto-correlation. The existence of auto-correlation in the errors represents a significant violation of the fundamental assumptions and requires attention.

(v) Partial residual plots

The partial residual plot provides insight into the relationship between the response variable y and the regressor X_j after removing the effects of other regressions Xi (where $i \neq j$). This plot effectively demonstrates the influence of Xj on the response y while considering the presence of other variables. Moreover, the partial residual plot proves to be a valuable tool for identifying outliers and assessing inequality of variance.

3.3.3 Method to analyse the performance of PMFBY

Compound annual growth rate (CAGR)

CAGR gives the annual growth rate over the period of time. CAGR is used to calculate the annual growth rate of number of farmers insured, number of insurance units, area covered under insurance, gross premium collected and sum insured of west Godavari district. Data of 2018,2019 and 2022 years are only available, so these used to calculate CAGR for the 5 years period of time by taking final value of year 2022 and initial value of year 2018.

$$\boldsymbol{CAGR = \left(\frac{Final\ value}{Initial\ value}\right)^{\frac{1}{Number\ of\ years}} - 1}$$

Sum insured (SI)

The "sum insured" represents the monetary compensation that a farmer will be entitled to receive in the event of total crop damage due to risks covered under the Pradhan Mantri Fasal Bima Yojana (PMFBY) scheme. These covered risks include yield losses caused by natural factors such as fire and lightning, storms, hailstorms, cyclones, typhoons, floods, droughts, pests, diseases, prevented sowing, post-harvest losses, and local calamities.

Insured farmers

Farmers who opt for crop insurance, whether voluntarily or as a requirement, fall into two categories: those who have voluntarily chosen to participate and those who are obligated to participate due to having obtained loans from institutional entities such as banks and agricultural cooperative credit societies.

Premium

Farmers are subject to a consistent premium rate, 2.0 percent for kharif crops, 1.50 percent for rabi crops, and 5.0 percent for annual horticultural and commercial crops. The central and state governments share the remaining portion of the premium payment equally.

Area approach and unit area of insurance

Geographical regions such as divisions, circles, and mandals with extensive occurrences of disasters are designated as the insurance units. Additionally, for specific localized disasters like hailstorms, landslides, cyclones, and floods, individual areas are selected as units for insurance coverage.

CHAPTER - IV

RESULTS AND DISCUSSION

Chapter 4

RESULTS AND DISCUSSION

4.1 Studying trend of Rice area, production and yield in West Godavari district of Andhra Pradesh

The area, production, and yield time series data for Rice in West Godavari district of Andhra Pradesh were gathered from reputable website data.icrisat.org which belongs to ICRISAT. Data were gathered and used between 1966 and 2017.

Area

The area's trend value was at its lowest point in 1966-1967, which is shown in Fig. 4.1, at 357 (000'ha), while it was at its highest point in 2017-2018, which is 393.22 (000'ha). These show an slightly upward trend in the area's overall trend. However, the largest area, 497.6(000'ha), was found in 1989-1990 and smallest area 317.8(000'ha) was observed in 1976-1977. Therefore, it is obvious from the Fig. 4.1 (which shows a graph of area trend values) that the overall trend is stagnant and there is no much difference in the area along the trend.

Production

According to Fig. 4.2, the trend of Rice production in West Godavari district of Andhra Pradesh is increasing, with the highest trend value of 1693.91('000 tonnes) found in 2017-2018 and the lowest trend value of 587('000 tonnes) found in 1966-1967.In 1976-1977, the lowest actual production 493.6('000 tonnes) was recorded, while the highest actual production of 1693.91('000 tonnes) was recorded in 2020-21. Fig. 4.2 (graph of trend values of production) ultimately shows a upward trend in West Godavari total Rice production.

Productivity

After examining figure 4.3, it is clear that the yield trend value in 1966-1967 was 1644.26kg/ha and that it gradually increased until it reached 4307.75 kg/ha in 2017-2018 and it is the highest yield recorded in the overall trend and in the year 1969-1970 saw a minimum actual yield of 1518.51 kg/ha. Fig.4.3(graph of trend values of yield) shows a clear upward trend of west Godavari Rice productivity.

4.1.1Compound Annual Growth Rates:

The CAGR values are calculated and presented in the table 4.1, utilizing time series data of Rice area, production and yield in West Godavari district of Andhra Pradesh. From the table we noticed that the CAGR value of area is low and CAGR value of yield is high which results in high CAGR value of production. The CAGR values are found to be highly significant for production and yield. The production and yield of Rice in west Godavari is increasing at a notable rate, area is also increasing but at a low rate.

Table 4.1 Compound Annual Growth Rates of Rice area, production and yield in West Godavari district of Andhra Pradesh

Categories	CAGR
Area	0.2%
Production	1.88%
Yield	1.675%

4.1.2Accuracy measure of trend analysis

The coefficient of determination (R-squared) values has been computed for each of the trends and are presented in Table 4.2. Notably, it was observed that the coefficient of determination for the "area" trend is relatively low, whereas for "production" and "yield," it is considerably high. It's worth mentioning that the removal of outliers from the data can lead to an increase in the coefficient of determination. Generally, values approaching 1 are considered indicative of the best-fit models, while other values are deemed acceptable representations of the data.

Table 4.2 Accuracy measure of trend analysis

Categories	R^2
Area	0.4365
Production	0.7891
Yield	0.8136

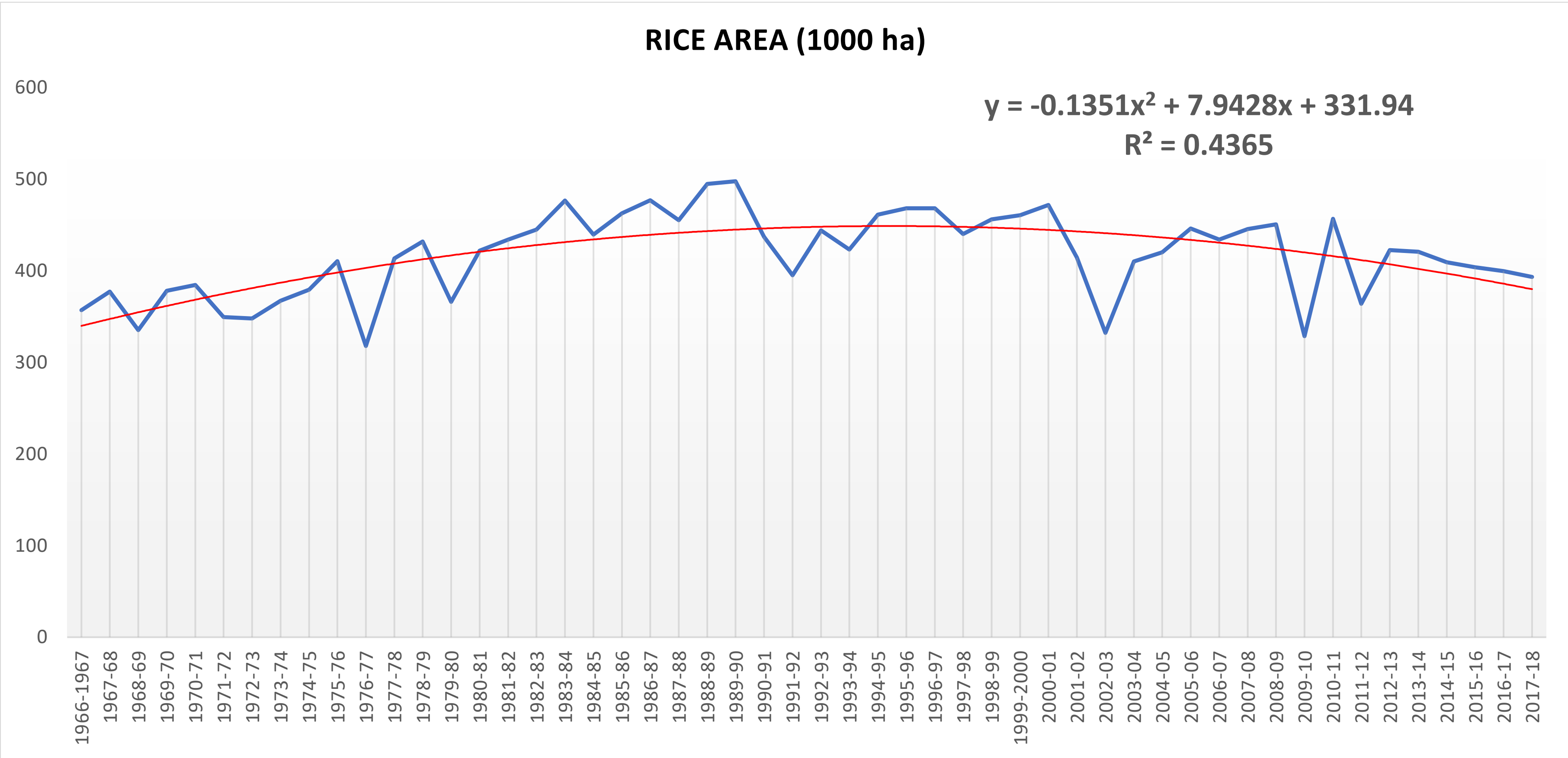


Fig. 4.1: Graph of trend value of Rice area in West Godavari district

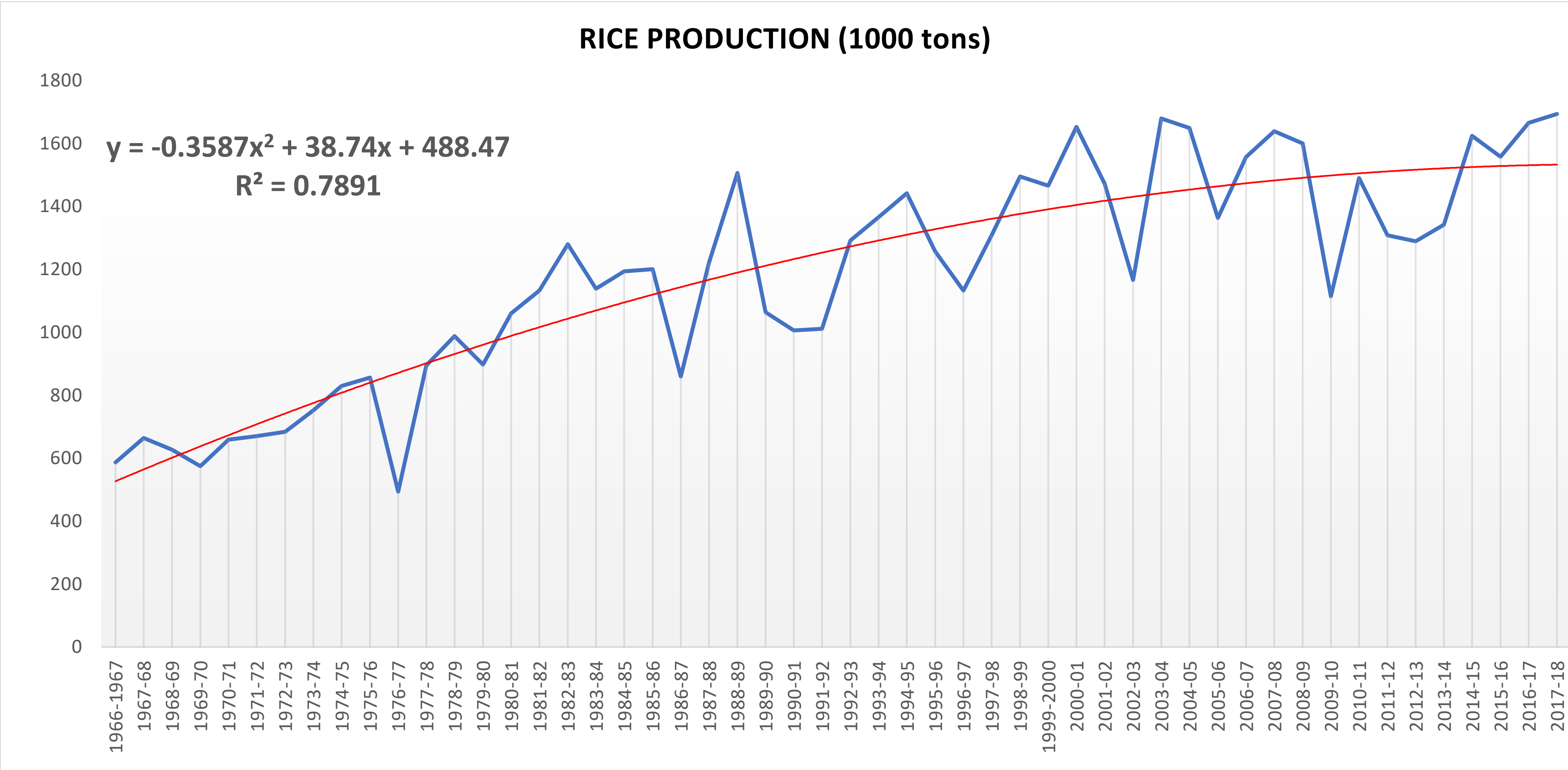


Fig. 4.2: Graph of trend value of Rice production in West Godavari

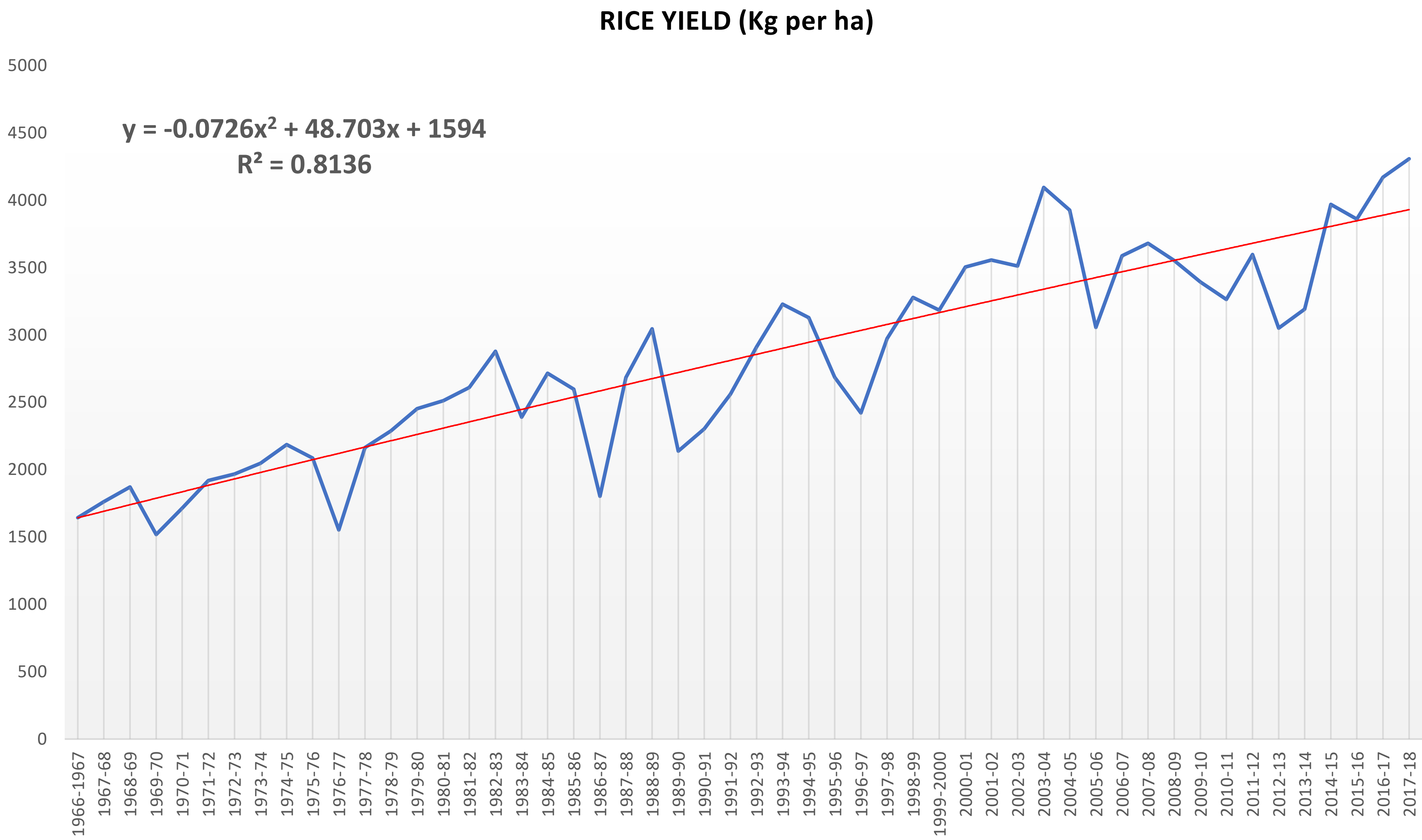


Fig. 4.3: Graph of trend value of Rice yield in West Godavari district

4.2 Developing forecast model for yield of Rice.

The development of forecast model has been carried out in the following stages

i. Selection of the samples

ii. Selection of fit forecast model from all possible regression models.

4.1 Sample selection

Two administrative regions, namely Tadepalligudem and Tanuku, were chosen within the West Godavari district of Andhra Pradesh. In each of these regions, a total of 5 villages were carefully selected. Within each village, 5 farmers were chosen for the study. From the agricultural fields of these selected farmers, one specific plot was identified for examination. Consequently, a total of 50 sets of data were gathered, focusing on various biometric characteristics of Rice plants, encompassing 10 factors that contribute to crop yield. These 10 characteristics, observed throughout the growth period, were treated as independent variables, while the actual Rice yield was regarded as the dependent variable.

Data is collected for recording the observations of following characters

1. Average plant population per m^2(X1)
2. Average plant height in cm (X2)
3. Average number of tillers per m^2(X3)
4. Average length of panicle in cm(X4)
5. Nitrogen (N_2) in kg/ha (X5)
6. Phosphorus (P_2O_5) in kg/ha (X6)
7. Potassium (K_2O) in kg/ha (X7)
8. Number of irrigations in the crop season (X8)
9. Disease infestation in percentage (X9)
10. Average plant condition (X10)

The basic statistical measure and moments of all variable are presented above are found that average number of plants per m^2 were 17.5, average plant height was 110.75cms, average no: of tillers were 20.04, average panicle length was 25, average N_2 application was 228 kgs/ha, average P_2O_5 application was 131.5 kgs/ha, average K_2O application was 65 kgs/ha and average number of irrigations were 22.4.

4.2.1 Selection of fit forecast model from all possible regression models.

A dataset comprising 50 observations was utilized for model development and validation. Specifically, 5 observations were set aside for the purpose of model validation, while the remaining 45 observations were employed in the analysis to construct various regression models. SAS 9.3 was employed to create these regression models using the 45 available observations.

On the basis of R^2, AdjR^2, RMSE, AIC, BIC and C.V the best five models were selected and R^2 value has been presented in Table 4.4

The five selected models underwent regression analysis and their results are presented in tables 4.5, 4.8, 4.11, 4.14, and 4.17. As the number of subsets increased, R-squared (R^2) also increased, but Root Mean Square Error (RMSE) also showed an increasing trend. Following the regression analysis, forecasting was carried out for all models, and a residual analysis was performed, which involved calculating the Mean Absolute Percentage Error (MAPE). Among these models, the 3rd model displayed a lower MAPE, indicating that its forecasted values deviated less from the observed values, as illustrated in table 4.20. Validity testing was conducted for all five models using 10% of the observations as a testing set. In this validity testing, the 3rd model continued to exhibit a low MAPE, as depicted in table 4.26. Overall, the 3rd model, characterized by an R^2 of 0.526 and an RMSE of 3.007, demonstrated superior performance compared to the other models. Therefore, the 3rd model, which consists of 6 parameters and is highly significant according to table 4.11, is the most suitable model for forecasting rice yield in the West Godavari district of Andhra Pradesh. This suggests that the regression subset comprising X1, X2, X3, X5, X7, and X8 should be considered the optimal subset for prediction purposes. Further details of the analysis for the best-fitted model for rice yield forecasting are presented in Table 4.12 (3rd model).

Based on the information provided, it can be concluded that the third model is the most suitable for forecasting Rice yield in West Godavari district, Andhra Pradesh. Additionally, the analysis of variance supports this conclusion as the F-value indicates statistical significance at a 1% level of significance. Furthermore, the low value of the variance inflating factor suggests that there are no signs of multicollinearity in the model. The 3rd model consists of parameters consisting of regression subset X1, X2, X3, X5, X7 and X8 i.e. average number of plants, average plant height, average number of tillers, Nitrogen(N_2) application, Potash (K_2O) application and number of irrigations respectively are contributing characters of Rice yield.

Table 4.3: Basic statistical measures

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
yield	45	94.01489	4.05971	4231	87.50000	102.00000
X1	45	17.54444	2.04167	789.50000	14.00000	22.00000
X2	45	110.75833	6.83419	4984	96.30000	128.00000
X3	45	20.04333	3.09002	901.95000	14.25000	27.00000
X4	45	24.93233	0.94302	1122	23.00000	27.00000
X5	45	228.17889	62.58800	10268	119.00000	295.00000
X6	45	131.54400	45.42314	5919	79.00000	265.50000
X7	45	65.01500	27.02230	2926	25.00000	115.00000
X8	45	22.46667	1.65968	1011	18.00000	25.00000
X9	45	9.42222	2.73437	424.00000	5.00000	15.00000
X10	45	3.48889	0.62603	157.00000	2.00000	4.00000

Table 4.4: Selected best five models among all possible regression statistic for forecasting of Rice yield

Model	No.of variables	R^2	Adj R^2	AIC	BIC	RMSE	CV
X1,X3,X4,X8	4	0.500	0.450	235.8	244.4	3.010	3.2
X1,X3,X5,X4,X8	5	0.517	0.455	237.1	246.7	3.007	3.18
X1,X2,X3,X5,X7,X8	6	0.526	0.451	239.2	249.6	3.007	3.19
X1,X2,X3,X5,X4,X7,X8	7	0.531	0.441	242	253	3.033	3.22
X1,X2,X3,X4,X5,X6,X7,X8	8	0.531	0.426	245.2	256.8	3.075	3.27

Table 4.5: Forecasting of Rice yield in West Godavari District of Andhra Pradesh for 1st model using regression analysis.

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	68.920	6.426	10.720	<.0001	0.000
X1	0.665	0.279	2.390	0.022	1.575
X3	-0.375	0.160	-2.350	0.024	1.182
X5	-0.035	0.008	-4.140	0.000	1.357
X8	1.288	0.324	3.980	0.000	1.400

Regression equation

$$\widehat{Y} = \mathbf{68.91983 + 0.66549}X_1 - \mathbf{0.37538}X_3 - \mathbf{0.03500}X_5 + \mathbf{1.28770}X_8$$

Root MSE	Dependent Mean	C.V	R^2	AdjR^2
3.01043	94.01489	3.20208	0.5001	0.4501

Table 4.6- Analysis of Variance for 1st Model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	362.669	90.6672	10	<.0001
Error	40	362.507	9.06267		
Corrected Total	44	725.176			

Table 4.7: Residual analysis for the best subset for forecasting of Rice yield in west Godavari district of Andhra Pradesh for 1st model.

Obs	Dependent Variable	Predicted value	Std Error	Residual	Student	Cook's	Hat Diag	Cov	DFFITS
1	92.6	95.758	0.893	-3.158	-1.098	0.023	0.088	1.068	-0.342
2	91.87	92.201	0.819	-0.331	-0.114	0.000	0.074	1.224	-0.032
3	96.33	92.345	1.059	3.985	1.414	0.056	0.124	1.002	0.538
4	90.5	90.695	0.807	-0.195	-0.067	0.000	0.072	1.222	-0.019
5	92.8	93.411	0.841	-0.611	-0.211	0.001	0.078	1.224	-0.061
6	92	93.941	0.857	-1.941	-0.673	0.008	0.081	1.167	-0.199
7	101.9	96.249	0.819	5.651	1.951	0.061	0.074	0.744	0.572
8	92	94.269	0.736	-2.269	-0.777	0.008	0.060	1.119	-0.195
9	94	92.018	0.822	1.982	0.684	0.008	0.075	1.156	0.193
10	98	97.764	1.129	0.236	0.085	0.000	0.141	1.319	0.034
11	88.92	92.271	0.930	-3.351	-1.170	0.029	0.095	1.054	-0.382
12	90	93.489	0.777	-3.489	-1.199	0.021	0.067	1.012	-0.322
13	100	98.877	1.283	1.123	0.412	0.008	0.182	1.357	0.192
14	97.2	95.099	1.198	2.101	0.761	0.022	0.158	1.254	0.328
15	98.5	95.405	0.845	3.096	1.071	0.020	0.079	1.065	0.314
16	92.62	90.508	1.546	2.112	0.818	0.048	0.264	1.417	0.487
17	101.8	101.069	1.409	0.732	0.275	0.004	0.219	1.439	0.144
18	93	93.386	1.322	-0.386	-0.143	0.001	0.193	1.403	-0.069
19	100	101.333	1.334	-1.333	-0.494	0.012	0.196	1.370	-0.242
20	96.8	96.921	1.072	-0.121	-0.043	0.000	0.127	1.300	-0.016
21	92.6	92.468	1.292	0.132	0.049	0.000	0.184	1.391	0.023

22	88.9	91.588	0.699	-2.688	-0.918	0.010	0.054	1.079	-0.219
23	98.2	89.950	0.838	8.250	2.853	0.137	0.077	0.394	0.915
24	91	92.234	0.613	-1.234	-0.419	0.002	0.041	1.158	-0.086
25	95	93.962	0.546	1.038	0.351	0.001	0.033	1.156	0.064
26	89.5	86.321	1.461	3.179	1.208	0.090	0.236	1.233	0.675
27	92.6	93.254	1.356	-0.654	-0.243	0.003	0.203	1.413	-0.121
28	90	90.592	0.884	-0.592	-0.206	0.001	0.086	1.236	-0.062
29	88	91.463	1.368	-3.463	-1.291	0.087	0.207	1.156	-0.665
30	91	94.342	0.751	-3.342	-1.146	0.017	0.062	1.024	-0.296
31	91	94.734	0.738	-3.734	-1.279	0.021	0.060	0.980	-0.326
32	92	94.786	1.056	-2.786	-0.988	0.027	0.123	1.144	-0.370
33	95.33	92.418	0.772	2.912	1.001	0.014	0.066	1.070	0.266
34	91	92.256	0.753	-1.256	-0.431	0.002	0.063	1.183	-0.110
35	93	93.168	0.897	-0.168	-0.059	0.000	0.089	1.245	-0.018
36	90	93.694	0.752	-3.694	-1.267	0.021	0.062	0.986	-0.329
37	102	97.209	0.962	4.791	1.680	0.064	0.102	0.877	0.580
38	92.5	95.288	0.770	-2.788	-0.958	0.013	0.065	1.081	-0.253
39	95	93.339	1.032	1.661	0.587	0.009	0.118	1.232	0.213
40	96.5	94.478	0.941	2.022	0.707	0.011	0.098	1.181	0.231
41	101.5	99.634	1.093	1.866	0.665	0.013	0.132	1.236	0.257
42	96.5	95.134	1.200	1.366	0.495	0.009	0.159	1.308	0.213
43	99	95.627	0.795	3.373	1.162	0.020	0.070	1.028	0.319
44	87.5	92.474	0.945	-4.974	-1.740	0.066	0.099	0.849	-0.591
45	90.2	93.248	0.786	-3.048	-1.049	0.016	0.068	1.059	-0.284

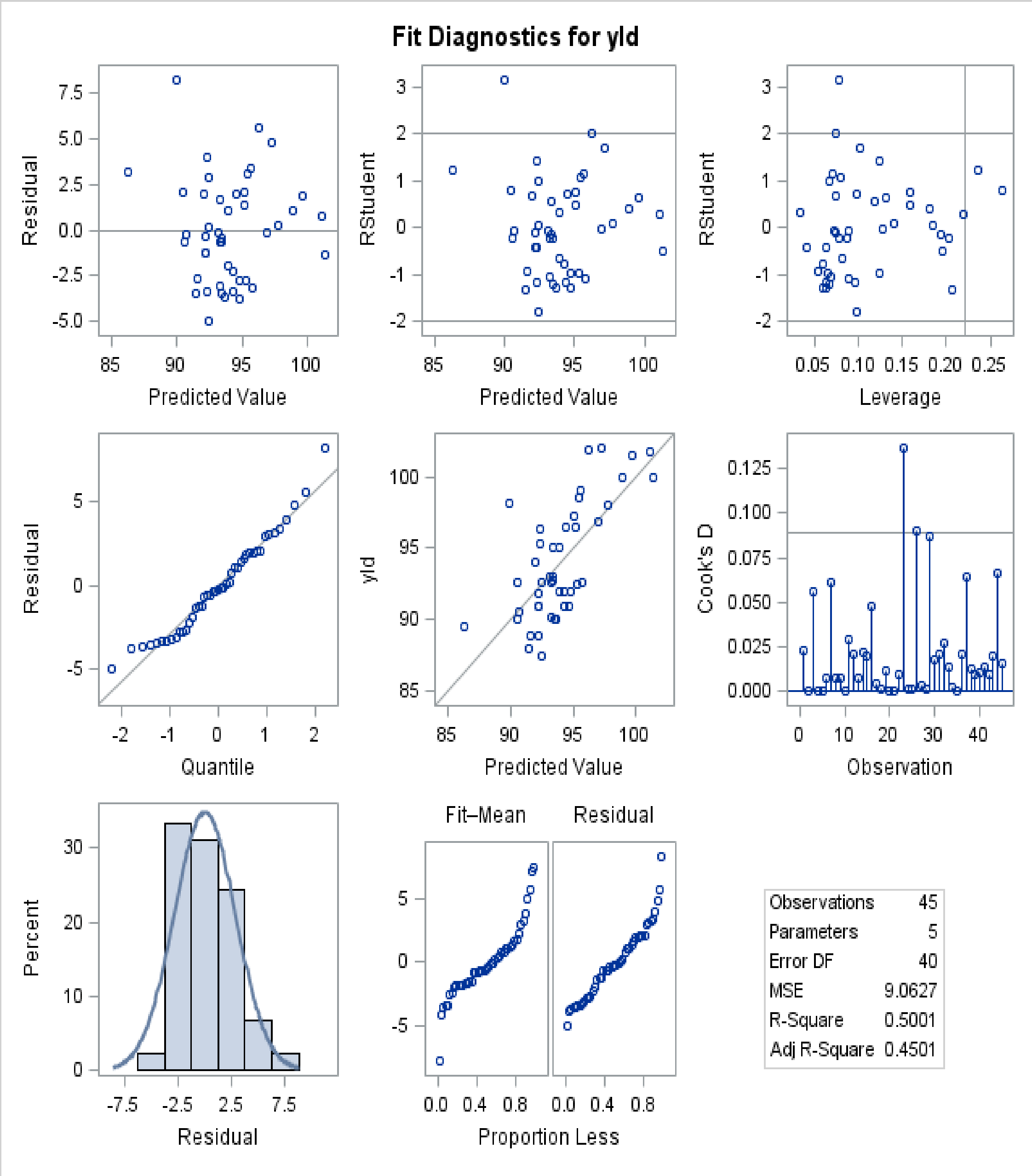


Figure 4.4: Fit diagnostics for yield (Model-1)

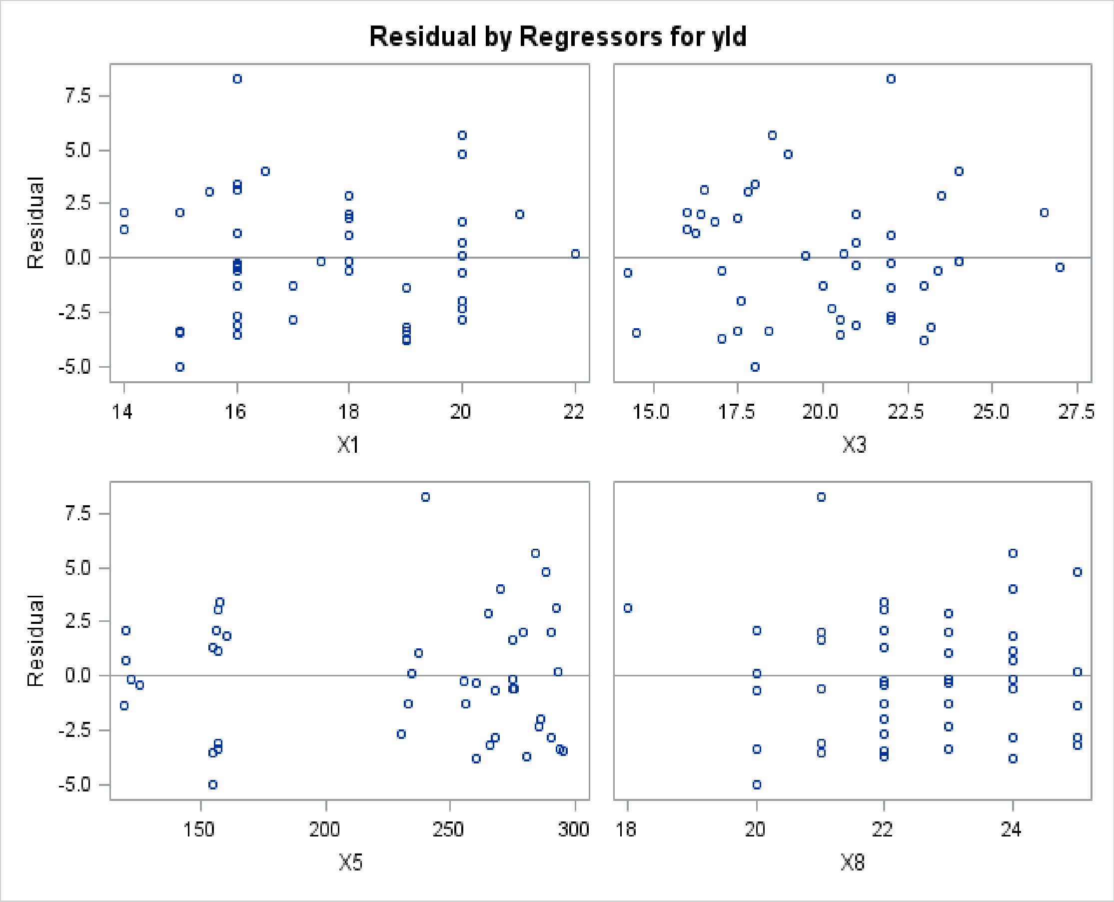


Figure 4.5: Residuals by regressors for Yield (Model 1)

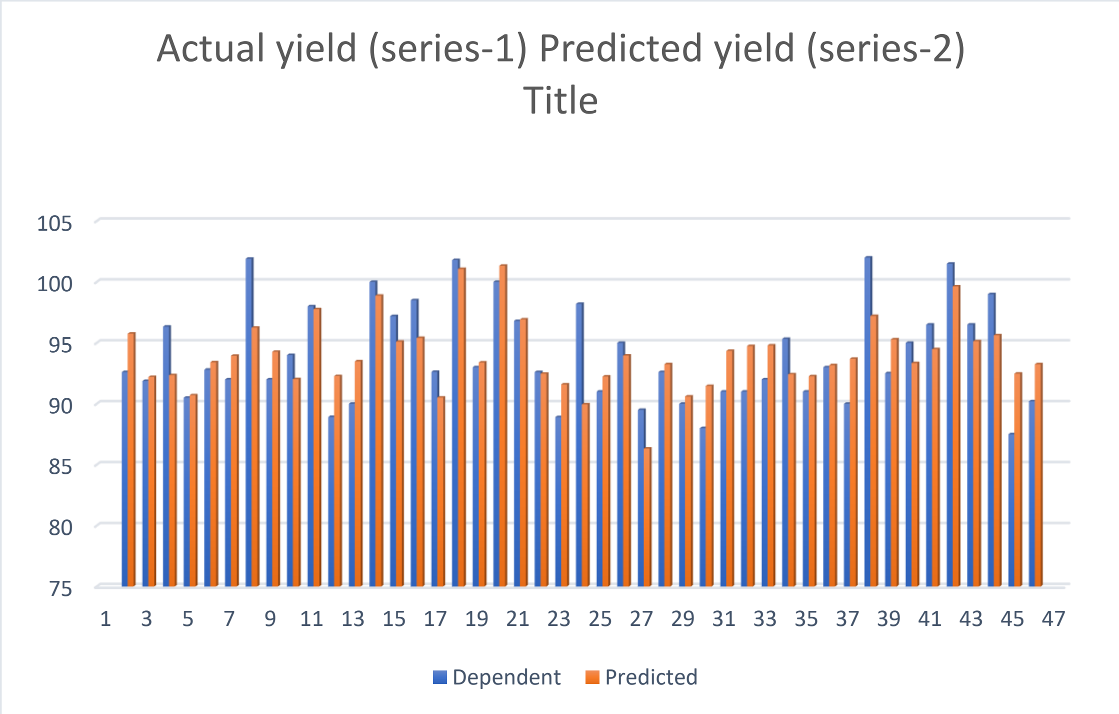


Figure 4.6: Histogram of actual and predicted yield (Model 1)

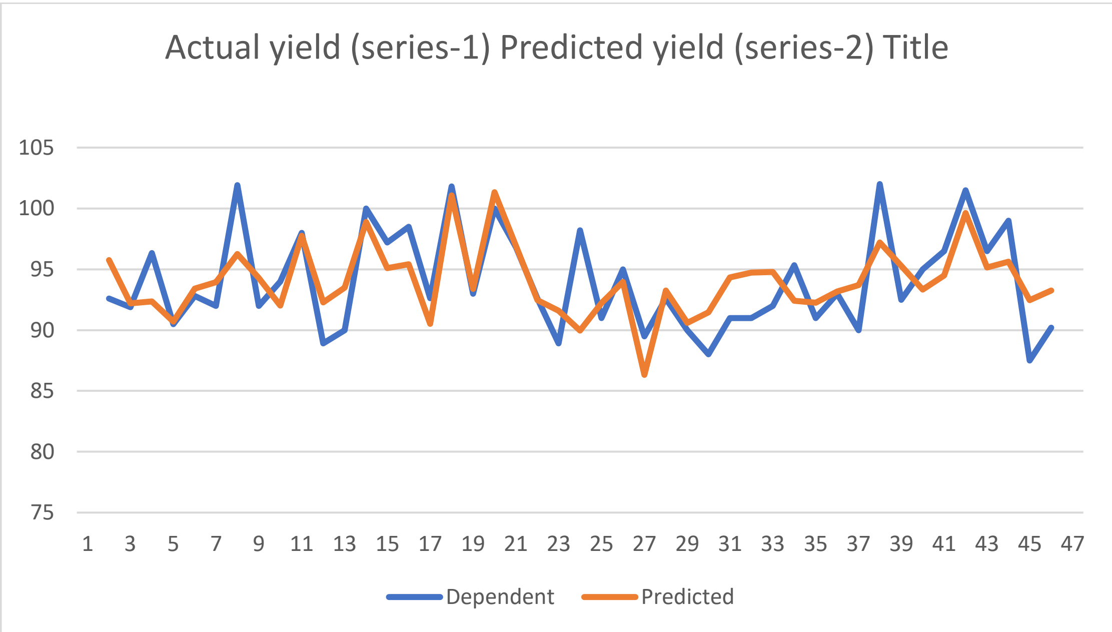


Figure 4.7: Line diagram of actual and predicted value (Model 1)

Table 4.8: Forecasting of Rice yield in West Godavari District of Andhra Pradesh for 2nd model using regression analysis

Regression equation

$$\hat{Y} = 56.34736 + 0.71870X_1 + 0.09617X_2 - 0.44142X_3 - 0.03126X_5 + 1.35254X_8$$

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	56.347	12.648	4.450	<.0001	0.000
X1	0.719	0.282	2.550	0.015	1.619
X2	0.096	0.083	1.150	0.256	1.592
X3	-0.441	0.169	-2.610	0.013	1.335
X5	-0.031	0.009	-3.470	0.001	1.559
X8	1.353	0.327	4.130	0.000	1.443

Root MSE	Dependent Mean	C.V	R^2	AdjR^2
2.99816	94.01489	3.18902	0.5166	0.4546

Table 4.9- Analysis of variance for 2nd model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	374.60639	74.92128	8.33	<.0001
Error	39	350.56913	8.98895		
Corrected Total	44	725.17552			

Table 4.10: Residual analysis for the best subset for forecasting of Rice yield in west Godavari district of Andhra Pradesh for 2nd model.

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Student Residual	Cook's D	Hat Diag H	Cov Ratio	DFFITS
1	92.6	96.050	0.925	-3.450	-1.210	0.026	0.095	1.027	-0.395
2	91.87	92.233	0.816	-0.363	-0.126	0.000	0.074	1.259	-0.035
3	96.33	91.731	1.182	4.600	1.669	0.085	0.155	0.887	0.734
4	90.5	90.291	0.877	0.209	0.073	0.000	0.086	1.277	0.022
5	92.8	93.414	0.838	-0.614	-0.213	0.001	0.078	1.259	-0.061
6	92	93.472	0.946	-1.472	-0.517	0.005	0.100	1.245	-0.170
7	101.9	96.573	0.862	5.327	1.855	0.052	0.083	0.732	0.576
8	92	93.243	1.153	-1.243	-0.449	0.006	0.148	1.330	-0.185
9	94	91.344	1.006	2.657	0.941	0.019	0.113	1.148	0.335
10	98	97.818	1.125	0.182	0.066	0.000	0.141	1.359	0.026
11	88.92	91.464	1.161	-2.544	-0.920	0.025	0.150	1.205	-0.386
12	90	93.127	0.835	-3.127	-1.086	0.017	0.078	1.054	-0.316
13	100	99.334	1.338	0.666	0.248	0.003	0.199	1.445	0.122
14	97.2	94.756	1.229	2.444	0.894	0.027	0.168	1.241	0.401
15	98.5	95.171	0.866	3.329	1.160	0.020	0.083	1.033	0.352
16	92.62	91.040	1.608	1.580	0.624	0.026	0.288	1.544	0.394
17	101.8	101.333	1.422	0.467	0.177	0.002	0.225	1.500	0.094
18	93	93.798	1.364	-0.798	-0.299	0.004	0.207	1.454	-0.151
19	100	101.348	1.329	-1.348	-0.502	0.010	0.196	1.399	-0.246
20	96.8	97.254	1.106	-0.454	-0.163	0.001	0.136	1.347	-0.064
21	92.6	93.145	1.414	-0.545	-0.206	0.002	0.223	1.493	-0.109

22	88.9	91.934	0.758	-3.034	-1.046	0.012	0.064	1.053	-0.274
23	98.2	90.168	0.855	8.032	2.795	0.115	0.081	0.333	0.919
24	91	92.598	0.687	-1.598	-0.548	0.003	0.053	1.178	-0.128
25	95	94.573	0.759	0.428	0.147	0.000	0.064	1.245	0.038
26	89.5	87.360	1.712	2.140	0.869	0.061	0.326	1.542	0.603
27	92.6	93.899	1.462	-1.299	-0.496	0.013	0.238	1.476	-0.275
28	90	90.839	0.906	-0.839	-0.293	0.001	0.091	1.269	-0.092
29	88	92.417	1.595	-4.417	-1.740	0.199	0.283	1.004	-1.123
30	91	95.034	0.959	-4.034	-1.420	0.038	0.102	0.947	-0.486
31	91	94.906	0.750	-3.906	-1.346	0.020	0.063	0.937	-0.351
32	92	95.061	1.078	-3.061	-1.094	0.030	0.129	1.113	-0.423
33	95.33	92.073	0.825	3.257	1.130	0.017	0.076	1.036	0.325
34	91	92.001	0.781	-1.001	-0.346	0.001	0.068	1.231	-0.092
35	93	92.941	0.915	0.059	0.021	0.000	0.093	1.289	0.007
36	90	92.959	0.983	-2.959	-1.045	0.022	0.108	1.105	-0.363
37	102	97.628	1.025	4.372	1.552	0.053	0.117	0.903	0.575
38	92.5	94.396	1.089	-1.896	-0.679	0.012	0.132	1.254	-0.263
39	95	92.778	1.138	2.223	0.801	0.018	0.144	1.236	0.327
40	96.5	94.263	0.955	2.237	0.787	0.012	0.102	1.182	0.263
41	101.5	100.174	1.185	1.326	0.481	0.007	0.156	1.336	0.205
42	96.5	94.692	1.255	1.809	0.664	0.016	0.175	1.323	0.304
43	99	95.505	0.799	3.496	1.210	0.019	0.071	1.000	0.336
44	87.5	91.582	1.218	-4.082	-1.490	0.073	0.165	0.985	-0.674
45	90.2	92.955	0.823	-2.755	-0.956	0.012	0.075	1.096	-0.273

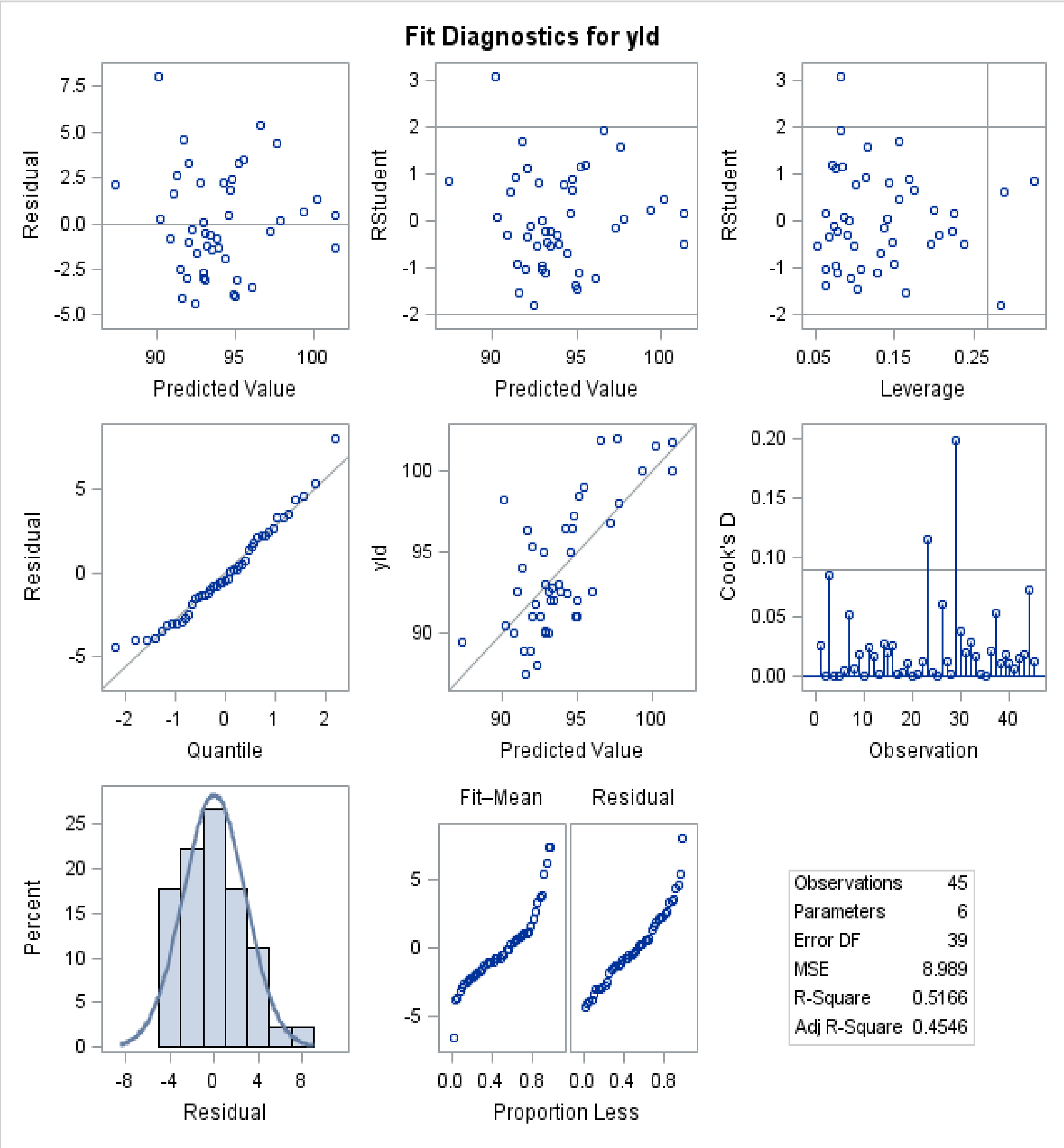


Figure 4.8: Fit diagnostics for yield (model 2)

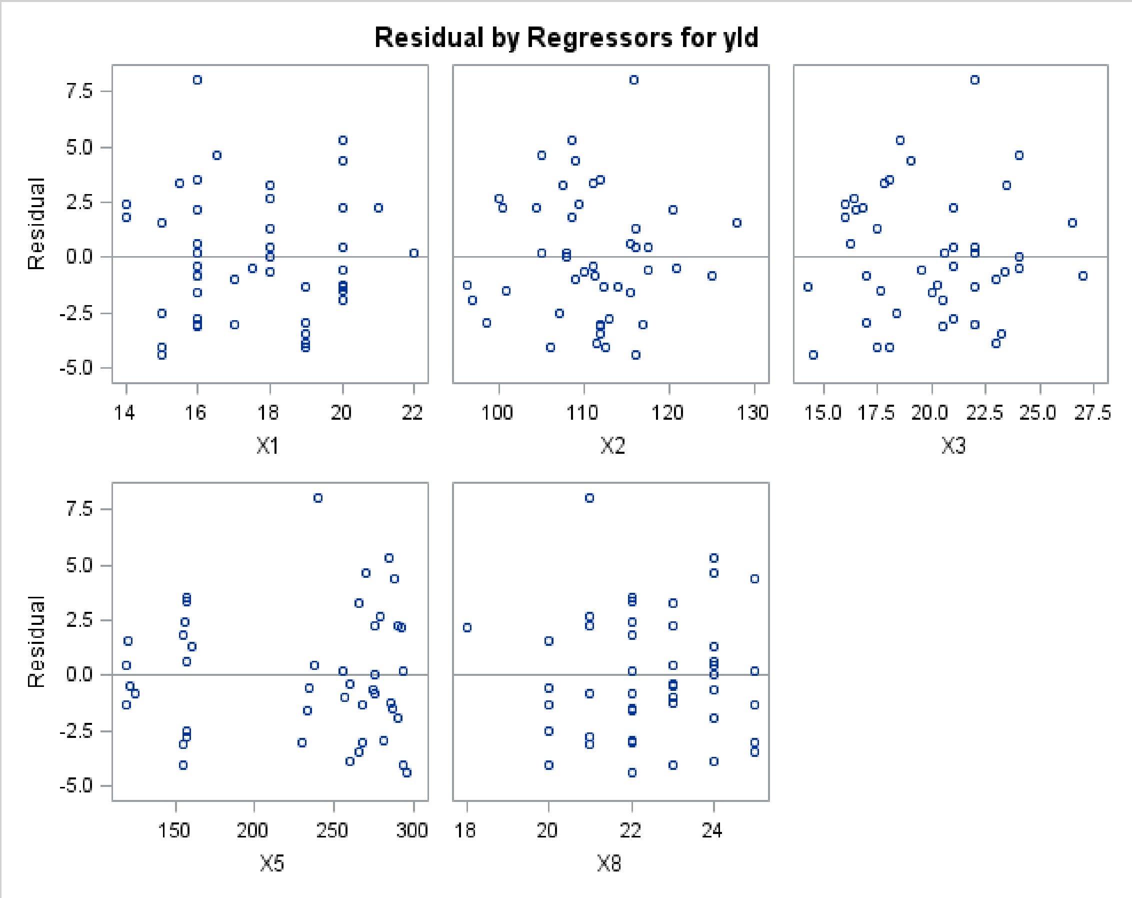


Figure 4.9: Residuals by regressors for Yield (Model 2)

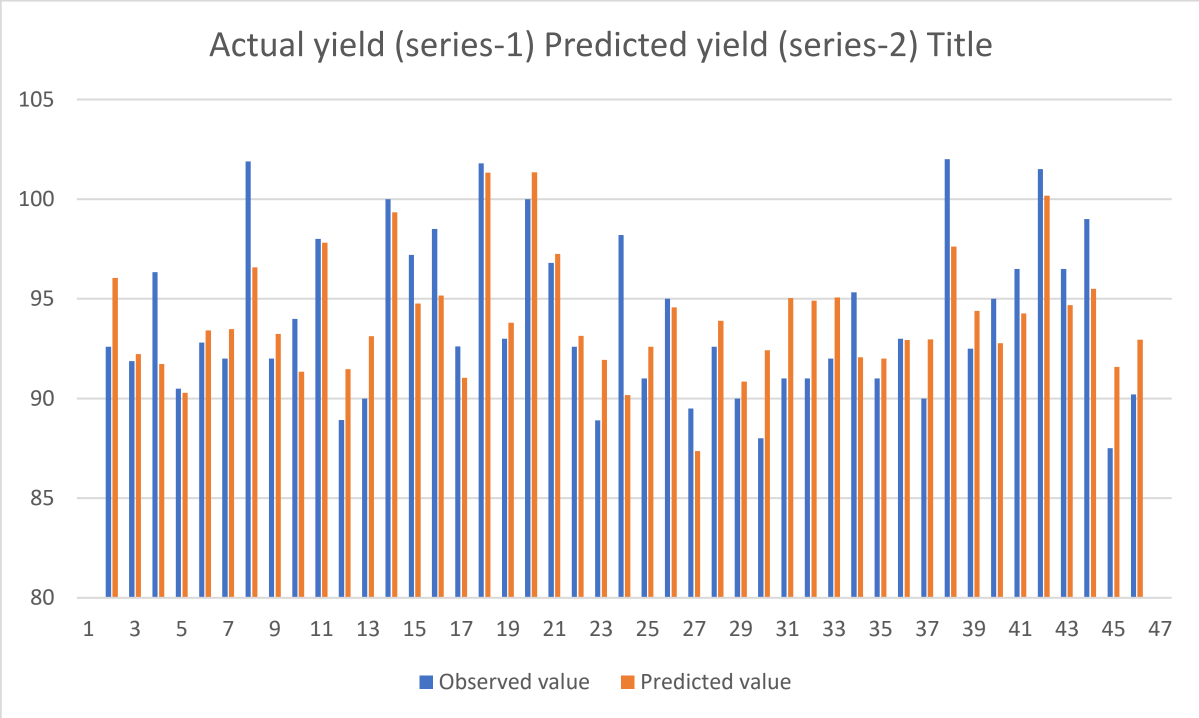


Figure 4.10- Histogram of actual and predicted yield (Model 2)

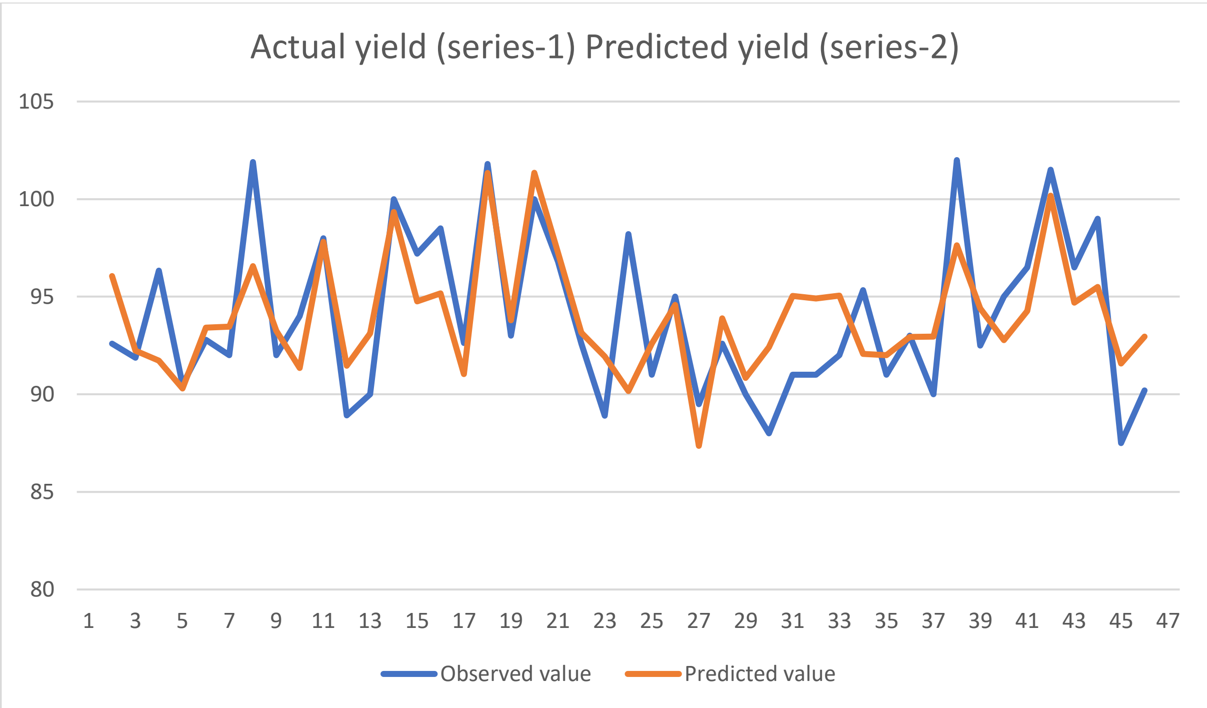


Figure 4.11-Line diagram of actual yield and predicted yield (Model 2)

Table 4.11: Forecasting of Rice yield in West Godavari District of Andhra Pradesh for 3rd model using regression analysis

Regression equation

$$\hat{Y} = 46.08838 + 0.80226X_1 + 0.14708X_2 - 0.36854X_3 - 0.02404X_5 + 0.02418X_7 + 1.28461X_8$$

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	46.088	17.291	2.670	0.011	0.000
X1	0.802	0.298	2.690	0.011	1.805
X2	0.147	0.102	1.440	0.158	2.364
X3	-0.369	0.189	-1.950	0.059	1.659
X5	-0.024	0.012	-1.960	0.057	2.862
X7	0.024	0.028	0.870	0.388	2.724
X8	1.285	0.337	3.810	0.001	1.524

Root MSE	Dependent Mean	C.V	R^2	AdjR^2
3.00732	94.01489	3.19877	0.5261	0.4513

Table 4.12- Analysis of variance for 3rd model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	381.50358	63.58393	7.03	<.0001
Error	38	343.67195	9.04400		
Corrected Total	44	725.17552			

Table 4.13: Residual analysis for the best subset for forecasting of Rice yield in west Godavari district of Andhra Pradesh for 3rd model.

Obs	Dependent	Predicted Value	Std Error	Residual	Student Residual	Cook's D	Hat Diag H	Cov Ratio	DFFITS
1	92.6	96.184	0.940	-3.584	-1.255	0.024	0.098	0.993	-0.416
2	91.87	91.980	0.868	-0.110	-0.038	0.000	0.083	1.315	-0.011
3	96.33	91.497	1.215	4.833	1.757	0.086	0.163	0.796	0.799
4	90.5	89.981	0.948	0.519	0.182	0.001	0.099	1.330	0.060
5	92.8	93.561	0.857	-0.761	-0.264	0.001	0.081	1.295	-0.078
6	92	93.487	0.949	-1.487	-0.521	0.004	0.100	1.273	-0.172
7	101.9	96.873	0.931	5.027	1.758	0.047	0.096	0.736	0.589
8	92	93.137	1.163	-1.137	-0.410	0.004	0.150	1.374	-0.170
9	94	91.035	1.070	2.966	1.055	0.023	0.127	1.121	0.402
10	98	98.318	1.265	-0.318	-0.116	0.000	0.177	1.461	-0.053
11	88.92	91.711	1.198	-2.791	-1.012	0.028	0.159	1.183	-0.440
12	90	93.753	1.103	-3.753	-1.341	0.040	0.135	0.992	-0.535
13	100	99.688	1.402	0.312	0.117	0.001	0.217	1.536	0.061
14	97.2	94.724	1.234	2.476	0.903	0.024	0.168	1.245	0.405
15	98.5	95.489	0.942	3.012	1.054	0.017	0.098	1.086	0.348
16	92.62	91.078	1.613	1.542	0.608	0.021	0.288	1.580	0.383
17	101.8	100.459	1.742	1.341	0.547	0.022	0.336	1.716	0.385
18	93	93.740	1.370	-0.740	-0.276	0.003	0.208	1.500	-0.140
19	100	100.285	1.805	-0.285	-0.118	0.001	0.360	1.880	-0.088
20	96.8	96.732	1.260	0.068	0.025	0.000	0.176	1.462	0.011
21	92.6	93.487	1.472	-0.887	-0.338	0.005	0.239	1.552	-0.188
22	88.9	91.864	0.765	-2.964	-1.019	0.010	0.065	1.061	-0.268
23	98.2	90.306	0.873	7.894	2.743	0.099	0.084	0.281	0.916
24	91	92.387	0.731	-1.387	-0.475	0.002	0.059	1.229	-0.118

25	95	94.785	0.800	0.215	0.074	0.000	0.071	1.296	0.020
26	89.5	87.359	1.717	2.141	0.867	0.052	0.326	1.555	0.601
27	92.6	93.246	1.647	-0.646	-0.257	0.004	0.300	1.701	-0.166
28	90	90.022	1.305	-0.022	-0.008	0.000	0.188	1.485	-0.004
29	88	92.219	1.616	-4.219	-1.663	0.160	0.289	0.998	-1.086
30	91	95.082	0.963	-4.082	-1.433	0.034	0.103	0.910	-0.491
31	91	94.983	0.757	-3.983	-1.369	0.018	0.063	0.903	-0.361
32	92	94.974	1.086	-2.974	-1.060	0.024	0.131	1.123	-0.411
33	95.33	92.040	0.829	3.290	1.138	0.015	0.076	1.023	0.328
34	91	91.859	0.800	-0.859	-0.296	0.001	0.071	1.276	-0.081
35	93	93.046	0.926	-0.046	-0.016	0.000	0.095	1.331	-0.005
36	90	92.619	1.060	-2.619	-0.931	0.018	0.124	1.171	-0.350
37	102	98.048	1.135	3.952	1.419	0.048	0.142	0.960	0.586
38	92.5	94.325	1.096	-1.825	-0.652	0.009	0.133	1.285	-0.253
39	95	92.710	1.144	2.290	0.823	0.016	0.145	1.242	0.337
40	96.5	94.785	1.129	1.715	0.615	0.009	0.141	1.308	0.247
41	101.5	100.906	1.454	0.594	0.226	0.002	0.234	1.559	0.123
42	96.5	94.529	1.273	1.972	0.724	0.016	0.179	1.332	0.336
43	99	95.972	0.963	3.029	1.063	0.018	0.103	1.087	0.360
44	87.5	91.705	1.230	-4.205	-1.532	0.067	0.167	0.926	-0.700
45	90.2	93.704	1.190	-3.504	-1.269	0.043	0.157	1.056	-0.552

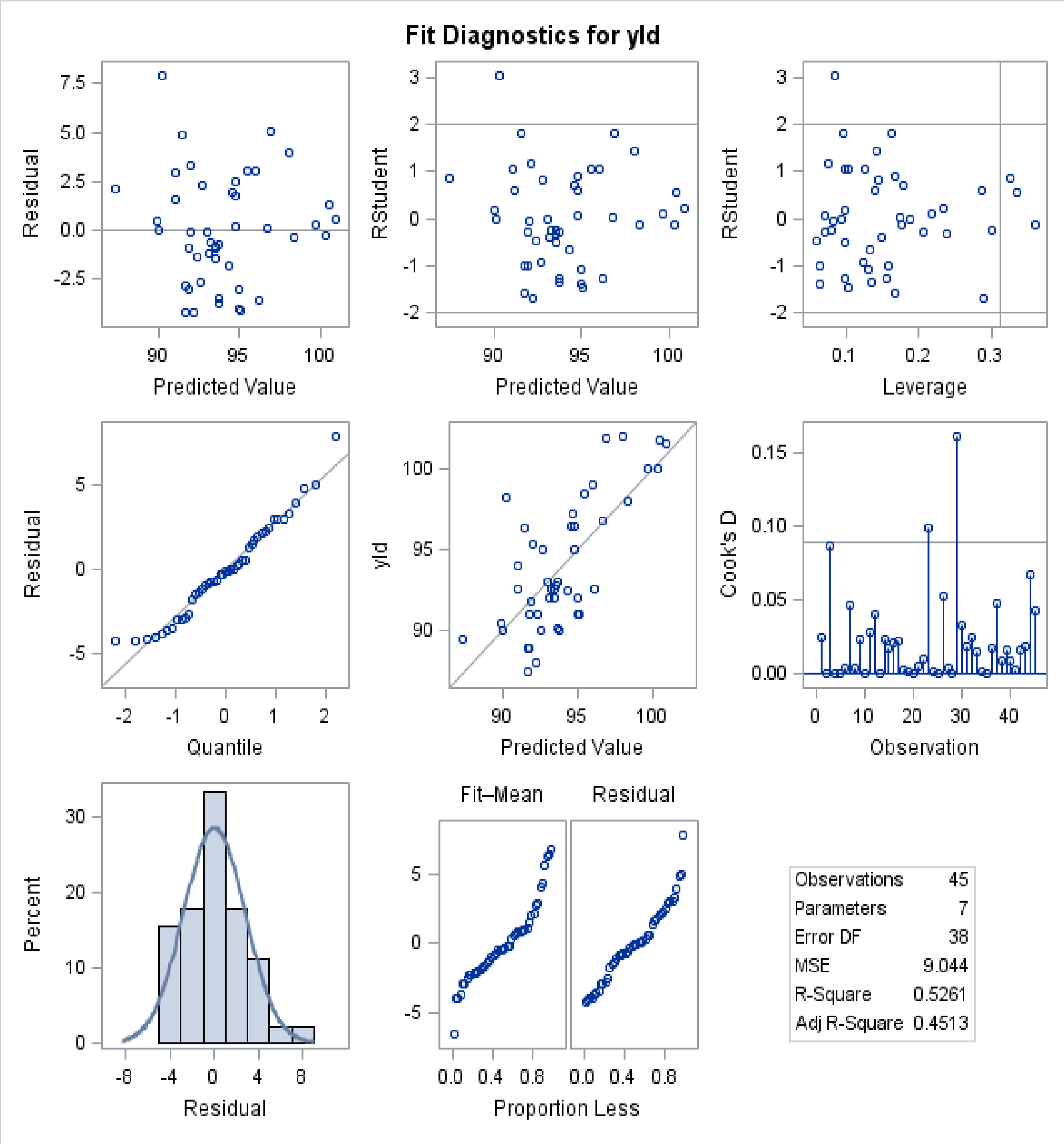


Figure 4.12: Fit diagnostics of Y for (Model 3)

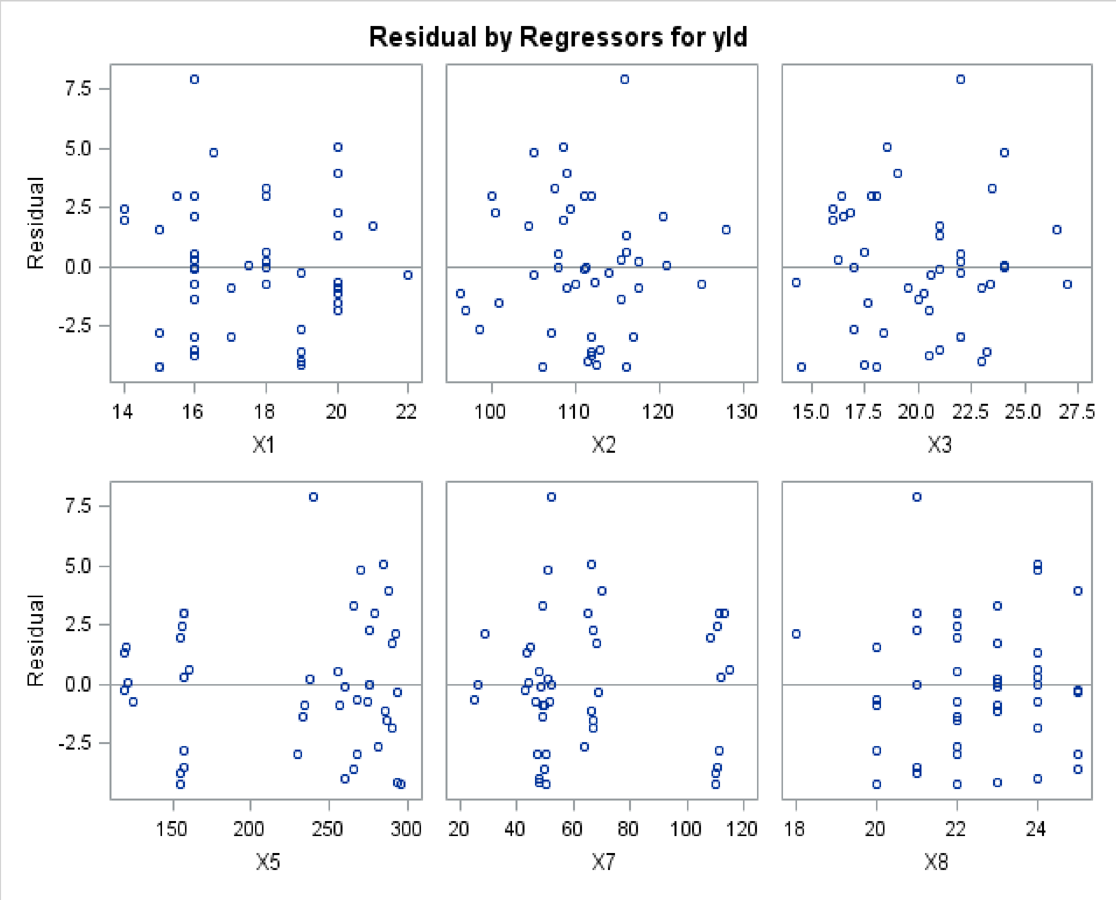


Figure 4.13: Residual regressors for yield (Model 3)

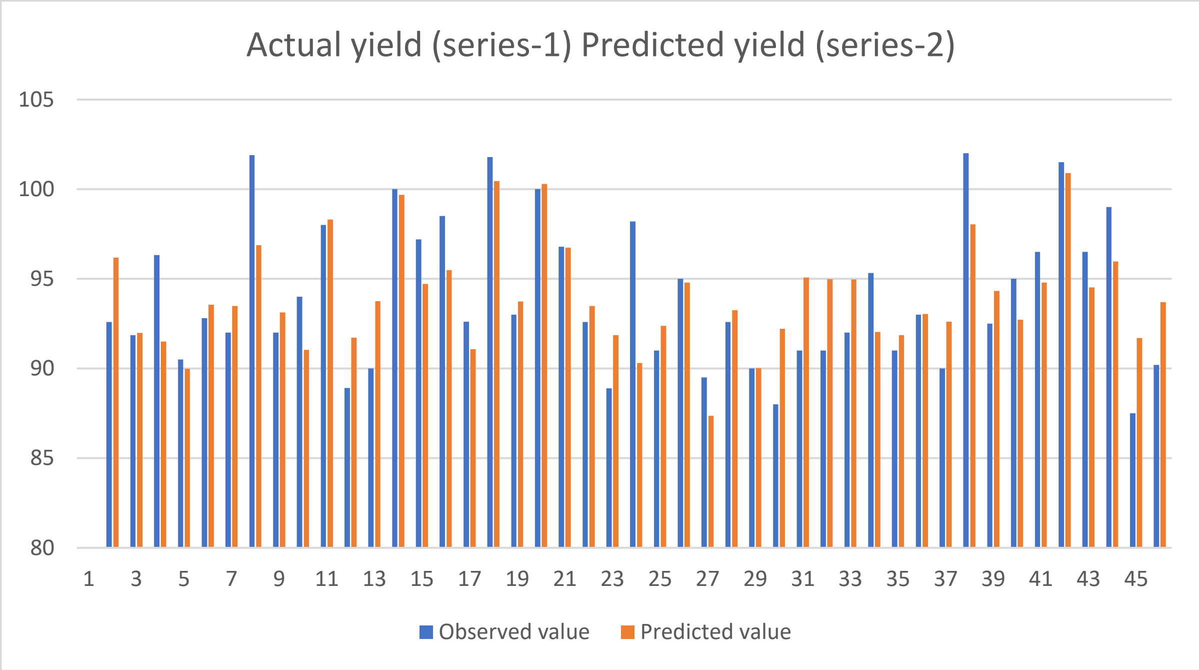


Figure 4.14: Histogram of actual yield and predicted yield (Model 3)

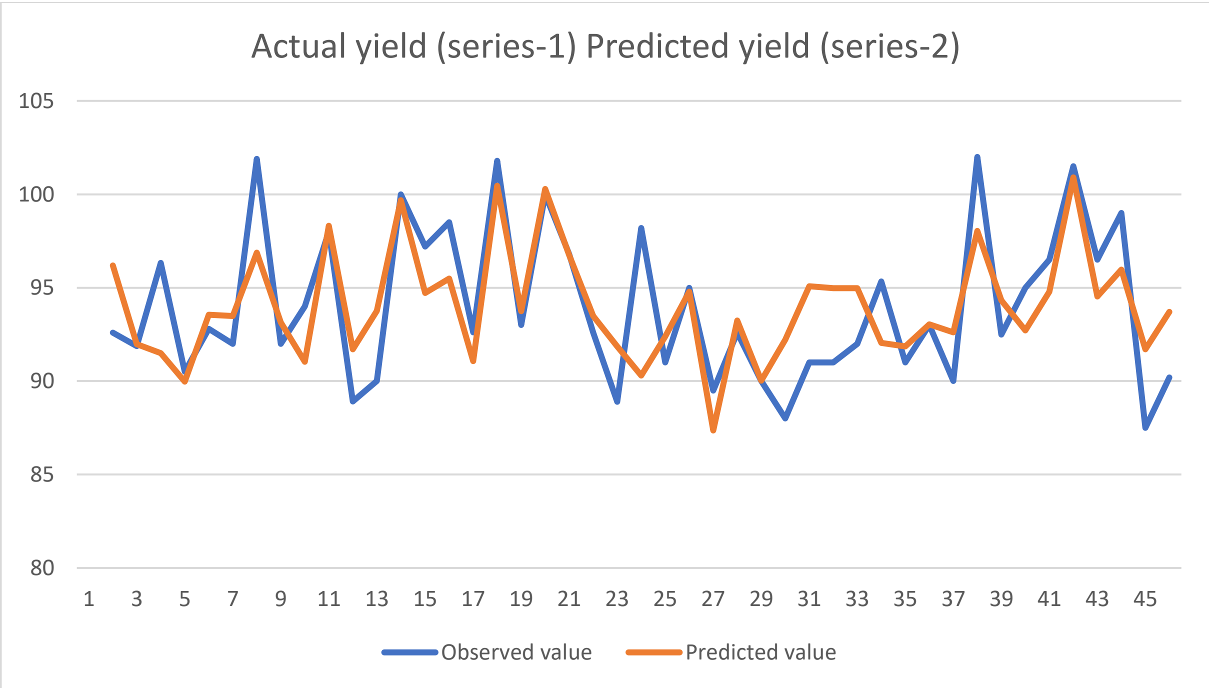


Figure 4.15- Line diagram of actual yield and predicted yield (Model 3)

Table 4.14: Forecasting of Rice yield in West Godavari District of Andhra Pradesh for 4th model using regression analysis

Regression equation

$$\widehat{Y} = 48.10415 + 0.74118X_1 + 0.15071X_2 - 0.40630X_3 - 0.01972X_5 - 0.00966X_6 + 0.01802X_7 + 1.28886X_8$$

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	48.104	17.768	2.710	0.010	0.000
X1	0.741	0.318	2.330	0.025	2.016
X2	0.151	0.103	1.460	0.152	2.373
X3	-0.406	0.201	-2.020	0.050	1.844
X5	-0.020	0.014	-1.370	0.178	3.857
X6	-0.010	0.016	-0.590	0.557	2.616
X7	0.018	0.030	0.600	0.549	3.101
X8	1.289	0.340	3.790	0.001	1.524

Root MSE	Dependent Mean	C.V	R^2	AdjR^2
3.03330	94.01489	3.22641	**0.5305**	**0.4417**

Table 4.15- Analysis of variance for 4th model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	384.74155	54.96308	5.97	0.0001
Error	37	340.43397	9.20092		
Corrected Total	44	725.17552			

Table 4.16: Residual analysis for the best subset for forecasting of Rice yield in west Godavari district of Andhra Pradesh for 4th model.

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Student Residual	Cook's D	Hat Diag	Cov Ratio	DFFITS
1	92.6	95.909	1.056	-3.309	-1.163	0.023	0.121	1.051	-0.434
2	91.87	91.976	0.876	-0.106	-0.037	0.000	0.083	1.358	-0.011
3	96.33	91.303	1.269	5.027	1.825	0.088	0.175	0.710	0.869
4	90.5	89.934	0.960	0.566	0.197	0.001	0.100	1.372	0.065
5	92.8	93.300	0.970	-0.500	-0.174	0.000	0.102	1.378	-0.058
6	92	93.661	1.002	-1.661	-0.580	0.005	0.109	1.299	-0.201
7	101.9	97.059	0.990	4.841	1.688	0.042	0.107	0.734	0.598
8	92	93.205	1.179	-1.205	-0.431	0.004	0.151	1.409	-0.180
9	94	91.382	1.228	2.618	0.944	0.022	0.164	1.225	0.417
10	98	98.278	1.278	-0.278	-0.101	0.000	0.178	1.510	-0.046
11	88.92	91.616	1.219	-2.696	-0.971	0.023	0.162	1.208	-0.426
12	90	93.559	1.159	-3.559	-1.270	0.034	0.146	1.021	-0.530
13	100	99.638	1.416	0.362	0.135	0.001	0.218	1.586	0.070
14	97.2	94.796	1.250	2.404	0.870	0.019	0.170	1.271	0.392
15	98.5	95.406	0.960	3.094	1.075	0.016	0.100	1.073	0.360
16	92.62	91.190	1.638	1.430	0.560	0.016	0.292	1.642	0.356
17	101.8	100.470	1.757	1.330	0.538	0.018	0.336	1.760	0.379
18	93	93.773	1.383	-0.773	-0.286	0.003	0.208	1.544	-0.145
19	100	100.316	1.822	-0.316	-0.130	0.001	0.361	1.940	-0.097
20	96.8	96.790	1.275	0.010	0.004	0.000	0.177	1.512	0.002
21	92.6	93.863	1.614	-1.263	-0.492	0.012	0.283	1.648	-0.306

22	88.9	92.425	1.220	-3.525	-1.269	0.039	0.162	1.040	-0.562
23	98.2	90.803	1.215	7.397	2.662	0.169	0.161	0.271	1.277
24	91	92.980	1.242	-1.980	-0.715	0.013	0.168	1.338	-0.319
25	95	95.178	1.044	-0.178	-0.062	0.000	0.118	1.411	-0.023
26	89.5	86.810	1.964	2.690	1.164	0.122	0.419	1.591	0.994
27	92.6	92.628	1.960	-0.028	-0.012	0.000	0.418	2.138	-0.010
28	90	89.523	1.561	0.477	0.183	0.002	0.265	1.682	0.109
29	88	92.562	1.729	-4.562	-1.831	0.202	0.325	0.863	-1.314
30	91	95.113	0.973	-4.113	-1.432	0.029	0.103	0.880	-0.492
31	91	94.734	0.872	-3.734	-1.285	0.019	0.083	0.942	-0.389
32	92	94.880	1.107	-2.880	-1.020	0.020	0.133	1.143	-0.400
33	95.33	91.797	0.931	3.533	1.224	0.019	0.094	0.988	0.397
34	91	91.711	0.845	-0.711	-0.244	0.001	0.078	1.333	-0.070
35	93	92.738	1.068	0.262	0.092	0.000	0.124	1.419	0.034
36	90	92.880	1.156	-2.880	-1.027	0.022	0.145	1.156	-0.424
37	102	98.184	1.167	3.816	1.363	0.040	0.148	0.968	0.575
38	92.5	94.394	1.111	-1.894	-0.671	0.009	0.134	1.304	-0.262
39	95	92.892	1.194	2.108	0.756	0.013	0.155	1.301	0.322
40	96.5	94.786	1.139	1.714	0.610	0.008	0.141	1.337	0.245
41	101.5	100.654	1.528	0.846	0.323	0.004	0.254	1.631	0.186
42	96.5	94.630	1.295	1.870	0.682	0.013	0.182	1.376	0.319
43	99	95.830	1.001	3.170	1.107	0.019	0.109	1.067	0.388
44	87.5	91.641	1.246	-4.141	-1.497	0.057	0.169	0.908	-0.686
45	90.2	93.476	1.261	-3.276	-1.187	0.037	0.173	1.103	-0.546

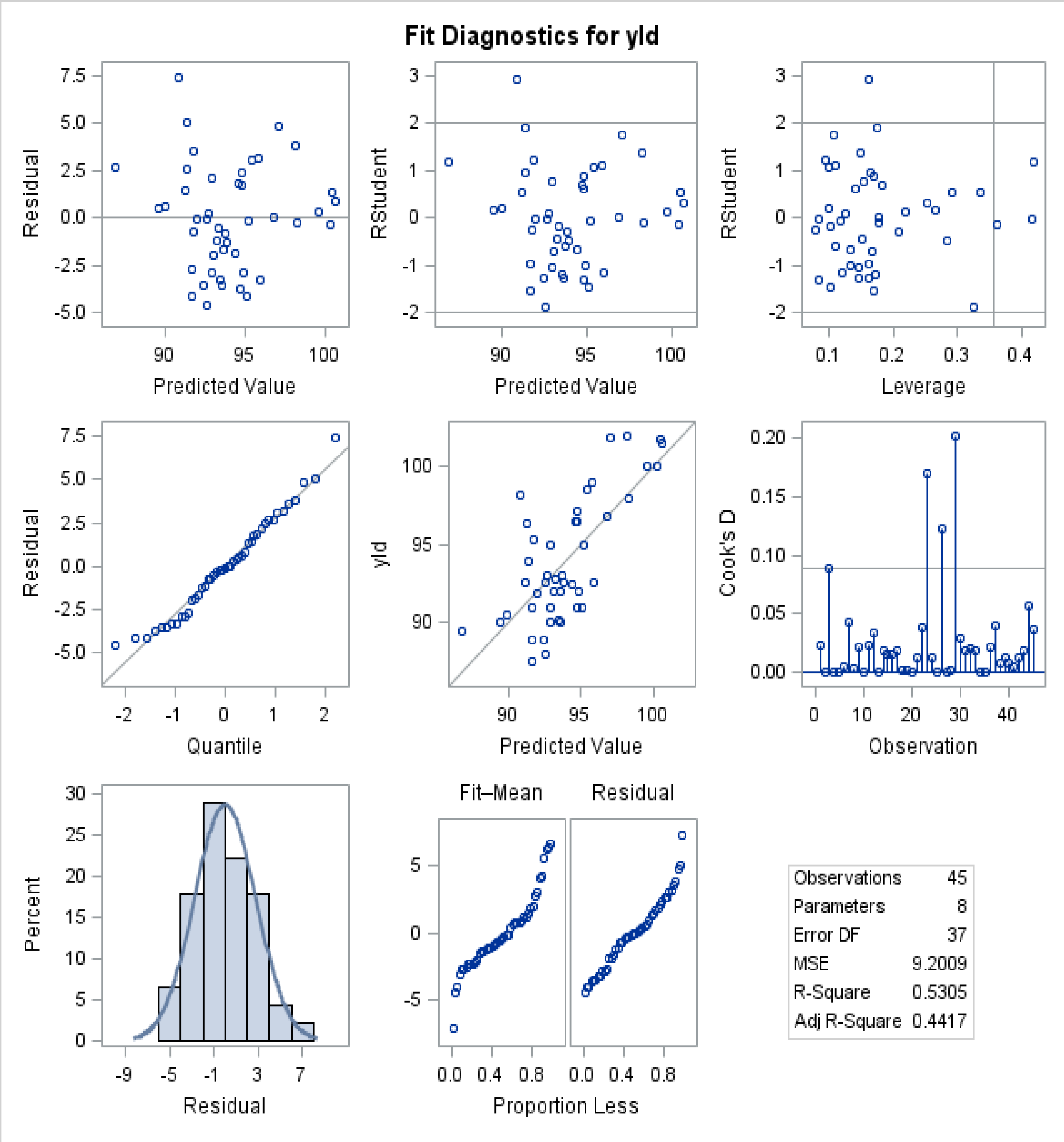
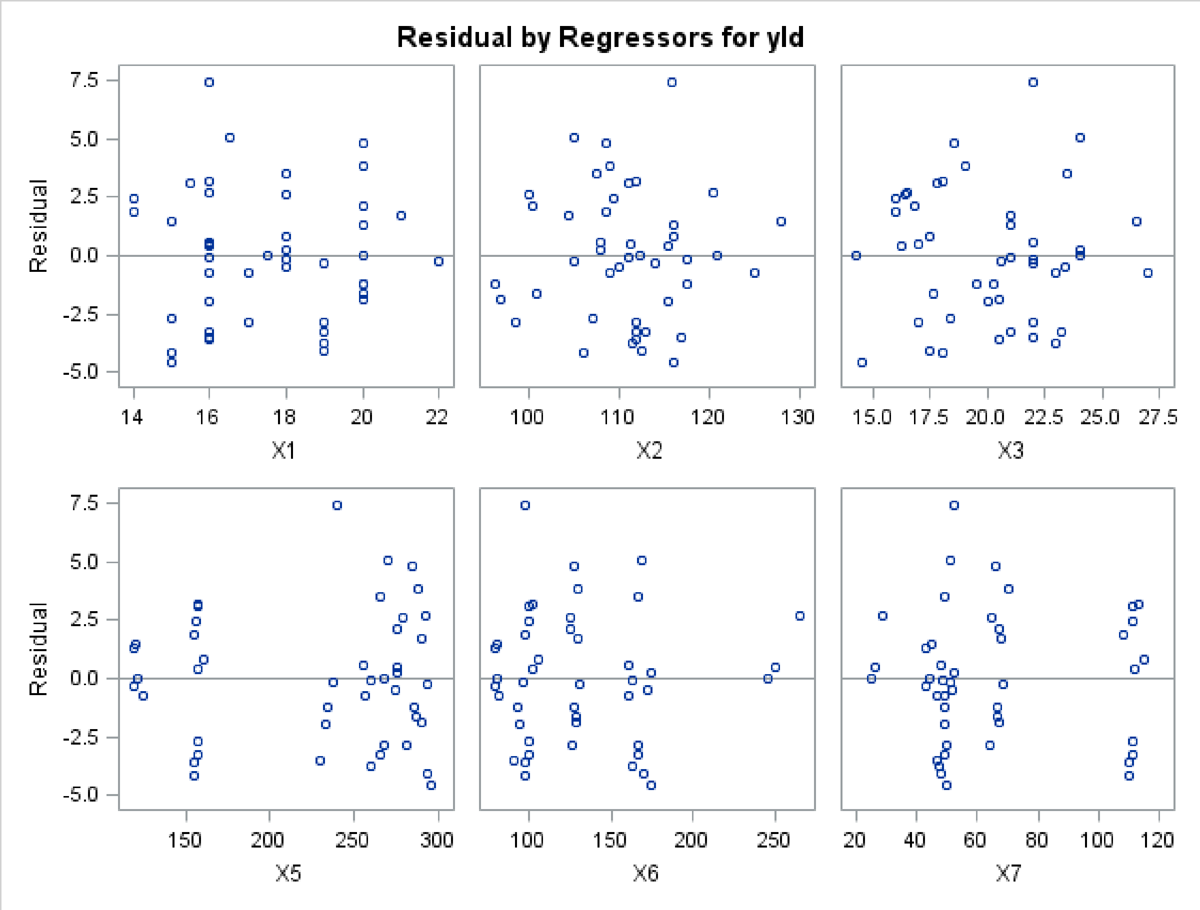


Figure 4.16: Fit diagnostics of yield (Model 4)



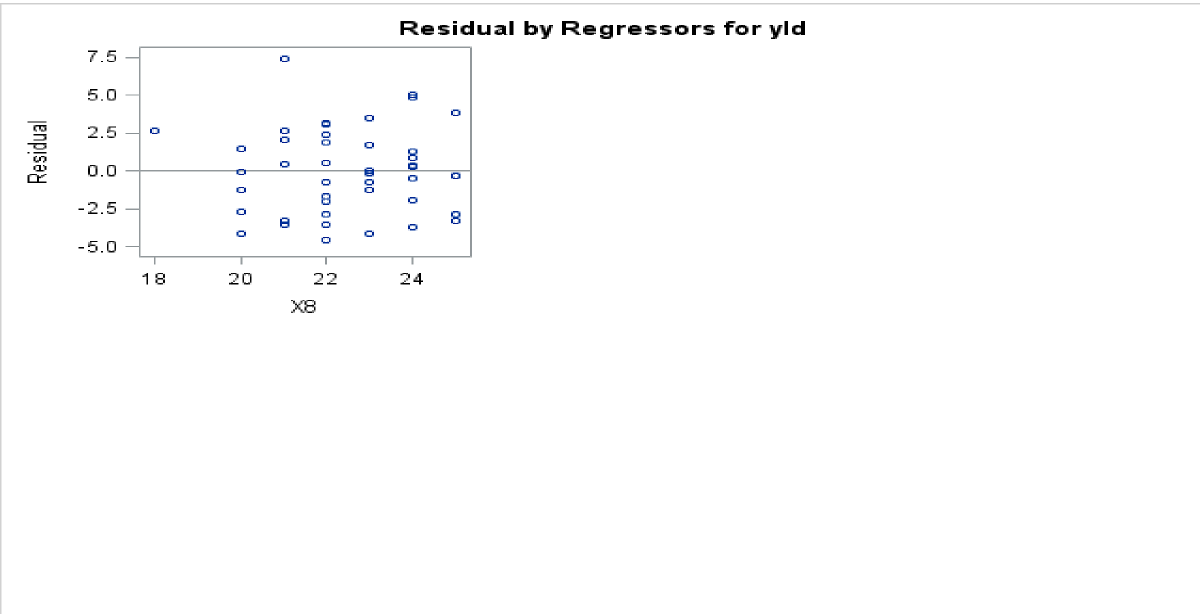


Figure 4.17: Residual regressors for yield (Model 4)

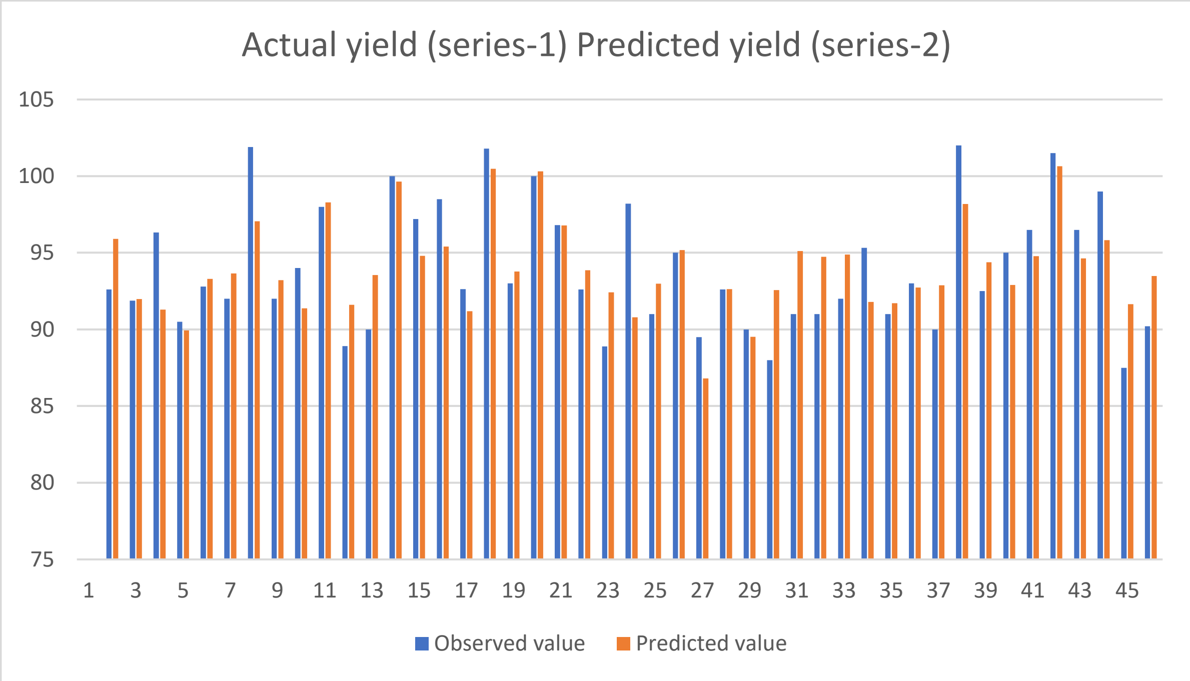


Figure 4.18- Histogram of actual yield and predicted yield (Model 4)

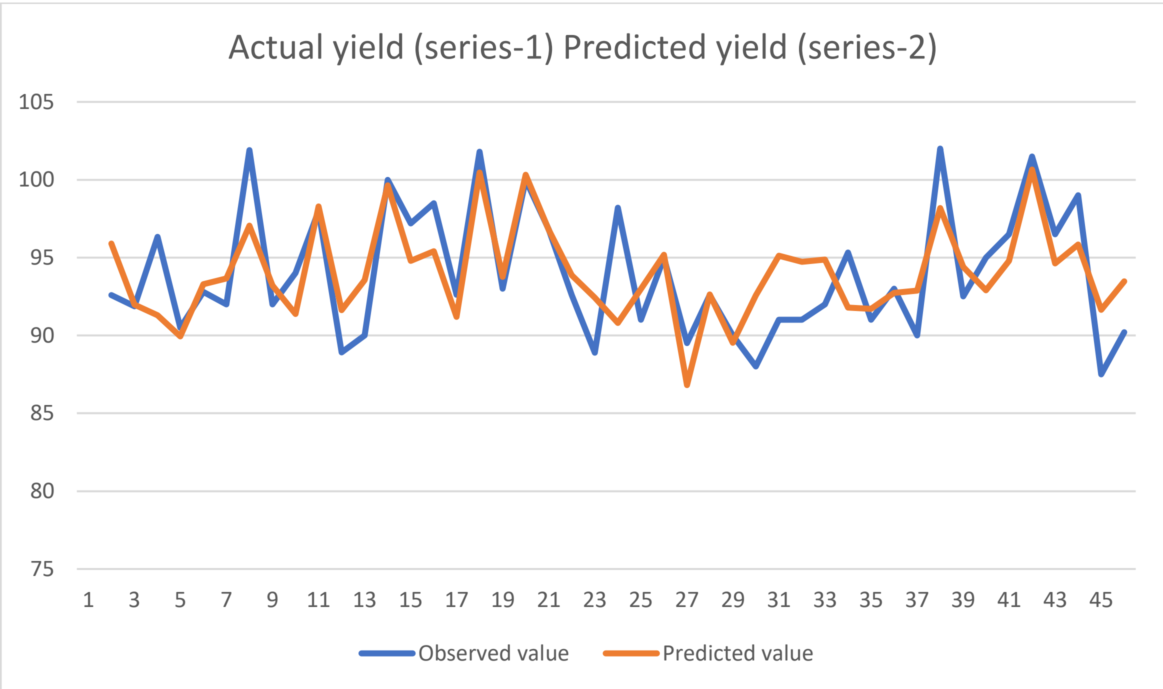


Figure 4.19 Line diagram of actual yield and predicted yield (Model 4)

Table 4.17: Forecasting of Rice yield in West Godavari District of Andhra Pradesh for 5th model using regression analysis

Regression equation

$$\hat{Y} = 48.94985 + 0.74638X_1 + 0.15268X_2 - 0.39805X_3 - 0.6806X_4 - 0.02022X_5 - 0.00895X_6 + 0.01944X_7 + 1.30247X_8$$

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
Intercept	48.950	20.354	2.400	0.021	0.000
X1	0.746	0.328	2.280	0.029	2.082
X2	0.153	0.107	1.430	0.161	2.479
X3	-0.398	0.224	-1.780	0.084	2.223
X4	-0.068	0.763	-0.090	0.929	2.409
X5	-0.020	0.016	-1.300	0.203	4.430
X6	-0.009	0.018	-0.490	0.628	3.217
X7	0.019	0.034	0.570	0.572	3.953
X8	1.302	0.377	3.450	0.001	1.823

Root MSE	Dependent mean	C.V	R^2	Adj R^2
3.07480	94.01489	3.27055	0.5307	0.4264

Table 4.18- Analysis of variance for 5th model

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	384.81678	48.10210	5.09	0.0003
Error	36	340.35874	9.45441		
Corrected Total	44	725.17552			

Table 4.19: Residual analysis for the best subset for forecasting of Rice yield in west Godavari district of Andhra Pradesh for 5th model.

Obs	Dependent Variable	Predicted Value	Std Error Mean Predict	Residual	Student Residual	Cook's D	Hat Diag	Cov Ratio	DFFITS
1	92.6	95.891	1.089	-3.291	-1.144	0.021	0.125	1.056	-0.435
2	91.87	91.976	0.888	-0.106	-0.036	0.000	0.083	1.405	-0.011
3	96.33	91.314	1.292	5.016	1.798	0.077	0.177	0.671	0.861
4	90.5	89.976	1.083	0.524	0.182	0.001	0.124	1.459	0.068
5	92.8	93.243	1.174	-0.443	-0.156	0.000	0.146	1.499	-0.064
6	92	93.660	1.015	-1.660	-0.572	0.004	0.109	1.332	-0.198
7	101.9	97.034	1.041	4.866	1.682	0.041	0.115	0.697	0.621
8	92	93.239	1.255	-1.239	-0.441	0.004	0.167	1.473	-0.195
9	94	91.381	1.245	2.619	0.932	0.019	0.164	1.237	0.412
10	98	98.297	1.312	-0.297	-0.107	0.000	0.182	1.571	-0.050
11	88.92	91.544	1.474	-2.624	-0.972	0.031	0.230	1.317	-0.531
12	90	93.584	1.207	-3.584	-1.267	0.033	0.154	1.010	-0.546
13	100	99.644	1.437	0.356	0.131	0.001	0.219	1.642	0.068
14	97.2	94.827	1.313	2.373	0.854	0.018	0.182	1.311	0.401
15	98.5	95.409	0.974	3.092	1.060	0.014	0.100	1.077	0.355
16	92.62	91.182	1.663	1.438	0.556	0.014	0.293	1.685	0.354
17	101.8	100.419	1.872	1.382	0.566	0.021	0.371	1.889	0.430
18	93	93.829	1.539	-0.829	-0.312	0.004	0.250	1.678	-0.178
19	100	100.294	1.863	-0.294	-0.120	0.001	0.367	2.028	-0.090
20	96.8	96.798	1.295	0.002	0.001	0.000	0.177	1.567	0.000
21	92.6	93.805	1.763	-1.205	-0.478	0.012	0.329	1.812	-0.331
22	88.9	92.448	1.263	-3.548	-1.266	0.036	0.169	1.029	-0.575

23	98.2	90.801	1.232	7.399	2.627	0.147	0.161	0.226	1.260
24	91	93.055	1.512	-2.055	-0.767	0.021	0.242	1.465	-0.431
25	95	95.163	1.071	-0.163	-0.057	0.000	0.121	1.465	-0.021
26	89.5	86.806	1.991	2.694	1.150	0.106	0.419	1.585	0.982
27	92.6	92.671	2.044	-0.071	-0.031	0.000	0.442	2.307	-0.027
28	90	89.540	1.594	0.460	0.175	0.001	0.269	1.749	0.105
29	88	92.465	2.064	-4.465	-1.959	0.349	0.451	0.851	-1.850
30	91	95.212	1.487	-4.212	-1.565	0.083	0.234	0.892	-0.883
31	91	94.731	0.885	-3.731	-1.267	0.016	0.083	0.932	-0.384
32	92	94.868	1.130	-2.868	-1.003	0.017	0.135	1.155	-0.396
33	95.33	91.807	0.951	3.523	1.205	0.017	0.096	0.984	0.394
34	91	91.716	0.858	-0.716	-0.242	0.001	0.078	1.377	-0.070
35	93	92.636	1.576	0.365	0.138	0.001	0.263	1.740	0.081
36	90	92.864	1.185	-2.864	-1.010	0.020	0.149	1.169	-0.422
37	102	98.170	1.194	3.830	1.351	0.036	0.151	0.950	0.576
38	92.5	94.437	1.229	-1.937	-0.687	0.010	0.160	1.362	-0.298
39	95	92.876	1.223	2.124	0.753	0.012	0.158	1.327	0.324
40	96.5	94.808	1.181	1.692	0.596	0.007	0.148	1.383	0.246
41	101.5	100.680	1.575	0.820	0.311	0.004	0.263	1.706	0.183
42	96.5	94.671	1.389	1.829	0.667	0.013	0.204	1.448	0.335
43	99	95.811	1.037	3.189	1.102	0.017	0.114	1.068	0.396
44	87.5	91.571	1.482	-4.071	-1.511	0.077	0.232	0.931	-0.847
45	90.2	93.521	1.373	-3.321	-1.207	0.040	0.199	1.110	-0.606

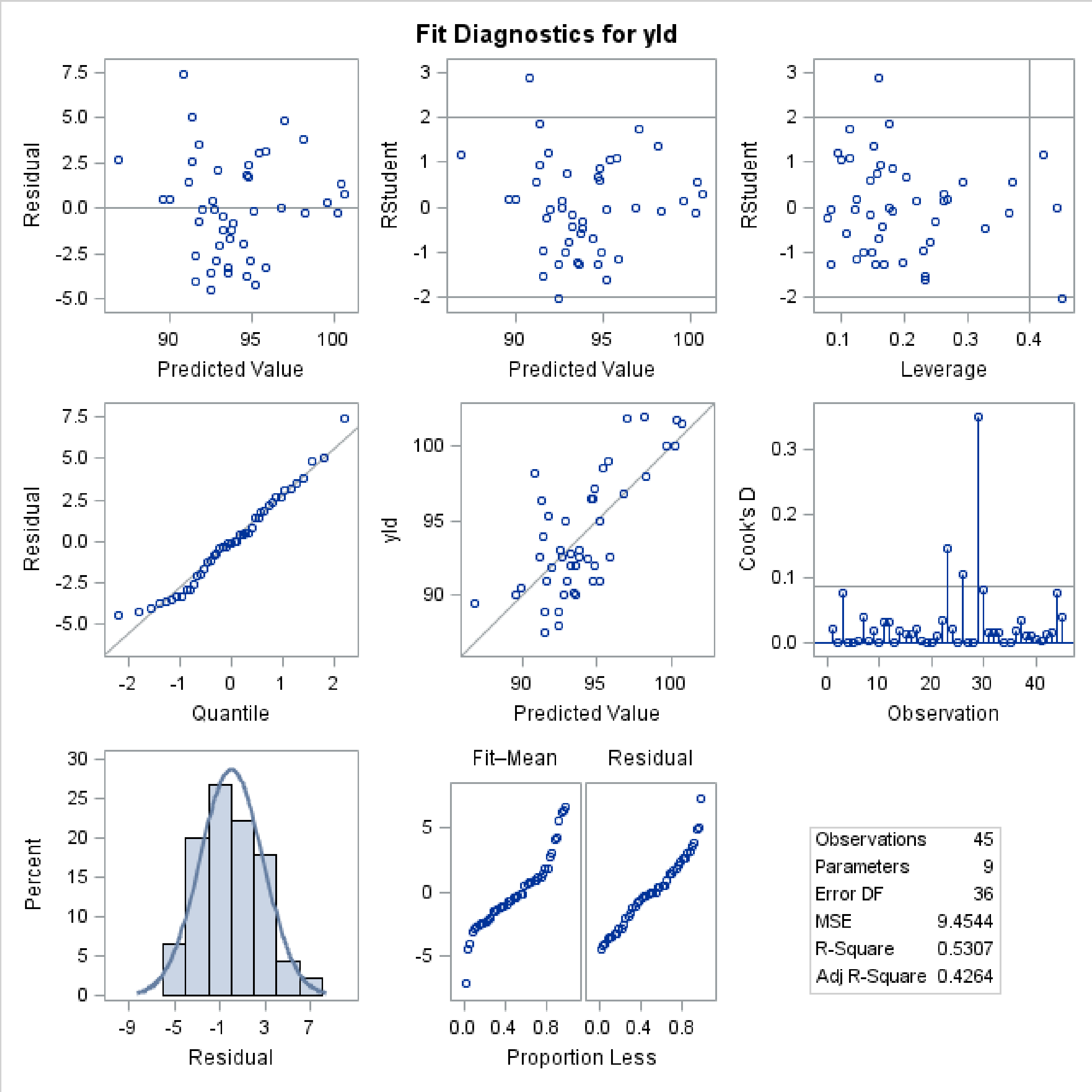


Figure 4.20: Fit diagnostics of Y for (Model 5)

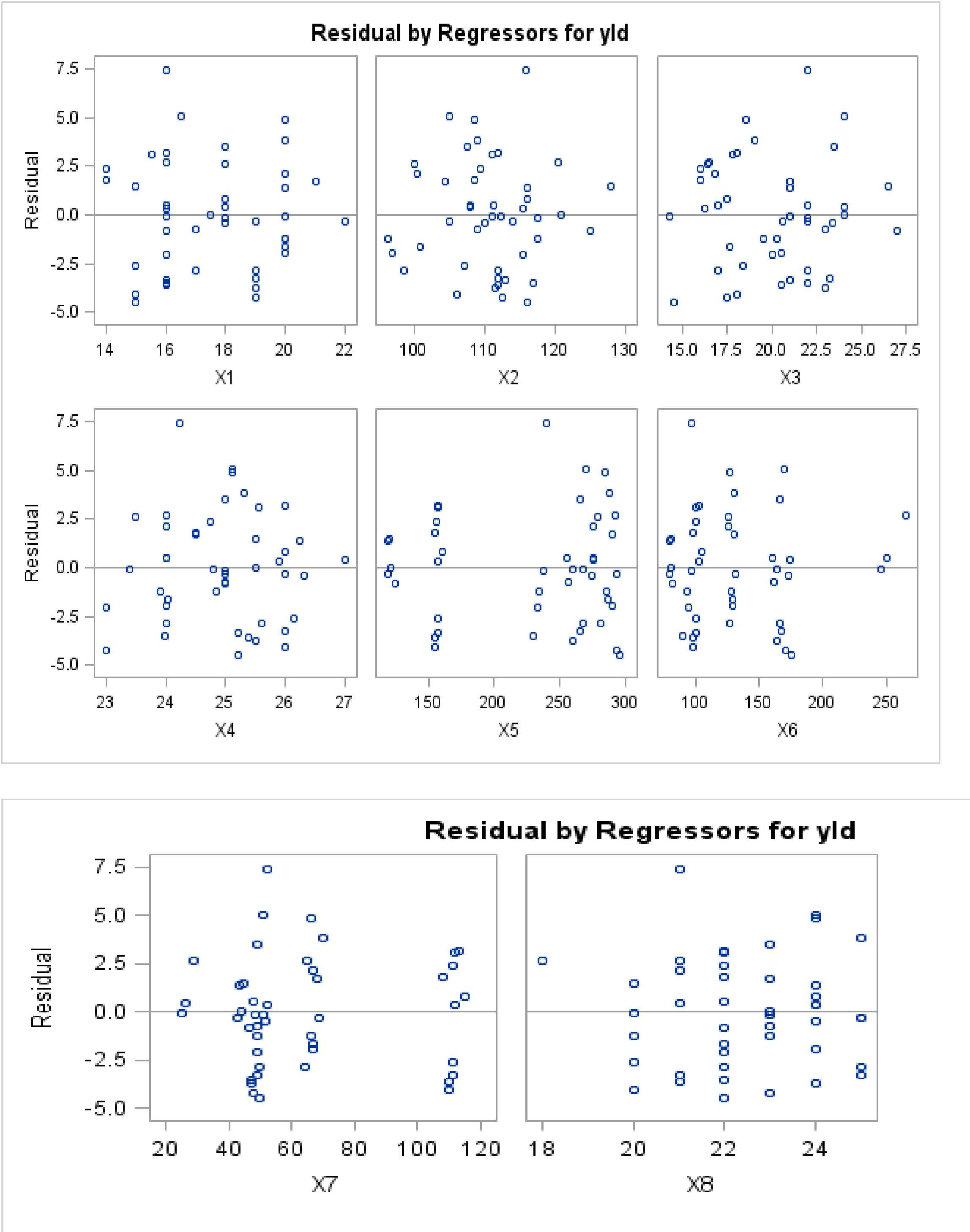


Figure 4.21: Residual regressors for yield (Model 5)

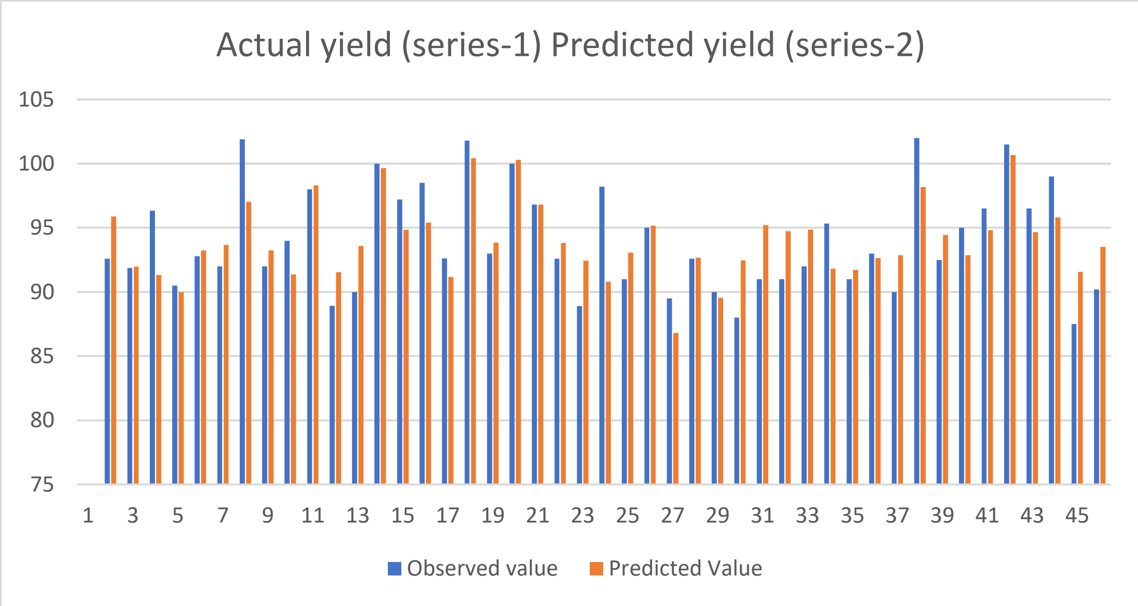


Figure 4.22 –Histogram of actual yield and predicted yield (Model 5)

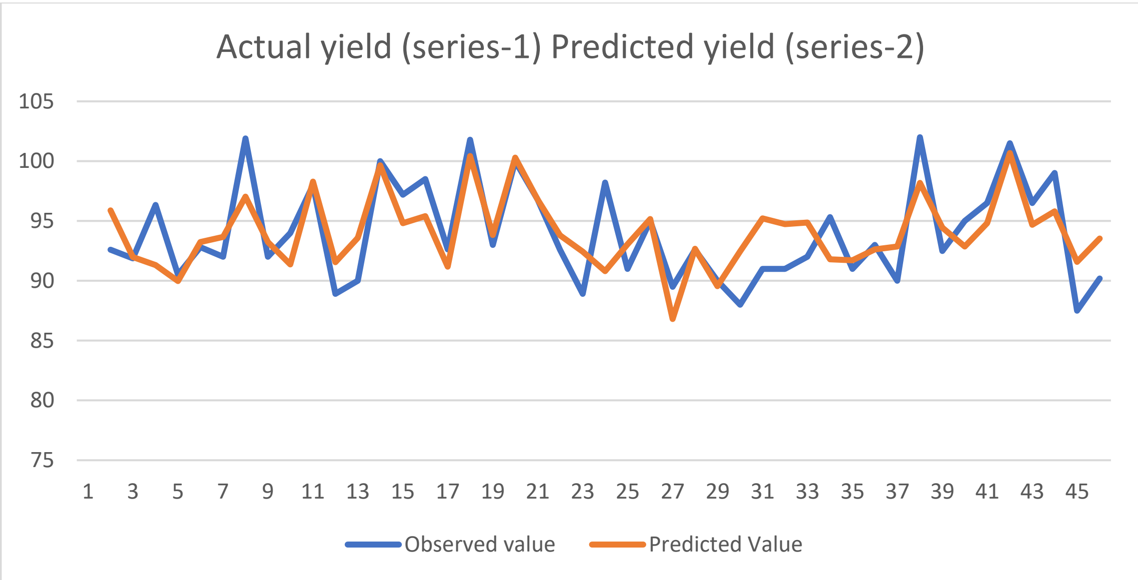


Figure 4.23- Line diagram of actual yield and predicted yield (Model 5)

Table 4.20: Residual analysis with MAPE for 5 models with 45 observations(Training data)

Model	MAE	MAPE
X1,X3,X4,X8	2.29	2.44
X1,X2,X3,X5,X8	2.26	2.40
X1,X2,X3,X5,X7,X8	**2.19**	**2.33**
X1,X2,X3,X5,X6,X7,X8	2.20	2.35
X1,X2,X3,X4,X5X6,X7,X8	2.20	2.35

Among the models considered, Model-3 with only 6 parameters and based on a dataset of 45 observations achieves the lowest Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE). This indicates that Model-3 provides predictions that closely align with the actual values, exhibiting minimal deviation.

Table 4.21: Error forecasting for observations not included in model building (1st Model)

$$\widehat{Y} = 68.91983 + 0.66549X_1 - 0.37538X_3 - 0.03500X_5 + 1.28770X_8$$

S.NO	X1	X3	X5	X8	Actual yield	Predicted yield	Error	Percentage error
1	16	27.5	122	20	93.40	90.73	2.67	2.86
2	20	21	117	24	100.40	101.16	-0.76	-0.75
3	17	27	130	22	94.50	93.88	0.62	0.66
4	18	22	118.5	25	98.60	100.69	-2.09	-2.11
5	18	25	121.5	23	95.50	96.88	-1.38	-1.44

Table 4.22: Error forecasting for observations not included in model building (2nd Model)

$$\hat{Y} = 56.34736 + 0.71870X_1 + 0.09617X_2 - 0.44142X_3 - 0.03126X_5 + 1.35254X_8$$

S.No	X1	X2	X3	X5	X8	Yield(Y)	Predicted Yield	Error	Percentage error
1.00	16.00	125.00	27.50	122.00	20.00	93.40	90.97	2.43	2.61
2.00	20.00	115.00	21.00	117.00	24.00	100.40	101.31	-0.91	-0.91
3.00	17.00	124.00	27.00	130.00	22.00	94.50	94.26	0.24	0.25
4.00	18.00	113.50	22.00	118.50	25.00	98.60	100.60	-2.00	-2.03
5.00	18.00	121.50	25.00	121.50	23.00	95.50	97.24	-1.74	-1.83

Table 4.23: Error forecasting for observations not included in model building (3rd Model)

$$\hat{Y} = 46.08838 + 0.80226X_1 + 0.14708X_2 - 0.36854X_3 - 0.02404X_5 + 0.02418X_7 + 1.28461X_8$$

S.No	X1	X2	X3	X5	X7	X8	Yield(Y)	Predicted Yield	Error	Percentage error
1	16	125	27.5	122	46	20	93.4	91.05	2.35	2.52
2	20	115	21	117	42.5	24	100.4	100.35	0.05	0.05
3	17	124	27	130	47.5	22	94.5	94.30	0.20	0.21
4	18	113.5	22	118.5	41.5	25	98.6	99.38	-0.78	-0.80
5	18	121.5	25	121.5	45	23	95.5	96.90	-1.40	-1.46

Table 4.24: Error forecasting for observations not included in model building (4th Model)

$$\hat{Y} = 48.10415 + 0.74118X_1 + 0.15071X_2 - 0.40630X_3 - 0.01972X_5 - 0.00966X_6 + 0.01802X_7 + 1.28886X_8$$

S.No	X1	X2	X3	X5	X6	X7	X8	Yield(Y)	Predicted yield	Error	Percentage Error
1	16	125	27.5	122	81	46	20	93.4	91.05	2.35	2.52
2	20	115	21	117	76.5	42.5	24	100.4	100.38	0.02	0.02
3	17	124	27	130	82.5	47.5	22	94.5	94.27	0.23	0.24
4	18	113.5	22	118.5	78	41.5	25	98.6	99.49	-0.89	-0.90
5	18	121.5	25	121.5	80	45	23	95.5	96.89	-1.39	-1.45

Table 4.25: Error forecasting for observations not included in model building (5th Model)

$$\hat{Y} = 48.94985 + 0.74638X_1 + 0.15268X_2 - 0.39805X_3 - 0.6806X_4 - 0.02022X_5 - 0.00895X_6 + 0.01944X_7 + 1.30247X_8$$

S.No	X1	X2	X3	X4	X5	X6	X7	X8	Yield(Y)	Predicted Yield	Error	Percentage error
1	16	125	27.5	25.7	122	81	46	20	93.4	91.03	2.37	2.53
2	20	115	21	26	117	76.5	42.5	24	100.4	100.34	0.06	0.06
3	17	124	27	25.5	130	82.5	47.5	22	94.5	94.30	0.20	0.21
4	18	113.5	22	26	118.5	78	41.5	25	98.6	99.46	-0.86	-0.87
5	18	121.5	25	25.5	121.5	80	45	23	95.5	96.91	-1.41	-1.47

Table 4.26: Model validation among five selected models

Model	MAE	MAPE
X1,X3,X4,X8	1.50	1.57
X1,X2,X3,X5,X8	1.47	1.52
X1,X2,X3,X5,X7,X8	**0.96**	**1.01**
X1,X2,X3,X5,X6,X7,X8	0.98	1.03
X1,X2,X3,X4,X5X6,X7,X8	0.98	1.03

In the above table from the validity testing model-3 has the lowest MAE and MAPE which is the good fitted model for the forecasting

4.3 Performance of Pradhan Mantri Fasal Bima Yojana insurance scheme in West Godavari District of Andhra Pradesh

In 2016, the government introduced a program named Pradhan Mantri Fasal Bima Yojana (PMFBY) with several new features. An allocation of Rs. 5500 crores were made for this initiative in the 2016-2017 budget. The primary goal of PMFBY is to provide crop insurance to farmers across India, offering uniform coverage at a consistent cost for all participants. This scheme was introduced as a replacement for the older crop insurance programs, namely the National Agriculture Insurance Scheme and the Modified National Agriculture Insurance Scheme, which had their own set of challenges.

PMFBY takes a region-centric approach, focusing on insuring entire agricultural regions. Despite its launch in 2016, official recorded data regarding the implementation of the Pradhan Mantri Fasal Bima Yojana insurance scheme in West Godavari district is only available for three years, specifically 2018, 2019, and 2022. Consequently, these years were chosen for the study's analysis, as the scheme has been in operation in the district since the 2016 kharif season.

4.3.1 Farmers covered under PMFBY during 2018,2019 and 2022 during kharif in West Godavari district

Table 4.27 provides data on the total number of farmers who registered for crop insurance during the kharif seasons of 2018, 2019, and 2022 in the district. It is noteworthy that the majority of these farmers were categorized as loanee farmers, accounting for 98.89 percent in 2018 and 83.13 percent in 2019. In 2022, a significant shift occurred as the government of Andhra Pradesh itself applied insurance coverage for all farmers who enrolled in the E-crop scheme, thereby classifying all enrolled farmers as loanee farmers for that year.

Moreover, there was an interesting trend in the participation of non-loanee farmers in the Pradhan Mantri Fasal Bima Yojana (PMFBY) scheme. In 2018, non-loanee farmers represented a minimal percentage at 1.11 percent, but this percentage notably increased to 16.9 percent in 2019.

Table 4.27: Farmers covered under PMFBY during kharif seasons of years 2018,2019 and 2022

Year	Loanee farmers	Non Loanee farmers	Total Farmers
2018-2019	1,49,790 (98.89%)	1,670 (1.11%)	1,51,460 (100%)
2019-2020	1,99,959 (83.13%)	40,556 (16.9%)	2,40,515 (100%)
2022-2023	6,04,529 (100%)	0 (0%)	6,04,529 (100%)

4.3.2 Farmers covered under PMFBY during 2018,2019 and 2022 during rabi in West Godavari district

Table 4.28 presents data regarding the total number of farmers who were insured during the Rabi seasons of 2018, 2019, and 2022 in the district. It is evident from the table that the majority of these farmers were classified as loanee farmers, constituting 91.4 percent in 2018 and 76.06 percent in 2019. However, a significant change occurred in 2022, where the government of Andhra Pradesh extended insurance coverage to all farmers who enrolled in the E-crop scheme, resulting in all enrolled farmers being considered as loanee farmers for that year.

An intriguing observation is the rise in participation of non-loanee farmers in the Pradhan Mantri Fasal Bima Yojana (PMFBY) scheme. In 2018, non-loanee farmers accounted for a modest 8.6 percent, but this percentage notably increased to 23.94 percent in 2019.

Table 4.28: Farmers covered under PMFBY during rabi season of years 2018,2019 and 2022

Year	Loanee farmers	Non Loanee farmers	Total Farmers
2018	11,036 (91.4%)	1,034 (8.6%)	12,070 (100%)
2019	61,540 (76.06%)	19,360 (23.94%)	80,900 (100%)
2022	4,81,217 (100%)	0 (0%)	4,81,217 (100%)

4.3.3 Performance of PMFBY in West Godavari district of Andhra Pradesh during kharif season

The analysis of the Pradhan Mantri Fasal Bima Yojana's (PMFBY) performance in West Godavari district, focusing on the coverage of farmers, units, insured area in hectares, total sum insured, and gross premium collection during the kharif seasons of 2018, 2019, and 2022, is detailed in Table 4.29. Furthermore, the compound growth rates of these metrics over a five-year period have been calculated and are presented in Table 4.30. Table 4.29 and 4.30 shows that total number of farmers covered under PMFBY in West Godavari district from kharif 2018 to kharif 2022 increased from 1,51,460 to 6,04,529 at a compound growth rate of 31 percent.

The number of insurance units covered under PMFBY in West Godavari district in 2018 kharif is only 400,857 units in 2019 and it is increased to 870 units in 2022. From 2018 to 2022 number of units increased at a compound annual growth rate of 16 percent.

The area insured under PMFBY in West Godavari district is increased from 87,950 hectares in 2018 to 180,570 hectares in 2022 at a compound annual growth rate of 15 percent.

The gross premium collected for PMFBY in West Godavari district is increased from 47.92 crores in 2018 to 105.07 crores in 2022 at a compound annual growth rate of 15 percent.

The sum insured during kharif 2018 was 626.31 crores and has increased to 1756 crores during kharif 2022 at a compound annual growth rate of 22 percent.

Certainly, the analysis of the Pradhan Mantri Fasal Bima Yojana (PMFBY) for the district during the kharif seasons from 2018 to 2022 indicates positive compound growth rates in various critical areas, including the number of farmers covered, insurance units, insured land area in hectares, total sum insured, and gross premium collected, underscoring the program's success in expanding its reach and impact over this period.

Table 4.29: Performance of PMFBY during kharif season

Year	Farmers insured	Insurance Units	Area (000'ha)	Gross Premium (Crores)	Sum Insured (Crores)
2018-2019	1,51,460	400	87.95	47.92	626.31
2019-2020	2,40,515	856	121.58	85.30	1,013.16
2022-2023	6,04,529	870	180.57	105.07	1,756

Table 4.30: CAGR of Performance of PMFBY during kharif season

Category	CAGR
Farmers	31%
Insurance Units	16%
Area	15%
Gross Premium	16%
Sum Insured	22%

Table 4.31: Performance of PMFBY during rabi season

Year	Farmers insured	Insurance Units	Area (000'ha)	Gross Premium (Crores)	Sum Insured (Crores)
2018-2019	11,070	694	10.59	3.29	85
2019-2020	80,900	754	37.05	18.97	265
2022-2023	4,81,217	798	143.68	62.83	1,347

Table 4.32: Performance of PMFBY during rabi season

Category	CAGR
Farmers	112.%
Insurance Units	2.8%
Area	67%
Gross Premium	80%
Sum Insured	73%

4.3.4 Performance of PMFBY in West Godavari district of Andhra Pradesh during rabi season

The analysis of Pradhan Mantri Fasal Bima Yojana's (PMFBY) performance in West Godavari district, focusing on the coverage of farmers, insurance units, insured land area in hectares, total sum insured, and gross premium collection during the rabi seasons of 2018, 2019, and 2022, is presented in Table 4.31. Additionally, the compound growth rates of these metrics over a five-year period have been calculated and are displayed in Table 4.32.

Table 4.31 and 4.32 shows that total number of farmers insured under PMFBY in West Godavari district from rabi 2018 to rabi 2022 increased from 11,070 to 4,81,217 at a compound growth rate of 112 percent.

The number of insurance units covered under PMFBY in West Godavari district is 694 in 2018, 754 units in 2019 and it is increased to 870 units in 2022. From 2018 to 2022 number of units increased at a compound annual growth rate of 2.8 percent.

The area insured under PMFBY in West Godavari district in rabi is increased from 10,590 hectares in 2018 to 1,43,680 hectares in 2022 at a compound annual growth rate of 67 percent.

The gross premium collected for PMFBY in West Godavari district in rabi is increased from 3.29 crores in 2018 to 62.83 crores in 2022 at a compound annual growth rate of 80 percent.

The sum insured during rabi 2018 was 85 crores and has increased to 1347 crores during kharif 2022 at a compound annual growth rate of 73 percent.

The analysis has shown consistent positive growth rates concerning the number of farmers insured under PMFBY, the coverage of insurance units, insured land area in hectares, total sum insured, and gross premium collection during the rabi seasons from 2018 to 2022 in the district. Additionally, positive compound growth rates have been observed regarding the number of farmers covered, insured land area in hectares, total sum insured, and gross premium collected during the rabi seasons from 2018 to 2022, emphasizing the program's expansion and effectiveness over this period.

Based on the analysis, it can be inferred that the performance of PMFBY in West Godavari district, Andhra Pradesh, has been commendable, as evidenced by the consistently positive growth rates in the number of farmers insured, insurance units covered, insured land area, total sum insured, gross premium, and net premium collected during both kharif and rabi seasons. Notably, the positive growth rate in the rabi season is higher compared to the kharif season, reflecting the program's effectiveness and impact in the region.

4.4. SOCIO ECONOMIC CONDITION OF RICE FARMERS

The farmer's socioeconomic situation has a significant impact on crop production. The information about the socioeconomic condition of Rice farmers is collected in my study area.

4.4.1 Age structure:

Older individuals possess a wealth of farming experience and a deeper understanding of effective crop cultivation techniques, particularly in relation to Rice farming. Consequently, age plays a significant role in the successful growth of Rice crops. The table and accompanying figure below provide an overview of age distribution among Rice farmers.

Table 4.33: Distribution of Rice farmers into different age groups

Category of age	Number	Percentage (%)	Code
Young age group (below 35 yrs.)	6	12	1
Middle age group (between 35-50 yrs.)	33	66	2
Old age group (above 50 yrs.)	11	22	3

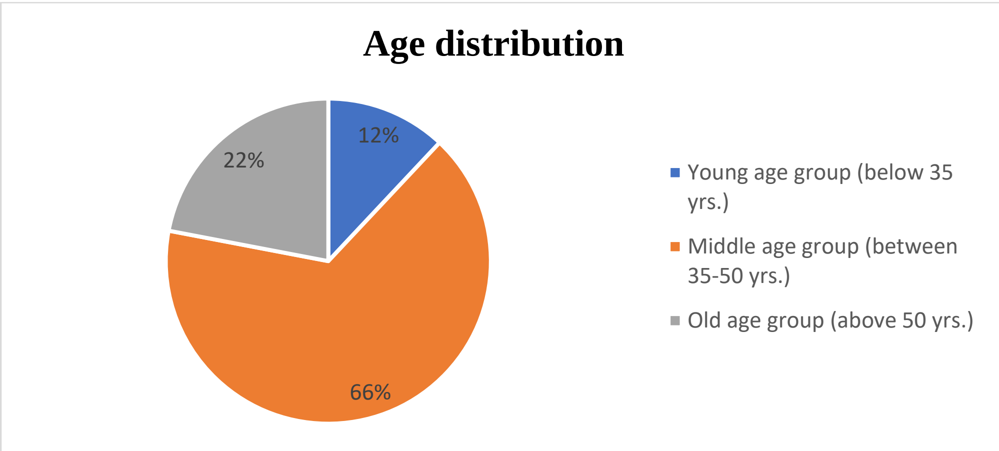


Figure 4.24: Age distribution among Rice farmers

4.4.2 Caste or category structure:

Caste constitutes an exclusive and inherited social hierarchy, wherein individuals of similar status, economic standing, professions, and distinct attributes are grouped together, setting them apart from other such clusters. This structured system within society remains inflexible, delineating diverse segments of residents residing within a particular geographical region.

Table 4.34: Distribution of different caste or category of Rice farmers

Caste	Number	Percentage (%)	Code
SC/ST	8	16	1
OBC	18	36	2
Un reserved	24	48	3

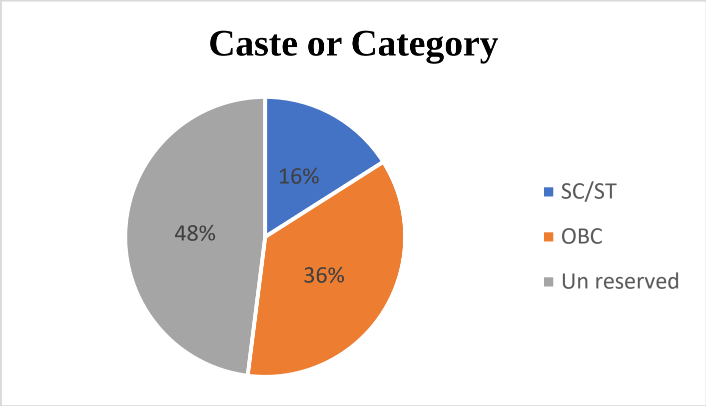


Figure 4.25: Distribution of caste between Rice farmers

The predominant engagement in Rice cultivation is by the unreserved caste farmers (48%), whereas participation in Rice cultivation is notably lower among SC/ST farmers (16%). This pattern can be attributed to the distribution of land ownership in the study area, where a majority of the land is possessed by farmers from the unreserved category. On the other hand, many SC/ST farmers own limited land, often leading them to work as laborers rather than being able to cultivate Rice.

4.4.3 Occupational structure:

In addition to a concise overview of an individual's wealth, earnings, and educational background, their occupation plays a pivotal role in determining their societal standing. Over time, both occupation and social class can undergo transformations. The broader spectrum of occupational categories encompasses five primary groups in these investigations: farm laborers, farmers and cultivators, traditional roles such as business proprietors, as well as service providers and individuals not falling within these defined categories. Occupation has a direct impact on a person's income, influenced by factors such as their willingness to undertake risks, investments in agriculture and other sectors, and their adoption of emerging technologies.

Table 4.35: Distribution of different occupation among Rice farmers

Category	Number	Percentage (%)	Code
Farm labour	14	28	1
Farmers and cultivators	29	58	2
Business/other traditional occupation	4	8	3
Service holder	3	6	4

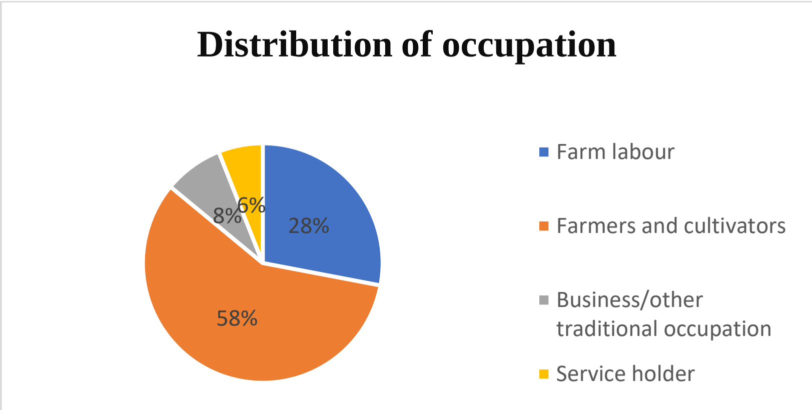


Figure 4.26. Distribution of social occupation among different Rice farmers.

Within the study area, a substantial majority of Rice cultivation is carried out by individuals who primarily engage in farming. Given that agriculture is the predominant occupation in this region, a significant portion of the population possesses larger tracts of land for agricultural purposes. Among these, farmers constitute the largest contingent, responsible for cultivating the majority of Rice, accounting for 58%. Following them, farm laborers contribute 28% to Rice cultivation, while individuals engaged in business or other conventional vocations make up 8%. A smaller proportion, approximately 6%, comprises service professionals.

4.4.4 Education and literacy:

Education encompasses the action or progression of acquiring knowledge, granting individuals the capacity to engage in critical thinking and decision-making. Furthermore, it equips individuals with the cognitive readiness to lead improved and more conscientious lives.

Table 4.36: Distribution of Educational qualification between Rice farmers

Category	Number	Percentage (%)	Code
Illiterate	0	0	1
Primary school	5	10	2
Middle school	9	18	3
High school	17	34	4
Intermediate	12	24	5
Graduation	7	14	6

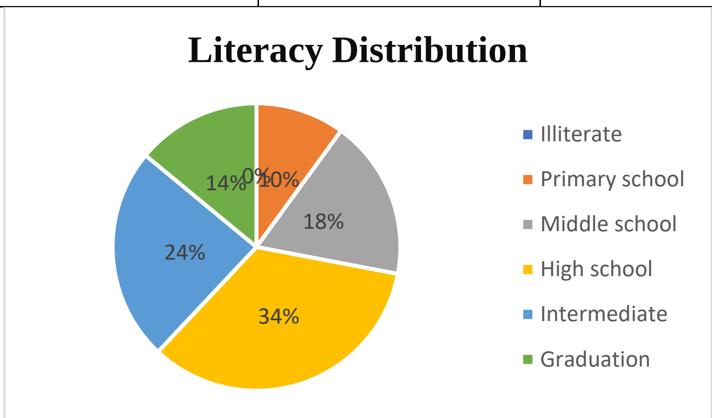


Figure 4.27: Distribution of education among different Rice farmers

From the above table and graph, it is clear that the most of the Rice farmers i.e., 34% went up to high school and they can write and read, 24% of the farmers went up to intermediate,18% of the farmers went up to middle school,10% went up to primary school and 14% of the farmers are graduated.

4.4.5 Family type

According to Table 4.31, the majority of families in the research region are nuclear families (64%), as opposed to nuclear families (36%). These show that while the joint families are becoming uncommon in rural regions, individuals are opting for nuclear families due to a range of factors such as enhanced education, urban influences, amenities, and more.

Table 4.37: Distribution of family type among Rice farmers

Category	Number	Percentage (%)	Code
Nuclear	32	64	1
Joint	18	36	2

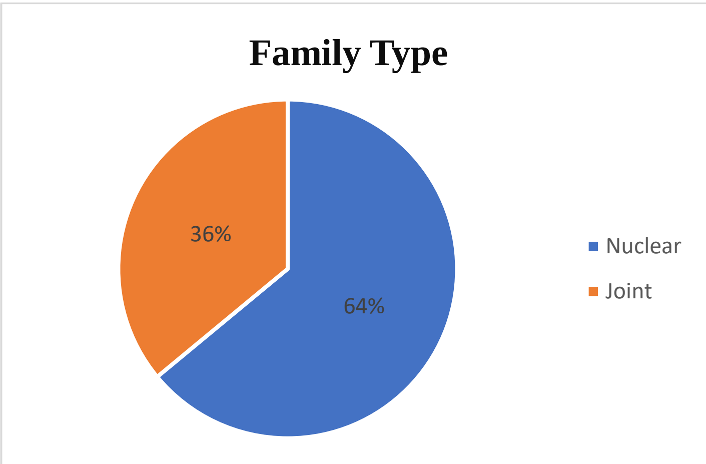


Figure 4.28: Distribution of family type among Rice farmers

4.4.6 Family size:

The family size denotes the count of individuals residing within a specific household. This family size significantly impacts the household's financial dynamics, as a larger family entail escalated expenditures and an increased need for income to sustain it. To address these dynamics, the classification of each farmer's family was undertaken, resulting in the formation of three distinct categories. The table 4.38 provides the enumeration of family members within each group, while figure 4.29 visually illustrates this categorization.

Table 4.38: Distribution of family size among Rice farmers

Category	Number	Percentage (%)	Code
Small family (up to 4 members)	10	20	1
Medium family (5-6 members	29	58	2
Large family (above 6)	11	22	3

The illustration below demonstrates that a predominant proportion of families fall into the medium-sized category, encompassing 5 to 6 members per family. This middle range constitutes 58% of the overall families. In contrast, larger families account for 22% of the total, while an equivalent 20% comprises small families. This distribution highlights the prevalence of nuclear families within the small family segment.

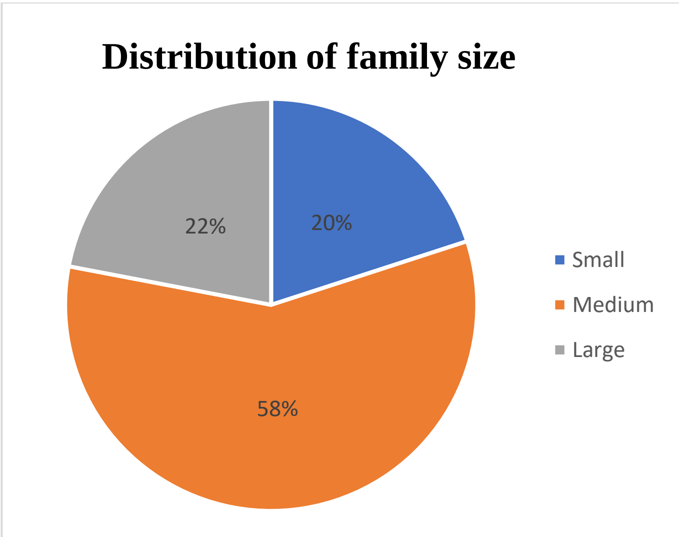


Figure 4.29: Distribution of family size among Rice farmers

4.4.7 Marital status

Simply said, marriage is the uniting of two people who are of different sex. Marriage has a direct impact on family size, which in turn has an impact on family income and spending. In the research area, the distribution of married and single farmers is shown in table 4.33 and figure 4.55.

Table 4.39: Marital status of Rice farmers

Category	Number	Percentage	Code
Married	47	94	1
Unmarried	1	2	2
Widow	2	4	3

So, from the table it is observed that the most of the Rice farmers are married (94%) i.e., 47 farmers are married out of 50 observed farmers.

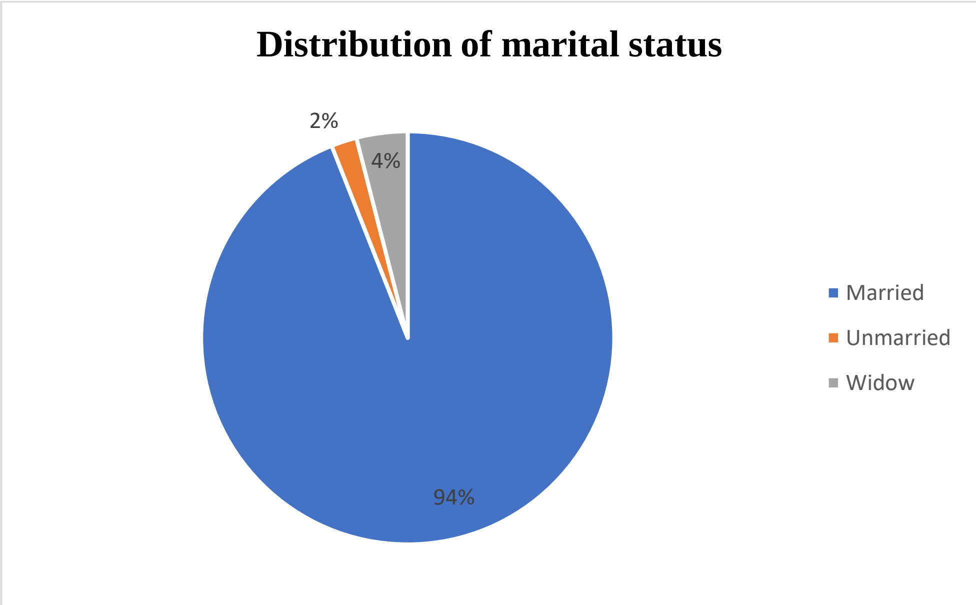


Figure 4.30: Marital status among Rice farmers

4.4.8 Size of operational land holding

The primary asset of agricultural farmers of utmost significance is the extent of their viable land resources. The economic position they hold is intricately linked with the quantity of land designated for active cultivation. Moreover, the costs incurred in running their agricultural activities are closely intertwined with the expanse of operational land under their possession. Comprehensive insights regarding the total operational land owned by Rice farmers can be found in Table 4.40, while a visual representation of this data is presented in Figure 4.31.

Table 4.40: Distribution of the size of the land holding by Rice farmers

Category	Number	Percentage	Code
Marginal(<1ha)	12	24	1
Small(1-2ha)	21	42	2
Semi medium(2-4ha)	9	18	3
Medium(4-10ha)	6	12	4
Large(>10ha)	2	4	5

From the above table 4.40 we can observe that the 42% of the farmers have small land holding for cultivation, 24% of the farmers are marginal land holders and only 4% of the farmers are large land holders.

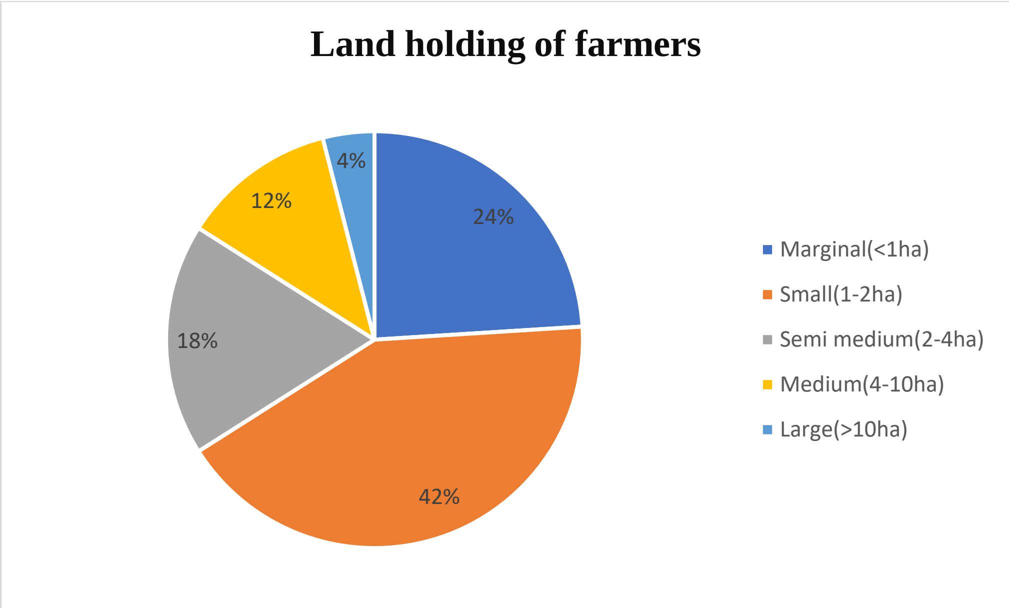


Figure 4.31: Distribution of size of operational land among Rice farmers

4.4.9 Farming experience of the farmers

As time progresses, the accumulation of experience becomes evident. Experience is acquired by engaging in a task over an extended duration. An experienced farmer is better equipped to manage their farm efficiently, navigate diverse situations adeptly, and potentially generate greater earnings compared to a less experienced counterpart. In alignment with these principles,

Table 4.41: Distribution of farming experience among Rice farmers

Category	Number	Percentage (%)	Code
Short (less than 1 year)	0	0	1
Medium (1 to 3 years)	2	4	2
Long (more than 3 years)	48	96	3

From the table 4.41 it is observed that almost all the Rice farmers (96%) are having experience of farming of more than three years, it is because the Rice is grown traditionally from generation to generation. Only 2% of the farmers are medium experienced as they started the farming recently.

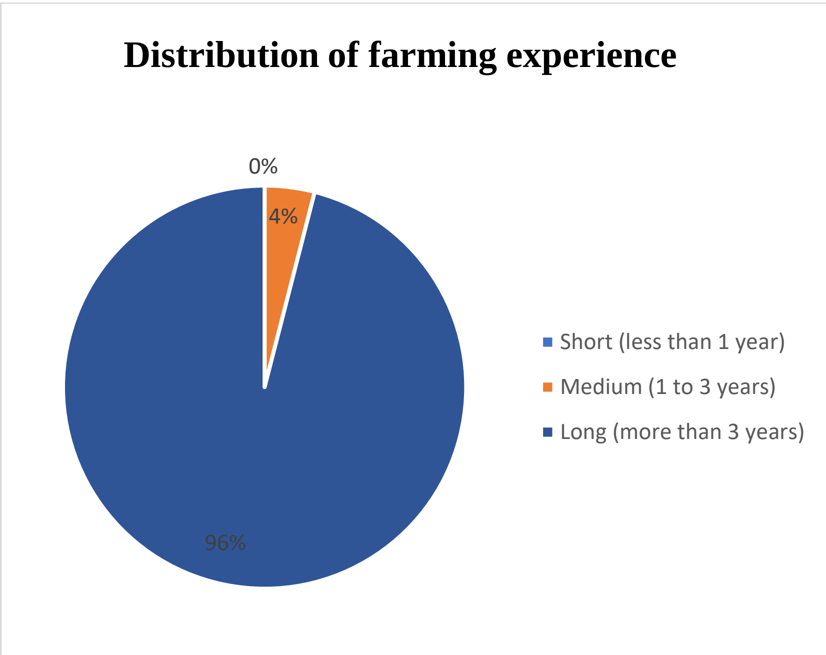


Figure 4.32: Distribution of farming experience among Rice farmers.

4.4.10 Source of information utilization:

The origins of information that respondents rely upon for farming hold significant importance, as erroneous data could erode their prosperity, while precise information has the potential to augment it. Consequently, these information sources have been categorized extensively and are detailed in Table 4.42, illuminating their impact on farmers' economic prospects.

Table 4.42: Different source from where Rice farmers are getting information

Category	Number	Percentage	Code
RBK	19	38	1
KCC	4	8	2
Agri. University	5	10	3
Research station	7	14	4
Television	12	24	5
Any other	3	6	6

It is evident that the majority of respondents (38%) acquire their information from RBK, followed by television (24%) and Research station (14 percent).Rythu Barosa Kendra(RBK) which is present in every village for farmers service acting as source of information for majority of farmers.

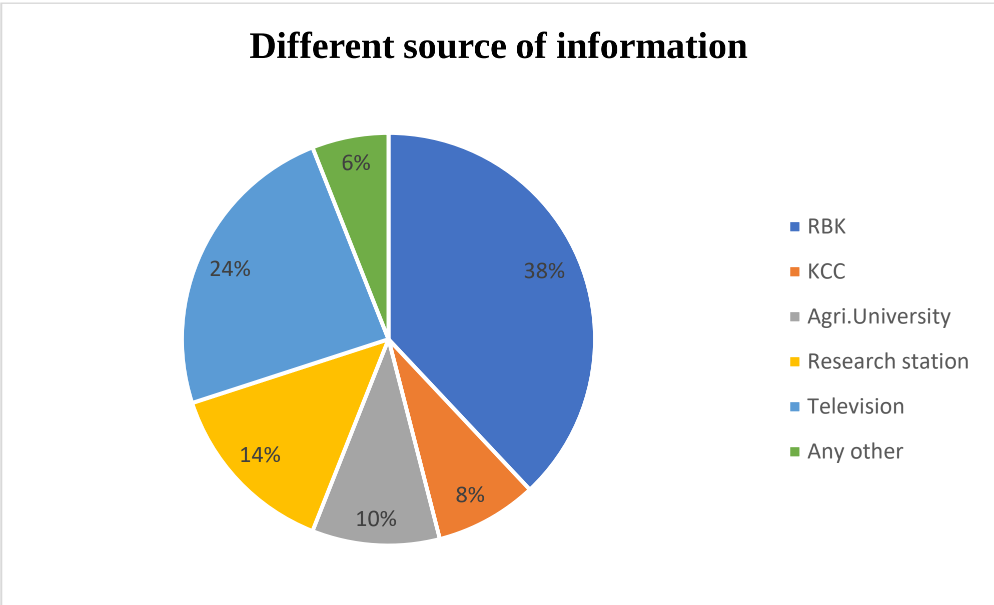


Figure 4.33: Distribution of different source of information among Rice farmers.

4.4.11 Social participation

Engagement in socially active collectives such as self-help groups, NGOs, and Bandhan groups tends to foster increased involvement. Involvement in diverse social groups offers valuable exposure and contributes to the equilibrium of individuals' economic standings within society. As evidenced by Table 4.43, a mere 38% of farmers partake actively in such social groups.

Table 4.43: Social participation among Rice farmers:

Category	Number	Percentage (%)	Code
YES	19	38	1
NO	31	62	2

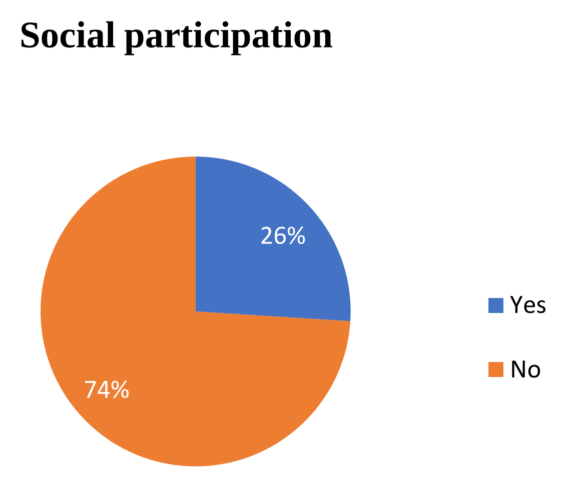


Figure 4.34: Social participation among different Rice farmers

4.4.12 Extension contacts:

Extension agents play a crucial role by acting as intermediaries connecting scientists and farmers. These extension workers offer farmers guidance, insights, and information on emerging technologies, novel practices, and essential skills, assisting them in troubleshooting production challenges. Ultimately, the contribution of extension agents results in the enhancement of farmers' economic outcomes. This engagement is reflected in Table 4.44 and visually represented in Figure 4.35, which present the frequency of interactions between farmers and extension personnel.

Table 4.44: Extension contacts among Rice farmers

Category	Number	Percentage (%)	Code
YES	15	30	1
NO	35	70	2

Evidently, a significant majority of the total respondents, constituting 70 percent, continue to rely on traditional methods of Rice cultivation and demonstrate a reluctance to embrace extension services. This situation highlights considerable prospects for extension agents to aid farmers in elevating their production levels and achieving greater financial stability.

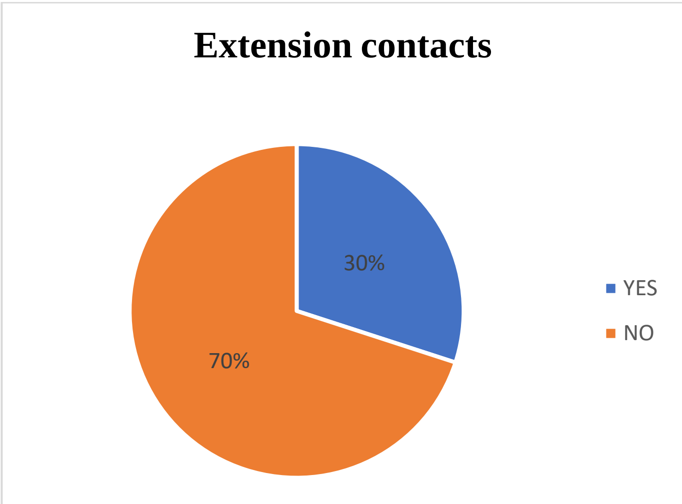


Figure 4.35: Extension contacts among Rice farmers.

4.4.13 Farm mechanization

Table 4.45: Farm mechanization among Rice farmers

Category	Number	Percentage (%)	Code
YES	9	18	1
NO	41	82	2

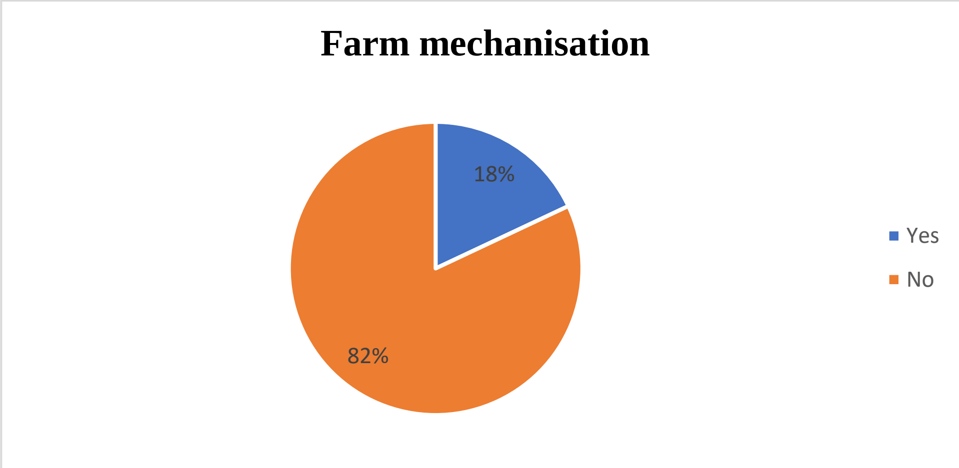


Figure 4.36: Farm mechanization among Rice growers

From the table 4.45 it is clear that only 18 percent of the farmers use mechanization. Since most of the farmers are small and marginal land holders, they can't afford farm mechanization.

4.4.14 Gender

The cultivation of crops and fieldwork necessitates a workforce. Within society, men generally exhibit greater physical fitness, enabling them to undertake arduous agricultural labour and remain more active than women. Men traditionally contribute a significant portion of the family's income. Despite advocating for gender equality, the rural farming economy continues to exhibit a higher reliance on men. The subsequent table illustrates the division of respondents based on their gender.

Table 4.46: Distribution of gender among Rice farmers.

Category	Number	Percentage (%)	Code
Male	50	100	1
Female	0	0	2

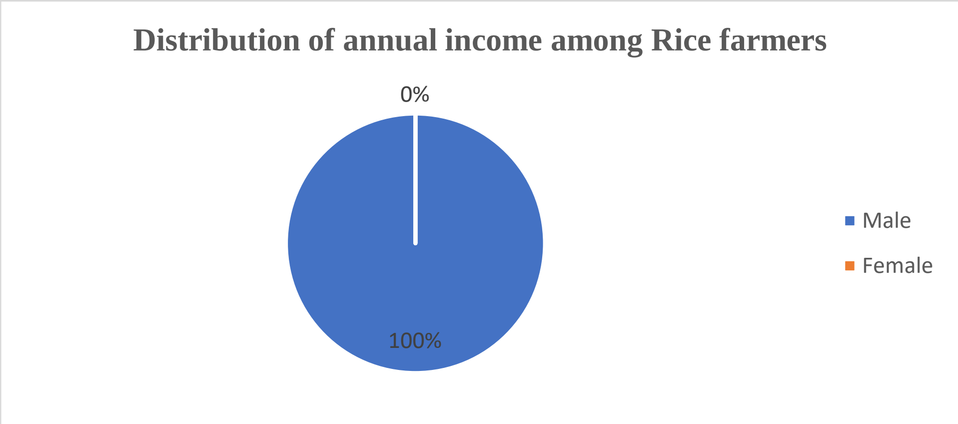


Figure 4.37: Distribution of gender among Rice farmers

The graph unmistakably portrays that all the farmers are male. This phenomenon is a reflection of the prevalent practice in the study area, where farming is primarily undertaken by men, while women predominantly assume the role of homemakers and handle household responsibilities. Female labour is occasionally engaged for tasks like weeding, while the bulk of the remaining agricultural tasks are carried out by male labours.

4.4.15 Land type:

Water accessibility is a crucial element in crop cultivation. In my study area all the 50 farmers have irrigation source for their land either from bore wells or canals.

Table 4.47: Land type of the Rice farmers.

Category	Number	Percentage (%)	Code
Irrigated	50	100	1
Un-irrigated	0	0	2
Partially-irrigated	0	0	3

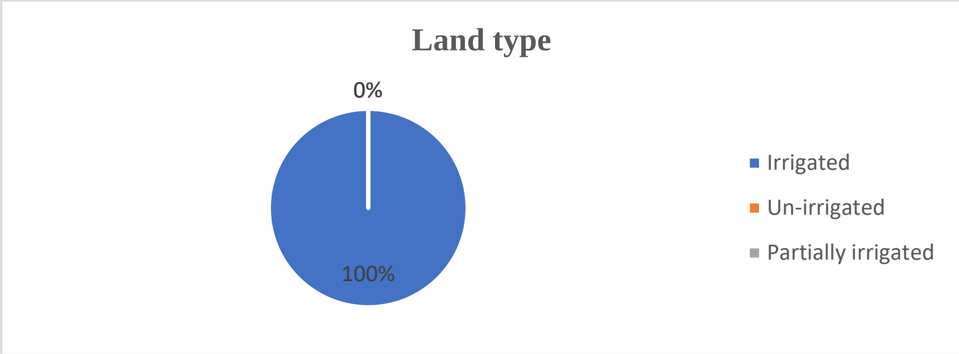


Figure 4.38: Land type distribution

4.4.16 Income

Income stands as the foremost factor that mirrors a farmer's economic condition. The financial resources at a farmer's disposal dictate not only their lifestyle but also their overall quality of life. The propensity of a farmer to embrace novel agricultural technologies and equipment, as well as their readiness to take risks with crops, often corresponds with their income level. In light of these considerations, Table 4.48 and Figure 4.39 furnish an overview of how respondents' family incomes are distributed across diverse categories.

Table 4.48: Distribution of annual income among the Rice farmers.

Category	Number	Percentage (%)	Code
Low income (up to 1 lakh)	12	24	1
Middle income (1 to 2.5 lakhs)	29	58	2
High income (more than 2.5 lakhs)	9	18	3

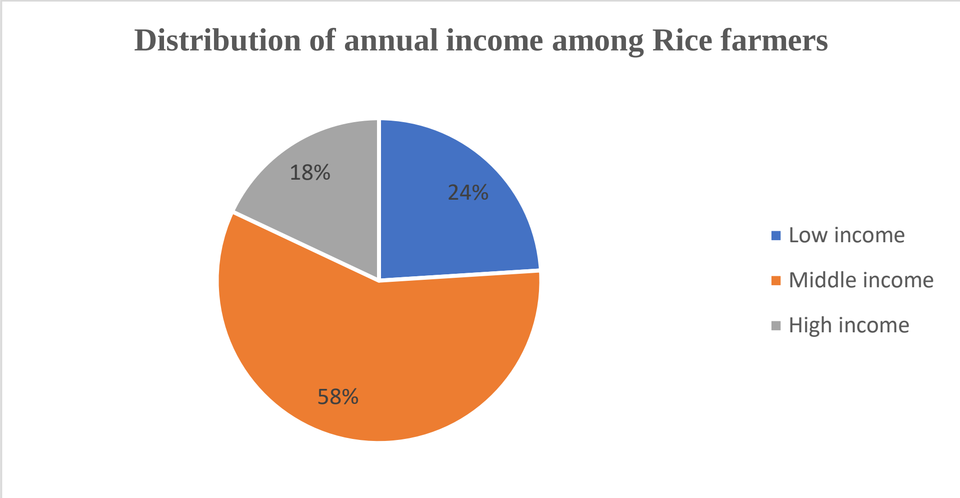


Figure 4.39: Distribution of annual income among Rice farmers

Most of the farmers in my study are middle income farmers are 58% and 24% farmers have low income. This is mainly due to most of them are having less land for cultivation. Nearly 18 percent of the farmers have high income.

CHAPTER - V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Rice, a vital crop that feeds many worldwide, plays a huge role in keeping our food supply steady, supporting people's lives, and keeping economies balanced. As the world's population keeps growing and the effects of climate change become clearer, making sure we have enough rice that's reliable has become extremely important. Being able to predict how much rice we'll get accurately could help us avoid not having enough to eat, plan how to grow crops better, and lessen the problems that come with changing weather patterns. As the West Godavari district known as one of the two districts of rice bowl of Andhra Pradesh, it is important to study about the forecasting of rice yield based on biometrical characters, trend of rice area, production, yield and performance of insurance scheme which has impact on income stability of farmers during the yield losses.

The trend analysis is carried out on the time series data related to rice cultivation in West Godavari district, Andhra Pradesh. Using graphical methods, we observed that the rice-growing area has remained relatively stable over the years, with minimal fluctuations. However, the trends in rice production and yield have shown a consistent increase over time. To assess the accuracy of these trends, we calculated the coefficient of determination (R2) for each of the graphs.

After a thorough examination of the Compound Annual Growth Rate (CAGR) figures for rice cultivation, we have discerned that the growth rates for rice area, production, and yield are all positive. However, it's important to note that the growth rates for production and yield are notably higher compared to the growth rate of rice cultivation area in West Godavari district

On the basis of crop condition, it was suggested that the rice yield is influenced by the environmental conditions and the application of nutrient. Thus, the following characters are considered to have effect on the rice yield.

1. Average plant population per m^2 (X1)
2. Average plant height in cm (X2)
3. Average number of tillers per m^2(X3)
4. Average length of panicle in cm(X4)

5. Nitrogen (N_2) in kg/ha (X5)
6. Phosphorus (P_2O_5) in kg/ha (X6)
7. Potassium (K_2O) in kg/ha (X7)
8. Number of irrigations in the crop season (X8)
9. Disease infestation in percentage (X9)
10. Average plant condition (X10)

Two administrative regions, namely Tadepalligudem and Tanuku, were chosen within the West Godavari district of Andhra Pradesh. In each of these regions, a total of 5 villages were carefully selected. Within each village, 5 farmers were chosen for the study. From the agricultural fields of these selected farmers, one specific plot was identified for examination. Consequently, a total of 50 sets of data were gathered, focusing on various biometric characteristics of rice plants, encompassing 10 factors that contribute to crop yield. These 10 characteristics, observed throughout the growth period, were treated as independent variables, while the actual rice yield was regarded as the dependent variable.

Multiple regression analyses were conducted, utilizing rice yield as the dependent variable and the ten mentioned characteristics as independent variables. To ensure model validity, approximately 10 percent of the observations were set aside for validation purposes. Five models were developed, and their performance was evaluated based on R-squared (R2), Root Mean Square Error (RMSE), Coefficient of Variation (CV), AIC and BIC statistics.

Ultimately, the best model was chosen through a thorough residual analysis, coupled with Mean Absolute Percentage Error (MAPE) assessments using 90 percent of the observations and validity testing with testing data (10 percent observations). The 3rd model emerged as the top choice due to its lower MAPE value compared to the other models, indicating that it exhibited less deviation in predicting values from the actual observed values.

Best Selected model for forecasting of rice yield in west Godavari district based on biometrical characters

$$\hat{Y} = 46.08838 + 0.80226X_1 + 0.14708X_2 - 0.36854X_3 - 0.02404X_5 + 0.02418X_7 + 1.28461X_8$$

Where,

$\hat{Y}$=Yield

X1=Average plant population per m^2

X2=Average plant height in cm

X3=Average number of tillers per m^2

X5=Nitrogen (N_2) in kg/ha

X7=Potassium (K_2O) in kg/ha

X8=Number of irrigations in the crop season

Residual analysis and the associated residual plot for the third model did not reveal any violations, as discussed in the results and discussion section. Moreover, when we computed the forecast error using 10 percent of observations that were not included in the model building process, we found that these errors fell within acceptable limits. Consequently, we anticipate that the proposed models will perform effectively. The R-square (R2) value for the proposed model stands at 0.526. This indicates that the combination of the selected characteristics explains 52.6 percent of the variation in rice yield within West Godavari district, Andhra Pradesh. Based on this observation, the 3rd model emerges as the most suitable choice for forecasting rice yield in west Godavari district. Furthermore, an analysis of variance confirms the model's significance at a 1 percent level, underscoring its reliability. Consequently, we have computed a forecasted rice yield of 94.01 quintals per hectare (q/ha) for West Godavari district with the assistance of the proposed model.

Between the Kharif and Rabi seasons from 2018 to 2022 in West Godavari district, Andhra Pradesh, there was a notable positive growth trend in several key aspects related to the Pradhan Mantri Fasal Bima Yojana (PMFBY) program. These aspects include the number of farmers enrolled, the count of insurance units covered, the insured area measured in hectares, the total sum insured, and the gross premium collected.

It's important to highlight that the Compound Annual Growth Rates (CAGRs) for the number of farmers insured, the area under coverage, the gross premium collected, and the sum insured were consistently higher during the Rabi season when compared to the Kharif season.

In particular, for the Kharif season of 2022, a total of 604,529 farmers were enrolled in the PMFBY program, covering an extensive area of 180.5 thousand hectares. Impressively, the program collected a gross premium of 105.07 crores, and the total sum insured reached a significant figure of 1,756 crores, surpassing the figures observed in all previous seasons.

From the analysis presented above, it can be deduced that the performance of the Pradhan Mantri Fasal Bima Yojana (PMFBY) in West Godavari district, Andhra Pradesh, has been commendable. This conclusion is drawn from the positive growth observed in various key metrics, including the number of farmers enrolled, the coverage of insurance units, the insured land area, the sum insured, and the gross premium collected. This positive trend was consistently evident in both the Kharif and Rabi seasons

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