"PRODUCTION DYNAMICS OF FOOD GRAINS IN BIHAR UNDER TEMPORAL FRAMEWORK"

By

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MASTER OF SCIENCE IN AGRICULTURE
(AGRICULTURAL ECONOMICS)

DEPARTMENT OF AGRICULTURAL ECONOMICS

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This is to certify that the work embodied in the thesis entitled "***PRODUCTION DYNAMICS OF FOOD GRAINS IN BIHAR UNDER TEMPORAL FRAMEWORK***" submitted by ***MS. JYOTI KUMARI*** bearing **Regd. No. M/AE/024/2020-21,** in partial fulfilment of the requirements for the award of the degree **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL ECONOMICS)** of the Post Graduate College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar is a record of the *bona fide* research work carried out by her under my supervision and guidance. 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 the 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 ***MS. JYOTI KUMARI***bearing Regd. No. M/AE/024/2020-21,a candidate for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE** with major in **AGRICULTURAL ECONOMICS** have gone through the manuscript of the thesis and agree that the thesis entitled "***PRODUCTION DYNAMICS OF FOOD GRAINS IN BIHAR UNDER TEMPORAL FRAMEWORK***" may be submitted by her in partial fulfilment of the requirements for the award of the degree.

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LIST OF ABBREVATIONS

Symbols		Abbreviations
%	:	Per cent
ha	:	Hectares
et al.	:	and others
Δ	:	change in
Kg.	:	Kilogram
GoB	:	Government of Bihar
ARIMA	:	Auto Regressive Integrated Moving Average
RMSE	:	Root Mean Square Error
MAPE	:	Mean Absolute Percentage Error
AIC	:	Akaike Information Criteria
BIC	:	Bayesian Information Criteria
ANN	:	Artificial Neural Network
ACF	:	Autocorrelation Function
PACF	:	Partial Autocorrelation Function
CV	:	Coefficient of variation
MAE	:	Mean Absolute Error
MSE	:	Mean Squared Error
SBC	:	Schwarz Bayesian Information Criteria
ARIMAX	:	Autoregressive Moving Average with Explanatory Variable
MLP	:	Multilayer Perceptron
RBF	:	Radial Basis Function
Fig.	:	Figure

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ABSTRACT

Using secondary data from 1991–1992 to 2020–2021 and a variety of statistical methodologies, the study calculated the growth rate, instability index, and decomposition analysis of area, production, and yield of foodgrains in Bihar and India. Area under foodgrains was showing negative growth rate in every decade. Production was showing increasing growth rate in first and third decade but in second decade production of foodgrain was showing negative growth rate. Yield of foodgrains was showing positive growth rate in every decade which was the main source of growth in production. Cereals were following the similar trend as of foodgrains. For pulses scenario was somewhat different. Pulse area as well as production was showing negative growth rate in every decade but its yield was showing positive growth rate in first two decade and negative growth rate in last decade. In cereals, area of rice was showing negative growth rate in all the decade but production and yield was showing positive growth rate in first and third decade and negative growth rate in second decade. Area under maize was showing negative growth rate in every decade except in second decade where it was found positive growth rate. Production of maize was showing positive growth rate in all the decades though its yield was also showing positive growth rate in first and third decade and

negative growth rate in second decade. Highest instability in area of foodgrains was observed in first decade but production and yield of foodgrains was showing highest instability in second decade. Production of food crops was showing highest instability during the overall study period. Yield effects of crops were contributing more than area effect in increasing foodgrains production. Net cropped area and gross cropped area in Bihar was following decreasing trend due to a decrease in cultivable area. Due to more intensive cultivation, the cropping intensity in Bihar has increased from 138% in2001-02 to 143% in 2018-19.From 2001–2002 to 2018–19, the yield of every crop under investigation increased. The area, production, and yield of foodgrains were predicted using the ARIMA model. The autoregressive (p) and moving average (q) parameters were identified based on significant spike in plot of (PACF) and (ACF) of various time series model. Forecasting was attempted for the years up to 2025–2026. ARIMA (2,1,1) was found the best fit model for area, production and yield of total foodgrains and cereals. This model had forecasted that area under foodgrain production would decrease in coming years but production and yield would increase. Similar pattern was observed in cereals also. For forecasting the area of pulses ARIMA (1,1,1) was found the best fit model. It was found that in the upcoming years, the area under pulses will diminish. Same ARIMA (1,1,1) was used for forecasting the production of pulses but it had revealed that pulses production would increase for a year and after that it would further decrease. For yield of pulses ARIMA (1,0,1) was found the suitable model and it had forecasted that yield of pulses would decrease in coming years. In light of the study's findings, It has been suggested that more effective production methods be used, fallow land be used for the production of pulses, short-duration varieties may be encouraged, and focused efforts from various line departments be made in order to ensure that Bihar is both food and nutritionally secure.

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CHAPTER - I

INTRODUCTION

INTRODUCTION

Agriculture forms the base and it is the primary sector of the Indian economy. The production of the agriculture sector effect the growth of economy and it helps in growth of the industrial sector because agriculture provides the raw material to the industrial sector. The share of agriculture sector in the country's GDP is declining continuously as it was 55.1 percent in 1950-51 and 19.9 percent in 2020--2021 (Source: Economic Survey, GOI, 2020-21). In spite of steady decline of its share in the GDP, it is still the major sector for the economy of the country. Performance of any economy is based on the growth rate of agricultural production among which food grain production is more significant because of two reasons. First , it gives the base for subsistence by providing important food items and second thing is that, nearly 57.8% of rural households depend on agriculture as their primary source of livelihood means that the lives and livelihoods of a large number of people depends on agriculture sector. More important thing than everything else is that it supports the largest population in the world irrespective of whether it is involved in the agricultural sector or in the non-agricultural sectors by providing food to the people.

After introduction of Green Revolution, the scenario of Indian agriculture has completely changed. Indian agriculture transformed to self sufficient from food scarce condition. This was achieved because several initiatives have been put in place by the administration and started different programs related to agriculture as well as some technological changes. After Green Revolution there was a complete change in agriculture production and productivity, and this was become possible by accepting new technologies. Area of agricultural land was increasing continuously under cultivation. Irrigation facilities were improved (with the help of assured and easy means of irrigation), chemical fertilizers were available at low cost and availability of high yield varieties of seeds in the market. Farm machineries have also reduced the duration of tillage, sowing, intercultural operations and harvesting process in agriculture.

The major crops in India has been divided into four categories viz. food grains, horticultural crops, cash crops and plantation crops. Food grains include cereals and pulses like wheat, maize, rice, pearl millet, sorghum, coarse cereals grams and peas etc. India is the world's top producer of pulses and ranks second in the production of wheat and rice. Top three foodgrains producing States of India are Uttar Pradesh (which produces around 19% of total food grains in the country), Punjab and Madhya Pradesh.

Foodgrains production and non-foodgrains production are two categories of agricultural output. In light of the problem with food security that most emerging nation, including India, face, the demand of food grains. The production of foodgrains and food security in the Indian setting become more significance as the population grows and the proportion of the population classed as poor rises. Pulses and grains are the two main ingredients of an Indian lunch. The primary foods consumed by practically the whole population are wheat and rice. The poorest of the poor are helped by coarse cereals, and pulses as the main source of protein and a necessary component of every Indian's diet. For practically the whole population, this is true. Either expanding the area under cultivation or improving agricultural productivity can enhance agricultural output. Increasing agricultural production by extensive measures was possible in the initial years of agricultural expansion. After saturation is reached in this respect, reliance on only the intensive measures can help increase the agricultural productivity. Growth in the productivity of food grains is profitable for an economy by ensuring food security, increasing the income as well as the welfare of farmers, helping in eradicating poverty and addressing hunger and malnutrition, reducing rural-urban migration, reducing the import bill and enhancing foreign earnings.

During last three decades, total food grains production had improved which increases from 173.87 million tonnes during 1991-92 to 310.74 million tonnes in 2020-21. Area under cultivation was 134.27 million hectares in 1991-92 and it decreased to 129.79 million hectares in 2020-21 but yield per hectare had increased from 1295 Kg/hectare in 1991-92 to 2394 Kg/hectare in 2020-21.Production of total cereals was 156.35 million tonnes in 1991-92 and it increase to 287.27 million tonnes in 2020-21, area under cultivation of cereals increased from 99.32 million hectare in 1991-92 to 101.01 million hectare in 2020-21 and yield of total cereals was 1574 Kg/hectare in 1991-92 and it increased to 2824 Kg/hectare in 2020-21. Production of pulses was 17.51 million tonnes during 1991-92 and it increased to 25.46 million tonnes in 2020-21. Area under farming of pulses was 34.94 million hectares in 1991-

92 and it decreased to 28.78 million hectares in 2020-21. Yield per hectare of pulses was 501 Kg/hectare in 1991-92 andin2020–21, it was raised to 885 Kg/hectare.

Production of rice increased from 74.67 million tonnes in 1991-92 to 124.36 million tonnes in 2020-21.Area under cultivation of rice was 42.64 million hectare in 1991-92 and it increased to 45.76 million hectares in 2020-21 and yield per hectare raised from 1751 Kg in 1991-92 to 2717 Kg in 2020-21. Maize production was 8.06 million tonnes in 1991-92 and it raised to 31.64 million tonnes in 2020-21.Area under cultivation of maize was 5.85 million hectare in 1991-92 and it grows to 9.89 million hectare in 2020-21 and yield per hectare of Maize was 1376Kg/hectare in 1991-92 and it has increased almost 2.5 fold to 3199 Kg/hectare in 2020-21. (Source: Directorate of Economics & Statistics, 2020-21)

The condition of agricultural growth in Bihar is somewhat different from rest of the country as it faced weather change of drought and flood simultaneously, which created a very difficult situation for agricultural development in the State. This State lies in the river plain, basin of the river Ganga. In Bihar approximately two-third of its area is arable which is mainly flat; it offers a very rich fertile land and ground water resources. This provides rich and diverse agriculture to Bihar. Rice, wheat and maize are the major cereal crops. Moong, gram, arhar, urad, lentil, khesari and pea are the main pulse crops cultivated in Bihar.

In Bihar, the net sown area consists of around 60% of the State's total land area. Compared to India's overall net crop sown area, which constitutes around 42% of its total geographic area, this is significantly higher. Because much of Bihar's plain region is ideal for agriculture, a substantial percentage of it is cultivated. However, just 6% of Bihar's total land area is currently covered by forests.

In every district of Bihar, rice is cultivated. Three different varieties of rice viz autumn rice, aghani rice and summer rice is grown in three different times of the year. The average rice production in Bihar is around 5 million tonnes every year. Some decades back, cultivation of wheat was very restricted to the western districts of Bihar. After success of green revolution, wheat was planted by farmers of Bihar on a large scale and now wheat occupies the status of major crop of the rabi season. The average annual production of wheat is about 4-4.5 million tonnes. Maize is also cultivated with an average annual production of about 1.5 million tonnes and shows a continuous positive trend in production. The leading food grain producer districts are Khagaria and Saharsa. Pulses like moong, peas, arhar and khesari are mostly cultivated in southern part of Bihar in comparison to northern Bihar.

Though enriched with good soil, adequate rainfall and good ground water availability Bihar has not utilized its full agricultural potential. Its agricultural productivity is one of the lowest in the country, which leads to rural poverty, low nutrition and migration of labours. Population of Bihar is about 124 million, it is the third most populated state in India and supports about 9% of population with only 2.9% of land mass of the country (Source: Economic Survey, GoB, 2019-20). Bihar also has the distinction of being the most densely populated state in our country (1106 persons/sq km) as against the national average of 382 persons/sq km. The State existence is among the most economically backward ones with one of the highest incidence of poverty (34%) and lowest per capita income (36% of national per capita income) in the country. However, during the last five years the growth rate of State's GDP has considerably increasing, with the state economy growing at over 10.5% per annum. (Source: Economic Survey, GoB, 2019-20).

The form of economy in Bihar has modified overtime, however, the importance of agriculture continues to be remarkable. Because it contributes 21% to GSVA (gross state value added) and gives employment to 67% of rural workforce (Bihar Economic Survey, GoB 2019-20). Agricultural households occupy approx. 51% of rural households, dominated by marginal and small scale farmers with marginal farmers (< 1 ha) occupying 91% of total farm households and owning about 57% of the operated land in Bihar. The existence of farmers with decreasing resource base would require more rigorous crop production with strong growth and stability in the sector for ensuring food security and improvement in their livelihood in Bihar. Bihar accounts for about 5% of country's total food grains production. It is third most populated State in India with 10.40 crore (as 2011 census). In food grain production it stands 7th in India**.**

Total food grain production in Bihar during 2020-21 was 15.38 Million tonnes out of which contribution of cereals were 15 million tonnes and pulses contribute 0.37 million tonnes. Production of rice was 6.74 million tonnes (5.33% of country's production) area under cultivation of rice was 3.02 million hectare. Production of maize was only 2.08 million tonnes (15% of country's production) and area under cultivation of maize is 9.89 million hectare. (Source: Directorate of Economics and Statistics, 2020-21)

As per ICMR Recommendation, the requirement of food grains per person is 135 Kg/year. But if we covert it in grain form with milling percent of 85% the requirement will be approx 158 Kg/year. According to that total requirement of food grains in Bihar is 16.43 million tonnes. But, Bihar meets up only 86.6% of its requirement from its current production level**.** Therefore, Bihar is not a self sufficient in food grains production against its requirement. With this background this study has been proposed with the following objectives;

Objectives

1. To analyze the temporal patterns of production, growth and decomposition of its components.
2. To examine the cropping intensity, yield and change in yield under changing land use dimensions.
3. To forecast the area, production and productivity of food grains using various model of time series.

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CHAPTER - II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

1. To analyze the temporal patterns of production-growth and decomposition of its components.

Hasan *et al.* (2008) examined the two important cereal crops, wheat and maize, have changed and are unstable in terms of area, productivity, and yield in Bangladesh. Utilizing several statistical methods, the analysis was built on secondary source of data from 1980–1981 to 2003–2004. They noticed a considerable rise in wheat area and production. But the yield did not rise as expected to fulfill the nation's need. During the research period, there was a notable increase in yield for maize. To meet the rising need of the nation, maize production and area both expanded. They also noticed that the growth rate of acreage, production, and productivity for wheat were slightly better than in the past, whereas these same growth rates were improving for maize. Although growth for both the crops ware erratic, maize's acreage and production exhibited particularly high erratic behaviour due to its rising inclination in recent years.

S. Kumar and D. Prashar (2012) analyzed on changing trends of foodgrains in Himachal Pradesh. The data were analysed using a straightforward percentage method as a statistical metric. The results indicated a downward pattern for area and an upward trend for food grain productivity in Himachal Pradesh (apart from barley and chickpea). Over the course of the study, trends in the output of foodgrains varied. There had been an increase in the area covered by high yielding cultivars of the three main food grains, rice, wheat, and maize. During the time of the study, the consumption of fertilizer increased. The area devoted to food grains had reduced, and it had been replaced with cash crops.

S. P. Acharya *et al.* (2012) observed growth in area, production and productivity of major crops in Karnataka. Using the compound growth function, the growth in the area, production, and productivity of various crops in Karnataka was observed. The crucial secondary data were acquired over a 26-year period, from 1982–1983 to 2007–2008. Growth rates revealed a noticeably positive growth in the area of pulses, vegetables and spices, fruits, and nuts, but a noticeably negative growth in the area under grains. The area planted with jowar, bajra, ragi, and minor millets is significantly decreasing each year. The area planted with rice had seen a little annual increase. The area planted with commercial crops and oilseeds increased negatively and minimally. Similar good growth was observed in the output of fruits, vegetables, legumes, and cereals. Oilseed and commercial crop production experienced negligible positive development. Cereals, legumes, and fruits all experienced considerable increases in crop productivity. Oilseed productivity had increased in a moderately favourable way. Commercial crop productivity showed negligible positive development, and vegetable productivity growth was negligible and negative.

Amod Sharma (2012) studied the trends in foodgrain production, area, and productivity in India's North Eastern States. This research was carried to look at the area, production, and productivity trends for foodgrains in India's north-eastern states. According to secondary source of data from 1980–1981 to 2011–2012, this study was built. The data were acquired from multiple official websites and publications. The linear, quadratic, and exponential functions were used for investigating the trends of the area, production, and yield of foodgrains in the northeastern states. The functional form that is linear was chosen to fit the trend since it had a greater R^2 value than the other two forms. In addition to these, estimates were made for the instability index, coefficient of variation, and compound growth rate. In this study, the impacts of area, productivity, and their interactions on boosting output were also assessed. The smaller coefficient of variation reveals that the growth of foodgrain crops was not problematic in the north-eastern states. The area, production, and productivity of Foodgrain crops' coefficients of variation (CV) were under 0.551 percent. The north eastern states' foodgrain crops had positive instability index for area, production, and productivity, which means there is less risk associated with farming these crops there. The expansion of the area as well as the connection between the area and yield of foodgrain crops in the states were responsible for the growth in production.

Amod Sharma (2013) analyzed the trends of area, production and productivity of food grain crops in India. The study had utilized data from different government sources and websites from 1950–1951 to 2012–2013. In that study, linear, quadratic, and exponential functions were employed to analyse the trends in the production, productivity, and area of food grains. Coefficient of variation (CV), and instability index were also determined in addition to this compound growth rate.

The study's findings indicated that the area, production, and productivity instability indicators for food grain crops were all favourable. Growing food grains was risk-free since the CV of the crops' area, production, and productivity was less than 0.322%. The study also demonstrated that the drivers of the rise in production were the area effect, the increase in yield impact, and their interactions.

Ranjit Kumar *et al.* (2014) studied production performance of maize in India with an approach to inflection point. In the country's major corn-growing States, the research has seen both expansion and instability in the production of maize. Additionally, an effort was made to predict its production under various scenarios for the short- and medium-term. According to the findings, maize yields in excess of 60% of areas were found to be less than 2 tonnes/ha. At the same time, a significant variation in maize yield was seen both between and within the States that produce maize. However, it was predicted that if the current macroeconomic situation and policies persist, the yield of maize will only increase by about 3 tonnes/ha by the year 2020. Additionally, it was predicted that demand for maize would increase more rapidly than production both domestically and internationally, which might create a very favourable potential scenario for Indian maize in the near future. Therefore, a different growth pattern than the current trend was required to meet the future expanding demand for maize on the domestic and international markets. India must set up its logistics and supply chain to accommodate the nearly doubling of the country's maize output in the coming years if it is to reach that type of inflection point.

M.G. Savitha and L.B. Kunnal (2015) analysed district wise growth performance of cereals in Karnataka. Using the compound growth rate function, they looked at the trend in growth rates of the four main grains grown in Karnataka: rice, maize, wheat, and sorghum. Five significant districts were selected for each crop for the study based on the highest area for a detailed analysis of the trend of growth rates in area, productivity, and production of grains. The necessary secondary information was acquired over a 15-year period, from 1998-1999 to 2012-2013. While the production and yield of all cereals were seen to increase annually, the area growth of all cereals indicated a significant annual decline. The area planted with wheat, maize, and paddy has shown a slight annual increase, whereas sorghum has experienced significantly negative growth over the entire state.

Ramandeep Kaur *et al.* (2015) analysed the area, production, and yield trends for significant crops in India. The purpose of this study was to inspect the patterns in the production, yield, and area of three significant Indian crops: castor, cotton, and banana. From 2000-01 to 2011-12, information on the acreage, production, and yield of these crops was gathered (12 years). Three crops, namely Banana, Cotton, and Castor, showed varying trends in terms of area (at the national (India), state (Gujarat), and district (Vadodara) levels), output (at the state (Gujarat), and yield (at the district (Vadodara) levels). At the state and national levels, cotton has an expanding trend in the area under crop, but there had been minor ups and downs at the district level. Throughout District and State levels, cotton production likewise exhibited an upward trend in yield. In terms of national level, the area planted with castor crops shown an upward trend, with deviations at district and state levels. Although the production of it varied, there was generally an increase at district and state levels. Although castor crop yield varied, an overall upward trend was evident. At all three levels, the area under the banana crop showed variances. Throughout the State level, it demonstrated annual instability, but at the District level, it showed a general decline. At the district level, its yield similarly exhibited a declining tendency.

N. Ahmad *et al.* (2017) studied growth performance and resource use efficiency of maize in Bihar based on economic perspectives. In different agro-climatic zones of Bihar, they looked at the expansion in area, production, productivity, and resource use efficiency of maize. Positive and statistically significant growth patterns in output and productivity were discovered. For both the linear and compound growth models, the diversity in area, production, and productivity were also reported to be favourable. The Data Envelopment Analysis (DEA) technique was used to analyse resource use efficiency on a zone- and state-level overall from 2008-09 to 2010-11. It was found that the technological efficiency of maize production throughout the state level was 64% for kharif maize and 71% for rabi maize. Farmers may cut expenses by 32% and 35% by choosing the best combination of inputs according to their price and quantity respectively. The allocative mean efficiencies of kharif and rabi maize were computed at 68% and 65%, respectively. Although zone-II farmers in Bihar were well renowned for their extensive rabi maize production, there is still a technical inefficiency of 24% and an allocative efficiency of 9%. Cost efficiency (CE) values placed an emphasis on lowering costs by 30% while maintaining output levels. Compared to zone I and zone II, zone III farmers were more technically proficient. Technical efficiency for kharif and rabi maize was discovered at the state level to be 88% and 87%, respectively, however Allocative efficiency was relatively low as compared to other zones i.e. 52% for rabi maize.

N. Eswaran and R. Revathi (2017) studied growth and performance of foodgrains in India with special reference to maize. Following this analysis, the author came to the conclusion that includes growing tendency in maize production, consumption, and export direction across the study period of 10 years, from 2004–2005 to 2013–2014. However, it had not experienced particularly strong increase in export volume, minimum support prices, or production. Data from a secondary source was used. It was discovered that maize was a highly important source of food for both humans and various types of cattle. Therefore, the government has to take the necessary actions to increase maize production in India in order to introduce value-added goods into various economic sectors.

Ruchi Malik (2017) studied growth, instability and decomposition analysis of food grains in India. Because the majority of people depend on agriculture for their livelihood, it had noted that the Indian economy is an agriculture-based economy that is still evolving. She used time series data for her research, spanning from the years 2001–2002 to 2015–16, focusing on the area, production, and yield of food grains in India. She made use of statistical information gathered from the RBI Handbook. The data pertaining to trends in area, production, and yield have been examined using straight forward statistical techniques. She also calculated the relative contributions of area and productivity to the expansion of the production of food grains. According to the study, both the area that was planted with food grains and crop yield had grown over time, which contributed to the increase in food grain output. However, since an increase in area cannot be sustained over the long term, it is important to adopt production techniques that will further increase the productivity of food grains.

Amalendu Kumar and K.M. Singh (2017) performed a study on maize production in Samastipur (Bihar). The core data used for the study came from 120 different home groups in six villages within two blocks in the Samastipur district. The key finding of the investigation was that farmers in the study area only grew maize on a big scale during the rabi season. Flooding and water logging were the main issues throughout the kharif season from August to January practically every year. Farmers were observed planting maize in general local varieties since it required less input due to the increased risk in the kharif and summer seasons. Farmers were told to avoid using hybrid maize in risky situations and stick to open-pollinated species (OPVs). The problems limiting the rise in productivity and production of maize in the areas include a shortage of good quality maize seed varieties, particularly under stress situations like droughts and floods, storage facilities, poor marketing facilities, etc. The main issue with use during the rabi season was that the hybrid variety of maize was widely planted for commercial purposes instead of being used for human sustenance. According to the survey, farmers kept their cultivated area unplanted throughout the kharif and summer seasons because of the higher risk involved. This study made the case for the necessity for additional development and research to boost production and productivity, particularly under the study area's abiotic stress circumstances with the development of acceptable hybrid maize varieties for human consumption. This was essential for the poor families of the region who were struggling financially to have access to food and nourishment.

Ranjeet *et al.* (2018) studied growth in Area, Yield and Production of Major Crops in Malwa Plateau Agro Climatic Zone of Madhya Pradesh. To determine the trajectory of a specific variable through time and to inform policy decisions, the study of growth is typically utilized in economic research. Most of the major Kharif and Rabi crops come from the Madhya Pradesh state's Malwa Agro climatic Zone. Using the compound growth function, it was possible to predict the growth rates in area, yield, and production of various Kharif (oilseed: soybean), Rabi (cereal crop: wheat, and pulse crop: chick pea) and Kharif (oilseed: soybean, cereals: maize, sorghum, and pulse crop: pigeon pea) crops in the Malwa Agro climatic Zone and Madhya Pradesh. The significant secondary data were gathered over a 15-year period, from 1999-2000 to 2013-2014. During the 15-year study period, the growth rate of crops was examined to determine how each affected the other in the season. The stability of the crops in terms of area, productivity, and yield was determined by calculating the coefficient of variation (CV) for the Malwa plateau agro climatic zone and MP state. On the basis of the study's findings, appropriate actions have also been employed.

Abhay Kumar *et al.* (2018) performed a temporal analysis on food grain production performance in Bihar. This study shows the increase in food grain output over the preceding three decades in Bihar's various agro climatic zones (1984 to 2014). Although there was an increase in food grain production over the time period in question, wheat and maize showed stable growth. All of the agro climatic zones had decreased pulse output, especially between 1984 and 1994. Due to lower food grain output during the base year, agro climatic Zone II had an advantage over the other three agro climatic Zones in terms of increasing food grain production (1984). Production of foodgrains raised between 2004 and 2014. All food grains were produced with a high level of instability, although rice had the highest level and wheat had the lowest. Repeated floods in north Bihar and drought in south Bihar were the main causes of the unpredictability in food crop production. Additionally, there was a significant correlation between growth and instability across all zones. The improved farmers' access to new technology and input allowed for a sustainable increase in foodgrain production. The three essential inputs—HYV seeds, fertilizer, and irrigation—all contributed significantly to the rise in Bihar's food grain production.

Singh and Shekhawat (2020) analysed productivity of food grain in India. The goal of this study was to examine trends in the area, production, and productivity of the main food grains grown in India from 1990–1991 to 2019–20. The behaviour of the data was studied using statistical techniques like trend analysis, analysis of variance (ANOVA), and line graphs. Major foodgrain crops' variability in area, production, and productivity were measured using the coefficient of variation (CV). The consequence of this study revealed rising patterns in output and productivity over the allotted time. There was a tendency towards less land being planted in rice. Major cereals like wheat, rice, and maize exhibited constant improvement, according to the production scenario of food grains, but the production of pulses was inconsistent. In addition to rice and wheat, maize occupies a significant position as a coarse cereal. It had been determined that India's overall food grain growth trend was positive and considerable.

Priyanka Kumari *et al.* (2021) performed a Study on Growth and Instability in Pulses Production in Bihar: A Decomposition Analysis. For their management and policy-making to assure the nutritional security of the continuously expanding population, an assessment of changes in the area, production, and productivity of the pulse crops was thought to be useful. The findings showed that, when compared to other pulses, lentils had greater annual growth rates for production and productivity. Green gram has lower stability indices than other pulse crops planted in the state: 7.04, 10.84, and 9.34 for its area, production, and productivity respectively. The decomposition study revealed that red gram had a negative influence on yield. The cultivation of it and its low productivity by marginal and small farmers in rainfed areas with inadequate crop management techniques may be the anticipated cause of the undesirable yield effect. The findings showed that the location had the biggest impact on production and that productivity had little bearing on the state. The study identifies the importance for technical interventions to improve the area planted with pulse crops and their productivity.

K. M. Singh *et al.* (2021) analysed the growth performance and profitability of rice production in India. This study calculated the growth pattern and instability in the acreage, output, and yield of rice in the major rice-growing states from 2001–2002 to 2018–19. The study found that, while it varied across states, the country's compound growth rate of rice-growing land was essentially constant over the previous two decades. However, positive and exceptional growth rates in output and yield were seen. More so than area, there is instability in rice output and yield. Although the adoption and development of new farming methods had enhanced rice production, higher production volatility over the research period revealed the impact of irregular monsoons on production. In many States, rice farming was not profitable, and farmers didn't receive any payments until the farm business income was computed. By prohibiting the purchase of rice below MSP or by implementing suitable measures to prevent the sale of farm products, particularly rice, in distress, the government may better protect the farmers.

2. To examine the cropping intensity, yield and change in yield under changing land use dimensions.

D. K. Sinha *et al.* (2016) analysed shrinking net sown area: an analysis of changing land use pattern in Bihar. For every activity that is increasing, land is a very significant natural resource. Bihar made up only 2.86% of India's total land area while contributing around 8.63% of the nation's total population. Three agro climatic zones—Zone I, Zone II, and Zone III—were assigned to the state of Bihar. According to the report, the net sown area has decreased on both a zonal and a state level.

Comparing zone III of the state's agro climatic zone to zones I and II, the net sown area decreased considerably. Because Zone III located in the middle of the State, urbanization happened more quickly. Additionally, the region's declining water level, fragmented land ownership, and growing population all contributed to changes in the land use pattern. Farmers left their land fallow in Zones I and II because of the terrible flood threat that could have destroyed their crops. Another factor contributing to the decline in net sown area in the state was the favourable changes in growth rate and land under groves and trees over the past ten years. To feed the expanding population, it was quite concerning that the net sown area was shrinking. Encourage farmers to produce more while taking into account the changing climatic circumstances and to protect future generations, stop wasting natural resources.

Neha Rani (2020) did comparative study of changing land use pattern in India after independence. This research attempted to analyse the changes in India's land usage patterns between 1950–1951 and 1999–2000. In this investigation, secondary data were utilized. Only 92.9% of India's total area (3287263 square kilometers) data were available. Which has 46.04% of the area dedicated to agriculture. The investigation revealed that all forms of land use had undergone slight changes. The forest area had grown from 14.2% to 22.52% throughout the research period. Additionally, the net area sown was raised from 41.77% to 46.07%.

3. To forecast the Area, production and productivity of Food grains using various model of time series.

Purna Chandra Padhan (2012) used ARIMA model for forecasting agricultural productivity in India. Agriculture productivity in India is greatly influenced by a number of variables, including timely application of the right fertilizer and pesticides, abundant rainfall, an ideal climate, and the environment. Therefore, predicting agricultural production is a tedious but important task because a substantial portion of India's population relies on agriculture for a living. A wide variety of single-variate and multiple-variate time series forecasting methods can be applied. The ARIMA model was used in this research to predict the annual productivity of a particular agricultural commodity. Depending on the availability of the necessary data, 34 different products have been selected for critical investigation. Authors forecasted the values for an additional five years starting in 2011 using annual data from 1950 to 2010. AIC minimum, lowest MAPE values and several other model selection criteria were used to confirm the model's validity. Tea offers the lowest MAPE values among the chosen crops, whilst cardamom offers the lowest AIC values.

Lasker Ershad Ali *et al.* (2013) used the ARIMA model to predict foodgrain production and demand in Bangladesh. In order to forecast correct values, they investigated a variety of differentiating techniques and time series models, such as the ARIMA model. Then they put in this model to project future grain production in various years. They used the difference between the estimated or expected number of food grains for a given year and the actual amount of those grains to assess accuracy. The outcome of the experiment demonstrated that the ARIMA model correctly predicted values in a variety of orders for various agricultural products. Since all of the predicted values were closer to the actual numbers. Although Bangladesh Bureau of Statistics had also predicted a good number, their approach produced a more accurate forecasting result.

K. Naveena *et al.* (2014) used a suitable time series model to forecast India's coconut production. The goal of this study was to identify a viable model for predicting the production of coconuts in India. Data from 61 years of time series, from 1951 to 2012, were analysed. Based on the lowest RMSE values, the most successful model has been selected. It has been noted that the ARIMA (1, 1, 1) model was discovered to be a suitable model for production forecasting. According to forecasts, there would be 1200 million coconuts, 8.51% more than now coconuts produced in 2020. Increased good management practices, coconut-growing land, and rising customer demand might be the reason.

Rahul Tripathi *et al.* (2014) forecasted productivity and production of Rice in Odisha, India, using ARIMA Model. Using univariate ARIMA models, the study was created from available data from 1950–1951 to 2008–2009, and it was then compared with data forecast for all of India. On the basis of notable spikes in the plots of the PACF and ACF of the various time series, the autoregressive and moving average parameters were chosen. While ARIMA (1, 1, 1) was the best model for estimating rice yield and production in Odisha, ARIMA (2, 1, 0) was determined to be adequate for all of India. Predictions for the upcoming three years—2007–2008, 2008–2009, and 2009–2010—were made using the best fitting ARIMA models based on the minimal value of the selection criterion, i.e., AIC and BIC. According to the data, rice productivity and production increased across the board for both Odisha and India, though Odisha is increasing at a slower rate than the national average.

Ramesh Dasyam *et al.* (2015) forecasted wheat production in India using time series model for trend analysis. In order to forecast wheat production in India, this study used each year's time series data from 1961 to 2013. Finding the best econometric model to analyse the trend of the nation's wheat output exponential smoothing, parametric regression, and auto regressive integrated moving average (ARIMA) models were applied and evaluated. Based on the performance of several goodness of fit criteria viz. Mean Absolute Error (MAE), MAPE, Mean Squared Error (MSE), RMSE, BIC, AIC, and R-squared values the best fitted model was selected. The Shapiro-Wilk test and the Run-test were both used to assess the assumptions of "Normality" and "Independence" of error terms. In this study, ARIMA (1,1,0) was discovered to be the most suitable model for predicting India's wheat production. By applying this technique, a projected value of 100.271 million tonnes (MT) by 2017–18 was achieved.

P. Mishra *et al.* (2015) enquired into instability and forecasted foodgrain production in India. The findings indicated that anticipating the behaviour of major food crops' output was crucial for preserving food and nutritional security. The key food crops' historical and projected production scenarios should be known to the planners. They had made an effort to analyse the performance of overall food grain production in India's largest States at that time (1950-2009). In terms of area, production, and yield of all food grains, they saw stability in the production behaviour. The study also demonstrated that the ARIMA model was used to estimate the area and production of all foodgrains in India. They identified a number of elements, including the availability of inputs to develop policies on implements and meteorological conditions, that contribute to the success of agriculture. The study used the production factors as auxiliary variables in the ARIMA model to improve forecast accuracy. The study discovered that when different components were added to the model, large estimated figures were closer to the observed figures. According to projections made using the best-fitting ARIMA models, Uttar Pradesh will be the most productive State in India in 2020 with a production of 49,455 thousand tonnes, a surface area of 19,982 thousand hectares, and a productivity of 2,718 kg/ha.

A Dash *et al.* (2017) estimated foodgrain production in Odisha by using the ARIMA model. By examining the state's production status of food grains, they looked into the state's agricultural scenario. Food grains occupy a large share of the overall planted land in Odisha during the kharif and rabi seasons. Cereals make up the majority of food grain during the kharif season, whereas pulses make up the majority during the rabi season. In this work, a time series modelling approach (the Box-Jenkins ARIMA model) was used to forecast the output of food grains in Odisha. The optimal ARIMA model was determined to have an order of 2,1,0 for kharif food grain production and 1,1,0 for rabi food grain production. The data that were kept back and not used for model construction were used to validate the chosen best fit models. Additionally, using the best fit model, efforts were made to anticipate future food grain output in the kharif and rabi seasons for a duration of up to three years as accurately as feasible. According to the results of the forecast, food grain output would increase from 2014–15 to 2016–17, in both the kharif and rabi seasons.

M. Hemavathi *et al.* (2017) forecasted area and production of food grain in India using ARIMA model. The production and area of food grains in India from 1950–1951 to 2014–2015 were studied using time series methods. The data were used to generate the auto ACF and PACF. The appropriate ARIMA Box-Jenkins model was employed. The model's effectiveness was evaluated using conventional statistical methods. Area and output in India were predicted using the ARIMA (1, 1, 0) and ARIMA (0, 1, 1) models for the four preceding years. According to the outcome, the area was expected to reach approximately 124.78 million hectares in 2019, with lower and higher limits of 115.29 and 134.27 million hectares, respectively. The model also indicated that, with a lower and upper limit of 247.44 and 294.73 million tonnes, respectively, the production of food grains was predicted to be around 271.09 million tonnes in 2019.

M. Hemavathi and K. Prabakaran (2018) In Thanjavur District of Tamil Nadu, India, the ARIMA model was used to anticipate the area, production, and productivity of rice as well as the status of its growth. The goal of this study was to forecast the acreage, production, and productivity of rice in Thanjavur, also referred to as the "Rice Bowl of Tamil Nadu." Time series analysis was used to look at data for the years 1990–1991 to 2014–2015. The data were used to generate the ACF and PACF. It was done using the appropriate Box- Jenkins ARIMA model. The model's effectiveness was evaluated using conventional statistical methods. For predicting area, Production and productivity ARIMA (0, 1, 2), (0, 1, 1), and (0, 1, 1) models were employed respectively to forecast five leading years. The results indicate that the predicted area for the year 2020 will be approximately 158.15 thousand hectares, with lower and upper limits of 122.80 and 200.85 thousand hectares, respectively. The predicted production for the same year will be approximately 637.05 thousand tonnes, with lower and upper limits of 216.47 and 1057.63 thousand tonnes, respectively. An exponential function (Y = ABt) that was fitted was used to examine the growth pattern. The findings demonstrated that rice's compound growth rate was negative and not statistically significant for area or production and productivity in the research period.

P. K. Sharma *et al.* (2018) utilizes the ARIMA Model, to predict maize production in India. They looked at how forecasting was a key technique for estimating the future acreage, production and yield, of any crop. The ARIMA is one of the strategies that were available for predicting future production. On the basis of an assessment of an appropriate ARIMA model, the study was conducted to anticipate maize output for the years 2018 to 2022. When several series' ACF and PACF were analysed, it became clear that ARIMA was the model that was best suited for forecasting based on diagnostics like ACF, PACF, AIC, SBC, and others. According to the fitted ARIMA model, maize production would rise by 13.76% over the subsequent five years, from 2017 to 2022.

Bhola Nath *et al.* (2019) used an ARIMA modelling approach to predict wheat production in India. India's wheat production was forecast using the Box-Jenkins ARIMA model. There had been a strategic application of time series model. The ARIMA (1,1,0) model was the top ARIMA model discovered for this investigation. By fitting the ARIMA (1,1,0) model in time series data, they attempted to anticipate the incoming wheat production as accurately as possible for a time frame of up to 10 years. The predicted outcomes had shown that the annual wheat production will increase in 2026–2027. With an average growth rate of about 4% each year, wheat production will continue to increase.

J. J. S. Inbaraj and A. Selvaraj (2019) studied area, production and yield of food grains in India based on time series approach. By using the time series method, information regarding the acreage, production, and yield of food grains from 1962–1963 to 2018–19 was analysed. One such technique that can be used with time series data and the Box-Jenkins approach is ARIMA. This approach is appropriate and widely used to predict the performance of food grains in India. To determine the model's suitability, predictive tests were run. This study will urge the government to implement the essential policy changes to maintain and stabilize the erratic performance of food grains in India as well as to take the necessary actions to improve its general performance.

S. Dharmaraja et al (2020) forecasted crop yield in India. In order to accurately estimate agricultural yield, this study provides both time-series and linear regression models. Data on Bajra yield in the Alwar district of Rajasthan was specifically taken into account for the fitting of the various forecasting models. Auxiliary variables were also chosen based on an understanding of crop growth stages, which had mediated the superiority of the time-series model. According to the study, ARIMAX is the most accurate forecasting model for estimating the Alwar kharif Bajra yield. MAE, RMAE, RMSPE, and inference from the RMSE ratio all point to the ARIMAX model being suitable for out-of-sample forecasting. However, it is vital to verify the residuals of the fitted model's assumptions before moving on to the next stage. The ARIMAX model was still being used to predict for 2017. In the Rajasthan district of Alwar, the expected bajra yield during the year 2017 was 2,152 kg/ha.

Senthamarai Kannan. K and K. M. Karuppasamy (2020) forecasted agricultural production using ARIMA model. In time series analysis, one of the most often used forecasting models is ARIMA. The Ministry of Agriculture & Farmers Welfare, Government of India, provided the necessary information. The projection for rice production from south India was made using the ARIMA (Box-Jenkins) model. For Andhra Pradesh, Karnataka, Kerala and Tamil Nadu, the fitted ARIMA model, ARIMA(0,1,1), ARIMA(0,1,1), ARIMA(0,1,2), and ARIMA (0,1,1). Review the various Parameter Estimation Measures, including BIC, RMSE, MAPE, MAE, MaxAPE, and MaxAE. The development and creation of a time series model for crop production with state-by-state comparisons was the major goal of this research project.

Monika Devi *et al.* (2021) Haryana's wheat production was predicted using a hybrid time series model. This study looked at the sustainability and instability for production of wheat in Haryana. The sources of the data were different editions of the Haryana Statistical Abstract for the study period of 1980–1981 to 2018–19. The experiment found that a growing trend pattern was seen in the area, production, and yield of wheat in Haryana. ANN methodology and the Box-Jenkins ARIMA model were utilized to build and assess the forecasting behaviour. Regarding the area, output, and yield of wheat, growth rates were seen as being positive in every sub period. The first sub-period, 1980-1989, saw the biggest growth in production and yield, but the second sub-period, 1990-1999, saw the highest growth in area. These results will be useful to policymakers and provide them with insights into numerous main crop production scenarios, which is essential for predicting the production behaviors of major crops for the security of food and nutrition.

K. K. Paidipati *et al.* (2021) predicted rice cultivation in India. In this study, the researchers attempted to forecast the yield of rice using support vector regression (SVR) models with different kernels (radial, polynomial, and linear basis function) for India as a whole and the top five rice-producing states by taking influence parameters, like the area under cultivation and production, into account as independent variables for the years 1962–2018. The best-fit models were chosen on the basis of hyper parameter optimization and cross-validation of various kernel parameters. For the training and testing datasets, the MAE and root-mean-square error (RMSE) were determined. According to the results, SVR with different kernels fitted to both India as a whole and the key rice-producing States would investigate nonlinear patterns to comprehend the precise circumstances of yield prediction. With the right resources, farmers, the federal government, and state governments will be able to anticipate rice harvest in the future.

Veluchamy Kasthuri and Subbiah Selvakumar (2021) forecasted foodgrains production using ARIMA model and neural network. Three models—ARIMA, MLP, and RBF—were employed in this study to anticipate the output of food grains in India. Bar charts were used to compare mean absolute error and mean percentage error. When compared to the MLP and RBF, the mean percentage error (MPE) and mean absolute error (MAE) for ARIMA models were the lowest. MLP and RBF were outperformed by the ARIMA model. When examining the autocorrelation and PACFs for grains, several models were taken into account. The model which was suited and forecasted data the best was the ARIMA one. With a BIC of 5.463, the model ARIMA (0,1,1) was determined to be the best fit for the food grains. When the anticipated values were seen, there was an upward trend from 2019 to 2023. The foodgrains production had raised from 301 to 324.66 thousand tonnes.

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CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODOLOGY

This chapter describes the details of various statistical methods, techniques and tests involved in estimation of parameters of the different equations and models along with the data which is used in the study. To begin with, lets detail the sources and nature of data. The study's calculations and analyses were entirely based on secondary data. Data on area, production and yield (productivity) for Bihar and India from year 1991-92 to 2020-21 was taken from Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. Units of these entities are area is in thousand-hectare, production in thousand tones and yield in kg per hectare. Secondary data on land used statistics of Bihar from period 1991 to 2018 was also taken from same source and used as panel dataset including time variant variables viz. cropping intensity, forest area, net crop sown area, total cropped area. The following sections provide a description of the study's methodology.

3.1 Growth Rate

The growth rate was calculated using the method that was used by several writers, Mohamed Elamin Abd Ellatif Mahir *et al.* (2010), J. S. Sonnad *et al.* (2011), Abhey Singh Godara *et al.* (2013), Edwin Kenamu *et al.* (2014) and many others and the steps followed are presented below. The compound growth rates were estimated using time as the independent variable and area, production, and productivity of the crops as the dependent variables.

$$Y = A\,(1 + r)^{t}$$

Where,

Y denotes dependent variables like area, production and productivity in the year ‘t’ for which growth rate is estimated.

A is constant

r stands for the annual increase rate.

t = Time element which takes the value of 1, 2, 3………. n

After transforming the model into a linear form by taking logarithms to base ‘e’,

$\ln Y = \ln A + t \ln (1 + r)$

Let, $\ln A = a$

$\ln (1+r) = b$

So, ln Y = a + bt

(1 + r) = Anti ln of b

r = (Anti ln of b)-1

The semi log function can be fitted using the Ordinary Least Squares (OLS) Technique since its parameters are linear (Y and t have a linear relationship). The following formula is used to calculate the compound growth rate (r), which is typically represented as a percentage.

r = [(Anti ln of b)-1] * 100

In log form b has been calculated by the following formula:

$$\ln b = \frac{\sum t \ln Y - (\sum t \sum \ln Y)N}{\sum t^2 - (\sum t)^2/N}$$

This equation presumes that agriculture's output in a given year would alter depending on its output in the year before. The student 't' test statistic was used to determine the growth rate's significance.

t = [r / S.E.(r)] with (n-2) df

Where,

S.E. (r) = 100 b X S.E. (log b)/ log10e

r = the compound growth rate

n = number of years

SE. (r) = standard error

df = degrees of freedom

t = r / S.E. (r) follows student 't' distribution with n-2 degrees of freedom.

According to log base rule, $\ln_e 10$ is worked out to be 2.3025 which follows 't' distribution with (n-2) degree of freedom, n is number of years considered under study.

3.2 Estimation of instability index

In India's agricultural economics literature, the expansion and instability of agriculture continue to be hotly debated topics. Although there is a clear need for increased agricultural development or production, the increase in production instability is seen negatively for a number of reasons.It increases the risk associated with agricultural output, has an impact on farmers' income, and influences their decisions to adopt high-paying technologies and invest in farming. Production instability has an impact on customers' purchasing power and price stability, and it makes low-income households more susceptible to market forces. Food management and macroeconomic stability depend on agricultural and food production stability. Estimates of instability are made for area, output, and yield.

Instability is the deviation from current. Instability index will be computed by applying measure of variability suggested by Cuddy- Della Valle Index (Cuddy and Valle 1978).

$$\text{Instability Index} = \text{CV} * \sqrt{1 - \text{Adj. R}^2}$$

$$CV = \frac{\text{Standard deviation of the variable}}{\text{Mean of the variable}} X\ 100$$

If the estimated coefficient of regression equation is not significant, then the CV itself is taken as instability index.

Where, CV is coefficient of variation & R2 is a time series trend regression's coefficient of determination that has been adjusted for the degree of freedom.

3.3 Decomposition of Growth Components

The technique of decomposition has been used to measure the relative contributions of area and yield towards the total production change with respect to different crops. Numerous researchers have utilized this model to research crop growth performance in the literature. The change in the production of crop between any time periods can be expressed as

Change in production = Area effect + Yield effect + Interaction effect

$\Delta P = A_0\Delta Y + Y_0\Delta A + \Delta A\Delta Y$

Where,

$\Delta P = A_tY_t - A_0Y_0$

$\Delta A = A_t - A_0$

$\Delta Y = Y_t - Y_0$

A_t = Area in current year

A_0 = Area in base year

Y_t= Yield in current year

Y_0= Yield in base year

Thus, the total change in production is attributed due to area and yield that can be decomposed into three effects viz; area, yield and interaction effects.

3.4 Autoregressive moving average (ARMA) Models

An ARMA (*p, q*) model is a combination of AR(*p*) and MA(*q*) models and is suitable for univariate time series modeling. In an AR(*p*) model the future value of a variable is assumed to be a linear combination of *p* past observations and a random error together with a constant term. Mathematically the AR(*p*) model can be expressed as:

$$y_t = c + \sum_{i=1}^{p} \varphi_i y_{it} + \varepsilon_t = c + \varphi_1 y_1 + \varphi_2 y_2 + \cdots + \varphi_p y_{t-p} + \varepsilon_t$$

Here y_t and ε_t are respectively the actual value and random error (or random shock) at time period *t*, $\varphi_i (i= 1, 2,...,p)$ are model parameters and *c* is a constant. The order of the model is represented by the integer constant p. But often the constant term is deleted for simplicity. The Yule-Walker equations are typically used to estimate the parameters of an AR process using the provided time series. An MA(q) model utilizes past errors as the explanatory variables, just as an AR(p) model regresses on the series' historical values.

$$y_t = \mu + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t = \mu + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t$$

Here μ is the mean of the series, θ_j(j =1, 2,...,*q*)are the model parameters and *q* is the order of the model. The unpredictable shocks are thought to be a white noise process, which is a series of independently distributed random variables (i.i.d.) with a constant variance σ^2 and a zero mean. The normal distribution is typically believed to be followed by the random shocks. In this way, a moving average model is theoretically a linear regression of the most recent time series observation against the random shocks of one or more earlier observations. The random error terms in the MA model cannot be predicted, making it more difficult to fit to a time series than an AR model. A general and helpful class of time series models known as the ARMA models may be created by effectively combining the properties of the autoregressive

(AR) and moving average (MA) models. An ARMA(p, q) model is described mathematically as:

$$y_t = C + \mathcal{E}_t + \sum_{i=1}^{p} \varphi_i Y_{t-i} + \sum_{j=1}^{q} \varphi_j \mathcal{E}_{t-j}$$

The p autoregressive and q moving average terms are referred to as q in the model's order of p. The lag operator and notation are typically used to edit ARMA models. The lag or backshift operator is defined as Ly_t = y_{t-1}. Polynomials of lag operator or lag polynomials are used to represent ARMA models as follows:

AR(p) model: $\mathcal{E}_t = \varphi(L)y_t$

MA(q) model: $y_t = \theta(L)\mathcal{E}_t$

ARMA(p, q) model: $\varphi(L)y_t = \theta(L)\mathcal{E}_t$

Here $\varphi(L) = 1 - \sum_{i=1}^{p} \varphi_i L_i and \theta(L) = 1 + \sum_{j=1}^{q} \theta_j L_j$

It is demonstrated in that Invertibility, or the ability to always be expressed in terms of an MA(∞) process, is a key characteristic of the AR(p) process. The roots of the equation (L) = 0 must all be outside the unit circle for an MA(q) process to be invertible. The Invertibility Condition for an MA process is what this circumstance is called.

3.5 Stationarity analysis (unit root test)

To test for a unit root using the ADF test, one estimates the following model

$$\Delta y_t = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{s-1}^{m} \beta_i \Delta y_{t-1} + \varepsilon_t$$

This is a regression of first-differenced series (Δy_t) on a constant term (α_0), a linear trend ($\alpha_2 t$), lagged levels (γy_{t-1}) and augmented with lagged differences ($\sum_{s-1}^{m} \beta_i \Delta y_{t-1}$) to capture the whole dynamic character of the procedure and fix autocorrelation of the residuals.

3.6 Autocorrelation and PACFs (ACF and PACF)

The ACF and PACF analyses must be performed in order to choose the best model for a given time series of data. These statistical measurements show the relationships between the data in a time series. Plotting the ACF and PACF against successive time lags is frequently helpful for modelling and forecasting purposes. The placement of AR and MA phrases can be determined using these graphs. Below we give their mathematical definitions:

For a time series $\{x(t), t = 0,1,2,..\}$ the Auto covariance and at lag *k* is defined as:

$$\gamma_k = \mathrm{Cov}(x_{t,} x_{t+k}) = E[(x_t - \mu)(x_{t+k} - \mu)]$$

The autocorrelation coefficient and at lag *k* is defined as:

$$\rho_k = \frac{\gamma_k}{\gamma_0}$$

Here μ is the mean of the time series, i.e.$\mu = E[x_t]$. The auto-covariance at lag zero i.e. γ_0 the variance of the time series. The autocorrelation coefficient k is dimensionless and independent of the scale of measurement, as is evident from the definition. Also, clearly $-1 \leq \rho_k \leq 1$. Statisticians Box and Jenkins termed γ_k as the theoretical Auto covariance Function (ACVF) and ρ_k as the theoretical ACF (ACF). Another measure, known as the PACF (PACF)is used to measure the correlation between an observation *k* period ago and the current observation, after controlling for observations at intermediate lags (i.e. at lags <*k*). At lag 1, PACF(1) is same as ACF(1). The detailed formulae for calculating PACF are given below. Since the stochastic process that governs a time series is typically unknown, it is impossible to calculate the ACF and PACF values, either in reality or in theory. Instead, these values should be calculated using the training data, or the current known time series. Sample ACF and Sample PACF are terms used to refer to the estimated ACF and PACF values from the training data. The following sample estimate is the best suitable for the ACVF at lag k:

$$c_k = \frac{1}{n}\sum_{t=1}^{n-k}(x_t - \mu)(x_{t+k} - \mu)$$

Then the estimate for the sample ACF at lag *k* is given by

$$r_k = \frac{c_k}{c_0}$$

Here $\{x(t), t = 0,1,2,3 \ldots\}$ is the training series of size *n* with mean μ.

The sample ACF plot can be used to choose the right model to match a time series of length N, as stated by Box and Jenkins. Since the ACF is symmetric around lag zero, only the sample ACF for positive lags up to a maximum lag of about N/4 must be plotted. Finding the maximum order of an AR process is made easier with the help of the sample PACF plot.

3.7 Autoregressive integrated moving average (ARIMA) Model

The ARMA models previously discussed are only applicable to stationary time series data. Many time series, including those that are socioeconomic and business-related, exhibit non-stationary behaviour in practice, nevertheless. Time series are non-stationary in their nature because they contain trend and seasonal characteristics. In light of this, ARMA models are insufficient from an application perspective to accurately characterize non-stationary time series, which are commonly encountered in exercise. In order to account for non-stationarity, the ARIMA model, which is a generalization of an ARMA model, is suggested. A non-stationary time series is rendered stationary in ARIMA models by applying finite differencing to the data points. The mathematical formulation of the ARIMA (p,d,q) model using lag polynomials is given below:

$$\varphi(L)(1-L)^d y_t = \theta(L)\varepsilon_t i.e., (1-\sum_{i=1}^{p}\varphi_i L^i)(1-L)^d y_t = (1+\sum_{j=1}^{q}\theta_j L^j)\varepsilon_t$$

Here, p, d, and q are integers larger than or equal to zero and denote, respectively, the order of the autoregressive, integrated, and moving average components of the model respectively. The integer d controls the level of differencing. Generally, d=1 is enough in most cases. When d=0, then it reduces to an ARMA (p,q) model. An ARIMA (p,0,0) is nothing but the AR(p) model and ARIMA(0,0,q) is the MA(q) model. ARIMA(0,1,0), i.e.$y_t = y_{t-1} + \varepsilon_t$ is a special one and known as the *Random Walk* model. For non-stationary data, such as economic and stock price series, it is frequently employed.

Autoregressive parameter is indicated by p.

If p =0 means that there is no Autocorrelation is the series.

If p=1 means the series auto-correlation is till one lag.

In ARIMA time series analysis, integrated is denoted by d. If d=0 means the series is stationary than there will be no need to take differentiation and If d=1 or 2 means the series is not stationary and to make it stationary than there will be need to take first and second order differentiation. Generally, more than two times of differentiation is not authentic.

In ARIMA model MA means moving the average, it is denoted by q. In ARIMA, If q=1 means that is an error term and there will be autocorrelation with one lag.

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CHAPTER - IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

To estimate the growth performance, instability index and decomposition analysis of area, production and yield of food grains in Bihar and India during the period 1991-92 to 2020-21, time series data on area, production and productivity was analyzed. The whole period was divided into three decades to understand the decadal performance. The periods 1991-92 to 2000-01, 2001-02 to 2010-11 and 2011-12 to 2020-21 have been referred to as period 1, period 2 and period 3 respectively. The results of this study have been presented in this chapter under the following sub-headings:-

1. Analysis of the temporal patterns of production-growth and decomposition of its components.

2. Examining the cropping intensity, yield and change in yield under changing land use dimensions.

3. Forecasting the area, production and productivity of Food grains with the use of ARIMA model of time series.

1. Analysis of the temporal patterns of production-growth and decomposition of its components.

1.1 Growth rate

In agriculture growth rates are widely used as these play important role in policy implications. The exponential compound annual growth rates were estimated by using log linear functions on the time series data on area, production and yield of different foodgrains. The semi log exponential functional form was used to analyze the trend in growth rate, which is one of the appropriate functional forms to estimate growth rate. Analyzing the growth rate trends in agricultural area, production and yield across space and time have remained issues of significant concern for researchers as well as policy makers. It had been discussed that analysis of the growth rate trends helps us to identify the changing pattern of crops and land use pattern under different crops and rate of change in area, production and yield of a crop and further help in making the suitable agricultural policies.

Table-1 Growth rate of area, production and yield of different foodgrains in India during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	**1991-92 to 2000-01**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-1.34***	0.17	-6.74***	0.78***	1.16***
Production	1.43***	2.02***	-5.17***	1.85***	3.74***
Yield	2.81	1.85***	1.67*	1.06**	2.55***
Particulars	**2001-02 to 2010-11**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	0.49	0.26	1.45**	0.11	2.91
Production	2.31**	2.25**	3.09**	1.70	6.00***
Yield	1.80***	1.97***	1.61**	1.59**	3.00**
Particulars	**2011-12 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	0.50**	-0.07	2.67***	0.29	1.15***
Production	2.12***	1.93***	4.58***	1.85***	4.01
Yield	1.61***	2.00***	1.85*	1.55***	2.82***
Particulars	**1991-92 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-0.10	-0.10*	-0.23	0.10*	1.98
Production	1.77	1.77	1.33***	1.60	4.71
Yield	1.89	1.89	1.56	1.50	2.67

*, ** and *** Significant at 1, 5 and 10 percent level.

From the Table 1 it was observed that growth rate in area of all the crops were either negative or very limited because population is increasing continuously and to accommodate them agricultural lands are used. Highest growth rate in area of foodgrains in India was observed in third period (0.50%). In production highest growth rate was observed in second period (2.31%). Highest growth rate in yield of foodgrains was observed in first period (2.81%) followed by second period (1.80%). Highest growth rate in area of cereals were observed in second period (0.26%) followed by first period (0.17%). Production was showing highest growth rate in second period (2.25%) followed by first (2.02%) and third period (1.93%). Cereals yield was showing highest growth rate in third period (2%) followed by second period (1.97%).

Table 2. Growth rate of area, production and yield of different foodgrains in Bihar during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	1991-92 to 2000-01				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-2.21**	-0.69	-11.07	-1.05*	-0.75
Production	2.13	3.18*	-8.94***	3.85	2.29**
Yield	4.44***	3.90**	2.39*	4.95	3.06**
Particulars	**2001-02 to 2010-11**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-0.78*	-0.63	-2.19***	-1.49**	0.83***
Production	-0.62	-0.59	-1.26	-2.89	0.79
Yield	0.16	0.04	0.95	-1.42	-0.03
Particulars	**2011-12 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-0.62**	-0.52*	-1.81***	-1.01	-0.62
Production	1.13	1.30	-4.15***	-0.18	1.05
Yield	1.77*	1.84*	-2.38**	0.82	1.68
Particulars	**1991-92 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	-1.56	-1.17	-4.47	-1.92	-0.24
Production	0.89**	1.17***	-3.68	0.95	2.21
Yield	2.49	2.37	0.82	2.92	2.46

*, ** and *** Significant at 1, 5 and 10 percent level.

During first period growth rate in area and production of pulses were negative. Area of pulses was showing highest growth rate in third period (2.67%) and its production was showing highest growth in third period (4.58%). Its yield was showing highest growth in third period (1.85%) followed by first period (1.67%). Growth rate in area of rice had decreased to 0.11% in second period and then increased to 0.29% in third period. In growth rate of production also first it decreased to 1.70% in second period then it increased to 1.85%. Highest growth rate in yield of rice was observed in second period (1.59%) followed by third period (1.55%). The growth rate of area of maize was 2.91 in second period which was highest. Highest growth rate in production was observed in second period (6%) followed by third (4.01) and first (3.74%) period. Yield was showing highest growth rate in second period (3%) followed by third period (2.82%).

From the Table 2 it had observed that area under every crop is decreasing in all the periods because area under cultivation is decreasing day by day. Although growth rate in area of foodgrains was negative in all the period but better growth rate (-0.62%) was observed in third period. Growth rate in production of foodgrains was highest in first period (2.13%) followed by third period (1.13%). In second period growth rate in production was negative because in 2000 Jharkhand was separated from Bihar and area has decreased too much and increase in yield could not compensate that much decrease in area so growth rate in production of foodgrains in second period was (-0.62%).Growth rate in yield of foodgrains was positive in all the decades as yield is increasing continuously due to use of various production technologies. Highest growth rate in yield of foodgrains was observed in first period (4.44%) followed by third (1.77%) and second period (0.16%).

Cereals was following same trend as of foodgrains as foodgrains are majorly govern by cereals only. Growth rate in area of cereals was negative in all the periods. Highest growth rate in production of cereals was observed in first period (3.18%) followed by third period (1.30%). In second period growth rate in production of cereals were negative (-0.59%). Yield of cereals were showing highest growth rate in first (3.90%) followed by third (2.37%) and second period (0.04%). Pulses were showing different scenario in comparison to cereals. Its area as well as production were showing negative growth rate in all the decades because farmers were shifting from pulse cultivation to highly remunerative maize cultivation. Although in comparison to all the three decades pulse production was better in second period. It was showing less negative growth rate in production of pulses (-1.25%). Highest growth rate in yield of pulses were observed in first period (2.39%) followed by second period (0.95%). In third period growth rate in yield of pulses were negative (-2.38%). Because Bihar have erratic pattern of climatic condition it is always facing flood or drought.

In rice cultivation first period (1991-92 to 2000-01) had performed better because growth rate in production (3.85%) and yield (4.95%) was positive. In second period (2001-02 to 2010-11) growth rate in area (-1.49%), production (-2.89%) and yield (-1.42%) was negative. In third period (2011-12 to 2020-21) growth rate in yield of foodgrains was positive (0.82%) but for area and production growth rate was negative. Area under cultivation of all the crops had decreased in all the decades but area under maize cultivation was showing positive growth rate in second period (0.83%) due to rabi maize. Rabi maize is popularly cultivated in northern part of Bihar. Highest growth rate in production of maize was observed in first period (2.29%) followed by third (1.05%) and second period (0.79%). Growth rate in yield of foodgrains was highest in first period (3.06%) followed by third period (1.68%).

1.2 Instability Index

CDV Instability index measures the extent of deviation from the trend. It illustrates, among other things, how susceptible the region is to natural disasters, particularly the effect of drought and flood. From the Table 3 and 4 it was observed that Instability index in area, production and yield of crops is highest in Bihar in comparison to national average because this state is facing frequent floods and droughts. Higher value of instability index is threathens the agriculture production and affect the livelihood of farmers which is a bothersome to economists and policy makers.

From the Table 3 it was revealed that foodgrains area was highly instable in second period (2.35) followed by first period (1.77). Production of foodgrains was showing highest instability in second period (6.17) followed by third (3.63) and first period (3.19). Highest instability in yield of foodgrains was also observed in second period (4.18) followed by first period (3.35). Cereals area were showing highest instability index in second period (2.21) followed by third period (1.69). Production was also showing highest instability in second period (6.14) followed by third period (3.39). And yield was showing highest instability in second period (4.20) followed by third period (3.40). Pulses area was showing highest instability in first period. Its production had highest instability in third period (10.14) followed by second period 8.61). Yield of pulses were showing highest instability in third period (7.11). In second period area of rice was showing highest instability (3.19) followed by third period (1.45). Production of rice was showing highest instability in second period

Table 3. Instability index of area, production and yield of different foodgrains in India during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	**1991-92 to 2000-01**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	1.77	0.84	9.00	1.06	1.42
Production	3.19	3.09	8.42	3.20	5.44
Yield	3.35	2.40	7.02	2.75	5.38
Particulars	**2001-02 to 2010-11**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	2.35	2.21	4.90	3.19	2.32
Production	6.17	6.14	8.61	7.37	9.68
Yield	4.18	4.20	4.64	4.93	9.04
Particulars	**2011-12 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	1.60	1.69	5.71	1.45	2.72
Production	3.63	3.39	10.14	2.58	4.65
Yield	3.22	3.40	7.11	2.35	3.85
Particulars	**1991-92 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	3.73	1.80	17.03	2.43	3.48
Production	5.86	5.35	19.71	5.68	7.38
Yield	4.15	4.23	7.08	4.17	6.43

(7.37) followed by first (3.20) and third period (2.58). Its yield was showing highest instability in second period (4.93) followed by first period (2.75). For maize highest instability in area was observed in third period (2.72) followed by second period (2.32). Highest instability in production of maize was observed in second period (9.68). Yield was also showing highest instability in second period (9.04).

Table 4. Instability index of area, production and yield of different foodgrains in Bihar during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	1991-92 to 2000-01				
	Foodgrains	Cereals	Pulses	Rice	Maize
Area	5.86	6.60	11.38	8.91	9.31
Production	11.56	12.13	12.83	22.36	8.22
Yield	9.26	10.40	9.61	20.69	7.94
Particulars	**2001-02 to 2010-11**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	3.56	3.96	3.90	6.04	1.77
Production	13.80	14.37	8.79	23.91	8.02
Yield	11.11	11.45	5.95	19.72	7.96
Particulars	**2011-12 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	2.10	2.10	4.61	3.53	3.24
Production	8.62	8.80	7.72	12.66	13.65
Yield	7.32	7.27	8.27	10.10	12.24
Particulars	**1991-92 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
Area	8.44	7.63	22.86	10.95	8.59
Production	17.25	17.68	22.91	26.13	14.84
Yield	12.98	13.63	10.35	22.20	11.09

Area of foodgrains was showing highest instability index in first period followed by second period. Among area, production and yield production was showing highest instability index because production is mainly depend on climatic factor. Foodgrains production was showing highest instability index in second period (13.80) followed by first (11.56) and third period (8.62). Yield of foodgrains was also showing highest instability index in second period (11.11) followed by first (9.26) and third period (7.32). Similar pattern of instability index was observed for cereals also.

Highest instability index in area was observed in first period (6.60) followed by second (3.96) and third period (2.10). Production was showing highest instability index in second period (14.37) followed by first period (12.13). And yield was also showing highest instability index in second period (11.45) followed by first period (10.40). Area of pulses were showing highest instability index in first period (11.38) followed by third period (4.61). Production was showing highest instability index in first period (12.83) followed by second (8.79) and third period (7.72). Yield of pulses were showing highest instability in first period (9.61) followed by third period (8.27). Among all the crops highest instability index in area, production and yield was observed for rice in all the periods. Highest instability index in area of rice was observed in first period (8.91) followed by (6.04). Production was showing highest instability index in second period (12.66) followed by first period (22.36). Yield of rice was also showing highest instability index in first period (20.69) followed by second period (19.72). Highest instability index in area of maize was observed in first period (9.31). Production of maize was showing highest instability in third period (13.65) and yield was also showing highest instability index in third period (12.24).

1.3 Decomposition analysis

The decomposition study demonstrates how area impact, yield effect, and their interaction effect all contribute differently to changes in total production. The technique of decomposition was used to calculate the relative contributions of area and yield to the overall change in production with regard to each crop. Thus, area and yield, which can be divided into three effects—yield, area, and interaction effects—are responsible for the overall change in production.

From the Table 5 it can be seen that yield effect was contributing majorly in change in production during first period. But in second and third period area effect as well as interaction effect was also contributing in change in production. In second period yield effect was contributing 76.21% area effect was contributing 21.37% and their interaction was contributing 2.42%.For cereals also majorly yield effect was contributing in change in production. In first period share of yield effect was 91.39%, area effect was sharing 7.35% and their interaction was sharing 1.26%.For pulses area effect was majorly contributing in change in production during first and second

Table 5. Relative percentage contribution of area, yield and their interaction in change in production of different foodgrains in and India during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	1991-92 to 2000-01				
	Foodgrains	Cereals	Pulses	Rice	Maize
ΔP	100	100	100	100	100
$A_0\Delta Y$	193.78	91.39	-23.34	61.99	65.61
$Y_0\Delta A$	-74.69	7.35	113.59	35.01	25.97
$\Delta A\Delta Y$	-19.09	1.26	9.75	3.00	8.42
Particulars	**2001-02 to 2010-11**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
ΔP	100	100	100	100	100
$A_0\Delta Y$	76.21	104.23	37.71	274.91	41.51
$Y_0\Delta A$	21.37	-3.71	54.76	-162.41	46.06
$\Delta A\Delta Y$	2.42	-0.52	7.53	-12.50	12.44
Particulars	**2011-12 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
ΔP	100	100	100	100	100
$A_0\Delta Y$	76.51	95.28	54.39	74.86	64.07
$Y_0\Delta A$	20.40	4.04	36.00	22.14	27.83
$\Delta A\Delta Y$	3.09	0.68	9.61	3.00	8.10
Particulars	**1991-92 to 2020-21**				
	Foodgrains	**Cereals**	**Pulses**	**Rice**	**Maize**
ΔP	100	100	100	100	100
$A_0\Delta Y$	107.84	96.31	168.59	82.94	45.30
$Y_0\Delta A$	-4.24	2.06	-38.85	11.00	23.53
$\Delta A\Delta Y$	-3.60	1.63	-29.74	6.07	31.17

P= production in 000' tonnes, A= area in 000'ha, Y= yield in Kg/ha

period. But in third period Yield effect was contributing majorly by 54.39% area was contributing 36% and their interaction was contributing 9.61%.The key factor driving changes in production in each period in both rice and maize was the yield effect. But in maize area effect was showing major contribution in production during second period. In this period area was sharing 46.06%, yield was sharing 41.51% and their interaction was sharing 12.44% in change in production of maize.

Table 6. Relative percentage contribution of area, yield and their interaction in change in production of different foodgrains in Bihar during the decades 1991-92 to 2000-01, 2001-02 to 2010-11, 2011-12 to 2020-21 and overall period of 1991-92 to 2020-21.

Particulars	1991-92 to 2000-01				
	Foodgrains	Cereals	Pulses	Rice	Maize
ΔP	100	100	100	100	100
$A_0\Delta Y$	679.62	272.02	-26.49	410.76	175.18
$Y_0\Delta A$	-388.01	-117.99	109.87	-194.51	-57.76
ΔAΔY	-191.61	-54.03	16.63	-116.25	-17.42
Particulars	2001-02 to 2010-11				
	Foodgrains	Cereals	Pulses	Rice	Maize
ΔP	100	100	100	100	100
$A_0\Delta Y$	52.81	55.71	-678.03	62.51	334.63
$Y_0\Delta A$	53.09	50.48	698.08	50.15	-263.46
ΔAΔY	-5.90	-6.19	79.95	-12.67	28.83
Particulars	2011-12 to 2020-21				
	Foodgrains	Cereals	Pulses	Rice	Maize
ΔP	100	100	100	100	100
$A_0\Delta Y$	160.95	145.06	53.03	-62.11	117.48
$Y_0\Delta A$	-52.86	-38.93	54.59	156.45	-12.99
ΔAΔY	-8.09	-6.14	-7.63	5.66	-4.49
Particulars	1991-92 to 2020-21				
	Foodgrains	Cereals	Pulses	Rice	Maize
ΔP	100	100	100	100	100
$A_0\Delta Y$	307.39	200.99	-15.70	332.91	115.84
$Y_0\Delta A$	-97.22	-48.75	103.66	-97.21	-9.14
ΔAΔY	-110.17	-52.24	12.04	-135.70	-6.69

P= production in 000' tonnes, A= area in 000'ha, Y= yield in Kg/ha

From the Table 6 it was found that change in production of foodgrains was majorly governed by yield effect in all the periods because yield is increasing continuously due to use of different production technologies. Cereals were following same trend as of foodgrains. Yield effect was only responsible for change in production of cereals in all the periods. However area effect was also contributing by 50.47% in second period. For pulse production area effect as well as interaction effect was responsible in first and second period. In first period area effect was contributing 109.86% and interaction effect was contributing 16.62%. But in third period Yield effect was also contributing 53.03%in total production. In first period yield effect (410.76%) was majorly contributing in total production. But in second period yield (62.51%) as well as area (50.15%) effect was contributing in total production. And in third period area effect (156.44%) was majorly contributing in rice production, interaction effect was had also contributed by 5.66%. In maize production yield effect was majorly contributing in total change in production in first and third period. But in second period yield effect as well interaction effect was contributing in total change in production. However major contribution was of yield effect.

2. Examining the cropping intensity, yield and change in yield under changing land use dimensions.

Table 7. Land use pattern in Bihar (Area in '000 ha)

This study has been done for only two decade because in the year 2000, Jharkhand was separated from Bihar. In comparison of today's agricultural scenario with 1991-92 was not adequate so, it had been compared with 2001-02 after bifurcation of the State. Total geographical area of Bihar is approximately 9.41 million hectares. Major proportion of geographical area was occupied by agricultural land and day by day it is decreasing. Both, net area sown and gross cropped area is decreasing because of population pressure and therefore share of agriculture in GDP is decreasing.The expansion of areas used for non-agricultural purposes can be linked to a variety of factors such as establishment of industries, recreational facilities, infrastructure development, and increase in residential areas. Cropping intensity is continuously rising as single piece of land was cultivated more than once to feed increasing population. Cropping intensity has increased from 139.4 in 2001-02 to 143.3 in 2018-19. Area under fallow land and forest cover has been raised by 59.68% and 18.64% respectively during the said period.

Variables	2001-02	2018-19	Absolute change	% change
Geographical Area	9,416	9,416	00	00
Reporting area for land utilization	9,360	9,360	00	00
Net area sown	5,664	5,167	-497	-8.77
Gross Cropped Area	7,897	7,406	-491	-6.21
Fallow land	697	1,113	416	59.68
Forests	622	738	116	18.64
Cropping Intensity	139.4	143.3	3.9	2.79

Change in yield

As we have seen area under agricultural use is decreasing day by day but yield of foodgrains i.e. cereals, pulses and oilseeds are increasing continuously. It is due to use of modern tools and techniques in agriculture. To meet the requirement of population farmers are doing intensive cultivation. They are using high yielding varieties, disease and pest resistant seeds, fertilizers to increase the yield of agricultural produce. Highest increase in yield was observed in oilseeds (48.74%) followed by maize (48.08%) and wheat (45.18%) and minimum change in yield was observed in pulses (20.05%) followed by rice (32.96%).

Table 8. Change in yield (Kg/Hectare)

Crops	2001-02	2018-19	Absolute change	% change
Food grains	1664	2402	738	44.35
Cereals	1760	2518	758	43.06
Pulses	788	946	158	20.05
Oilseeds	839	1248	409	48.74
Rice	1465	1948	483	32.96
Maize	2504	3708	1204	48.08
Wheat	2065	2998	933	45.18

3. Forecasting the area, production and productivity of Food grains with the use of ARIMA model of time series.

Auto-regressive integrated moving average (ARIMA) model was used to forecast the area, production and productivity of foodgrains because data of research was showing linear trend. ARIMA methodology was carried out in three stages i.e. identification, estimation and diagnostic checking. During identification stage, models are identified, next parameters are estimated at estimation stage, and at last in diagnostic checking stage, model's suitability is evaluated. If the model was found inadequate, all the three stages are repeated until satisfactory model was selected. The fitting of ARIMA models was done using SPSS.

3.1 Food grains

3.1.1 Forecasting the area under foodgrains in Bihar

Trend estimation

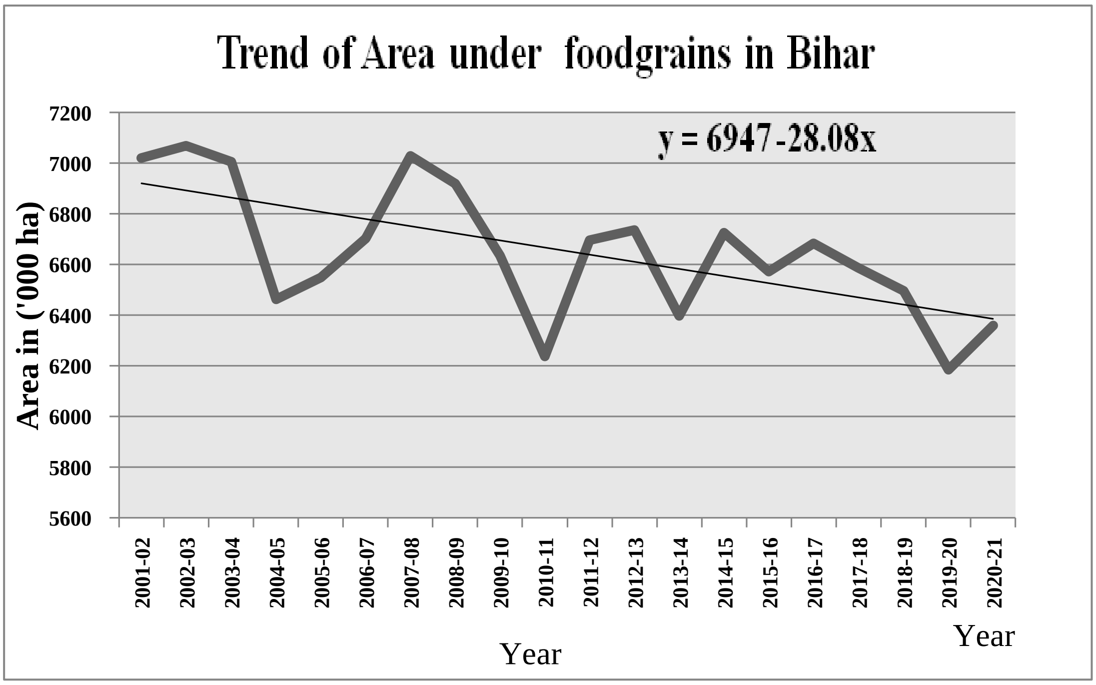

Fig.1: Graph of trend value of foodgrains area ('000 ha) in Bihar

The trend value of area of foodgrains has been plotted in Fig.1. This plot is showing that area of foodgrains is decreasing linearly. Maximum area under foodgrains in Bihar was 7069.9 thousand hectare in 2002-03 and minimum area under foodgrains in Bihar was 6183.15 thousand hectares during the year 2019-20.

The fitted trend equation was obtained as-

$y = 6947-28.08x$

Where y was area in thousands hectare and x was years.

Table 9. Selection of best model for area of foodgrains in Bihar

Models	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.20	246.36	2.88	11.46
ARIMA (0,1,1)	0.21	231.00	2.58	11.19
ARIMA (1,1,1)	0.24	233.14	2.48	11.36
ARIMA (2,1,0)	0.05	261.37	2.81	11.59
ARIMA (2,1,1)	**0.35**	**222.80**	**2.35**	**11.33**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of foodgrains ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.35 and 2.35 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the area under foodgrains in Bihar.

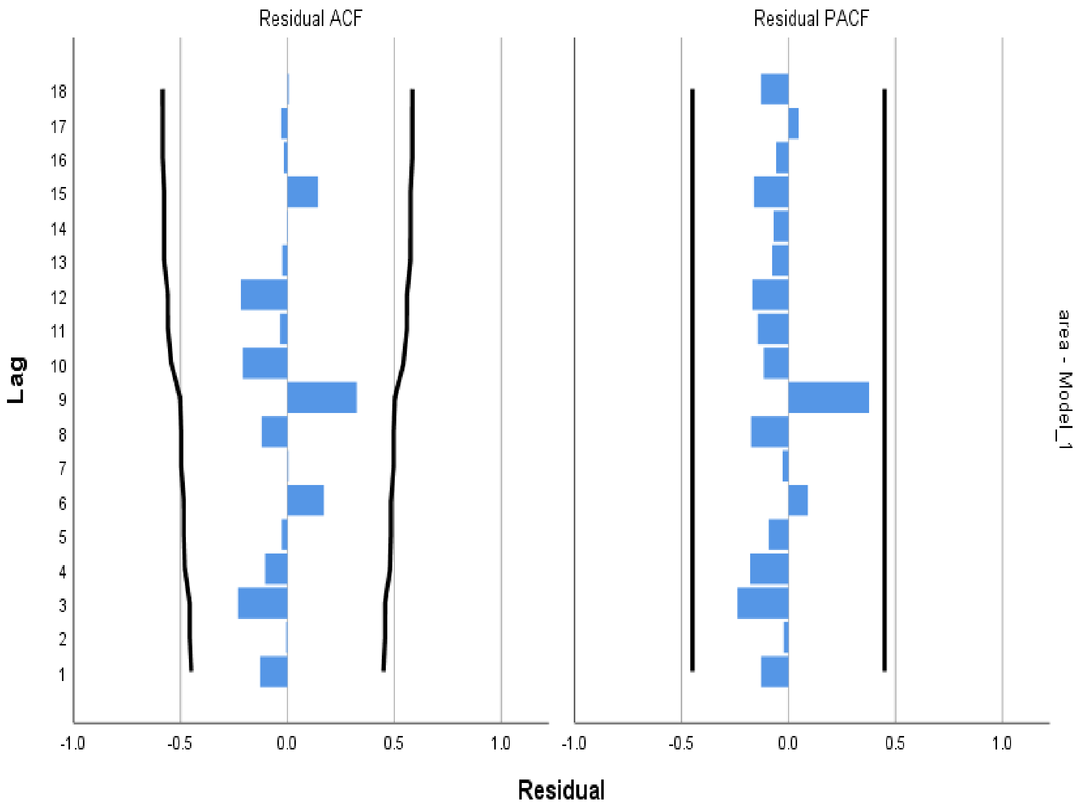

Fig.2: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for foodgrains area Forecasting

Table 10. Forecasting of area under foodgrains in Bihar

Years	Forecast (000'ha)	Upper confidence limit	Lower confidence limit
2021-22	6479.18	6920.76	6037.6
2022-23	6410.11	6870.59	5949.64
2023-24	6316.65	6792.01	5841.29
2024-25	6292.15	6771.01	5813.28
2025-26	6294.44	6775.99	5812.89

The model ARIMA (2,1,1) was used to forecast the area of foodgrains for the period 2021-22 to 2025-26. It has been found that area under foodgrains would decrease from 6479.18 thousand hectare to 6294.44 thousand hectare. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.1.2. Forecasting of production of foodgrains in Bihar

Trend estimation

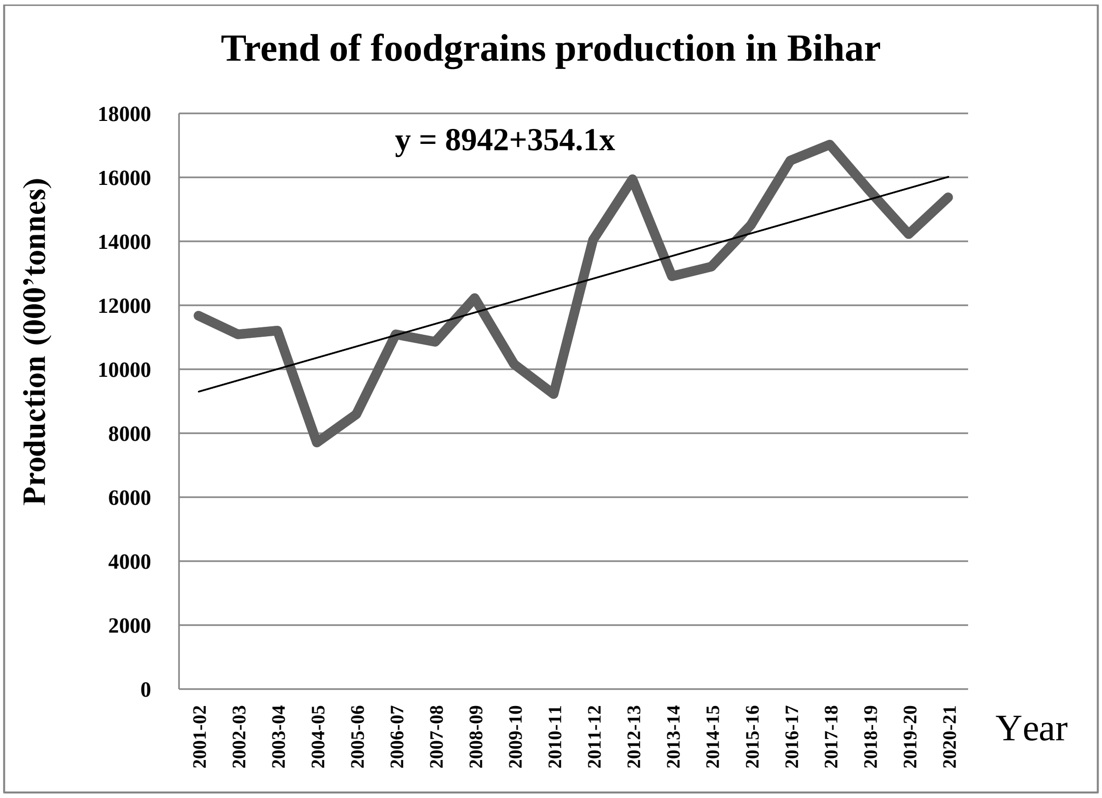

Fig.3: Graph of trend value of foodgrains production (000' tonnes) in Bihar

The trend value of production of foodgrains has been plotted in Fig.3. This plot is showing that production of foodgrains is increasing linearly. Minimum production of foodgrains in Bihar was in the year 2004-05 (7704.4 thousand tonnes) and maximum production of foodgrains in Bihar was in 2017-18 it was 17036 thousand tonnes.

The fitted trend equation was obtained as-

y= 8942+354.1x

Where y was production in thousands tonnes and x was years.

Table 11. Selection of best fit model for foodgrains production in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.59	1841.97	11.36	15.48
ARIMA (0,1,1)	0.52	1976.43	13.13	15.48
ARIMA (1,1,1)	0.58	1901.82	12.52	15.56

ARIMA (2,1,0)	0.62	1804.53	10.70	15.46
ARIMA (2,1,1)	**0.65**	**1775.56**	**11.21**	**15.48**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of foodgrains ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.65 and 11.21 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the production of foodgrains in Bihar.

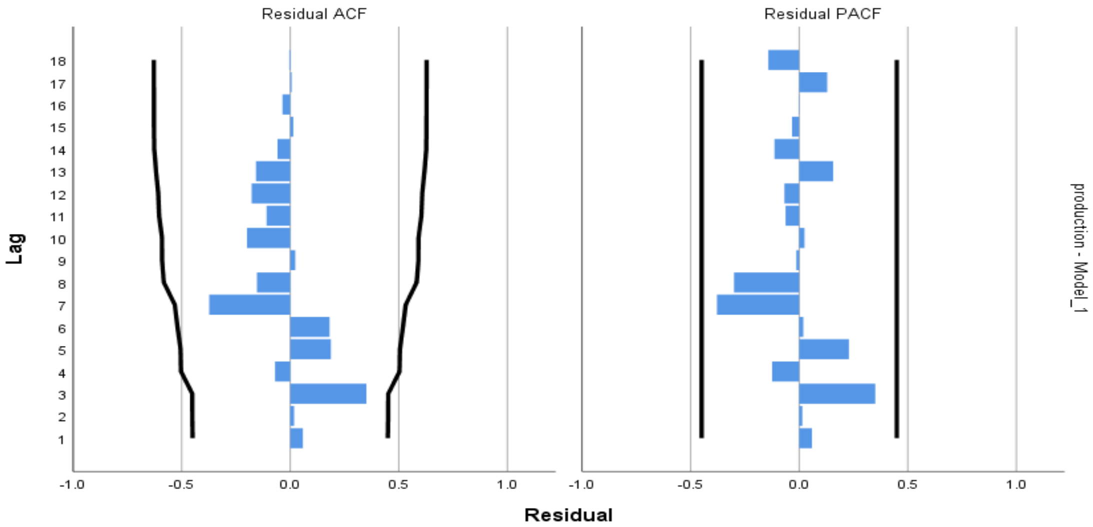

Fig.4: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for foodgrain production

Forecasting

Table 12. Forecasting of foodgrains production in Bihar

Years	Forecast (000'tonnes)	Upper confidence limit	Lower confidence limit
2021-22	17063.65	20507.69	13619.6
2022-23	17661.30	21527.88	13794.72

2023-24	17492.37	21421.39	13563.36
2024-25	17509.66	21575.29	13444.03
2025-26	17995.82	22058.61	13933.02

The model ARIMA (2,1,1) was used to forecast the production of foodgrains for the period 2021-22 to 2025-26. It has been found that production of foodgrains would increase from 17063.65 Kg/ha to 17995.82 Kg/ha. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.1.3 Forecasting of yield of foodgrains in Bihar

Trend estimation

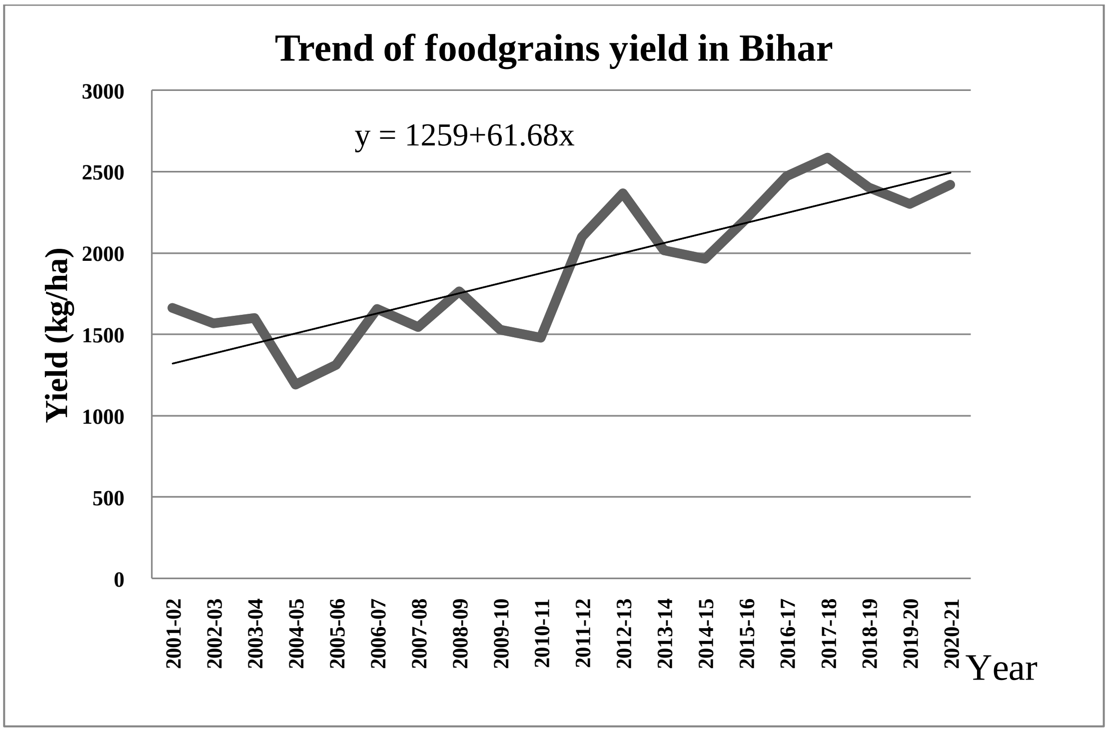

Fig.5: Graph of trend value of foodgrains yield (Kg/ha) in Bihar

The trend value of yield of foodgrains has been plotted in Fig.5. This plot is showing that yield of foodgrains is increasing in linear trend. Minimum yield of foodgrains in Bihar was 1192 Kg/ha in the year 2004-05 and maximum yield under foodgrains in Bihar was 2587 Kg/ha in the year 2017-18.

The fitted trend equation was obtained as-

y=1259+61.68x

Where y was yield in kg/ha and x was years.

Table 13. Selection of best fit model for foodgrains yield in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.69	251.06	11.32	11.50
ARIMA (0,1,1)	0.67	255.86	11.30	11.40
ARIMA (1,1,1)	0.72	243.75	10.95	11.45
ARIMA (2,1,0)	0.74	233.05	9.09	11.36
ARIMA (2,1,1)	**0.76**	**232.98**	**9.58**	**11.32**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of foodgrains ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.76 and 9.58 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the yield of foodgrains in Bihar.

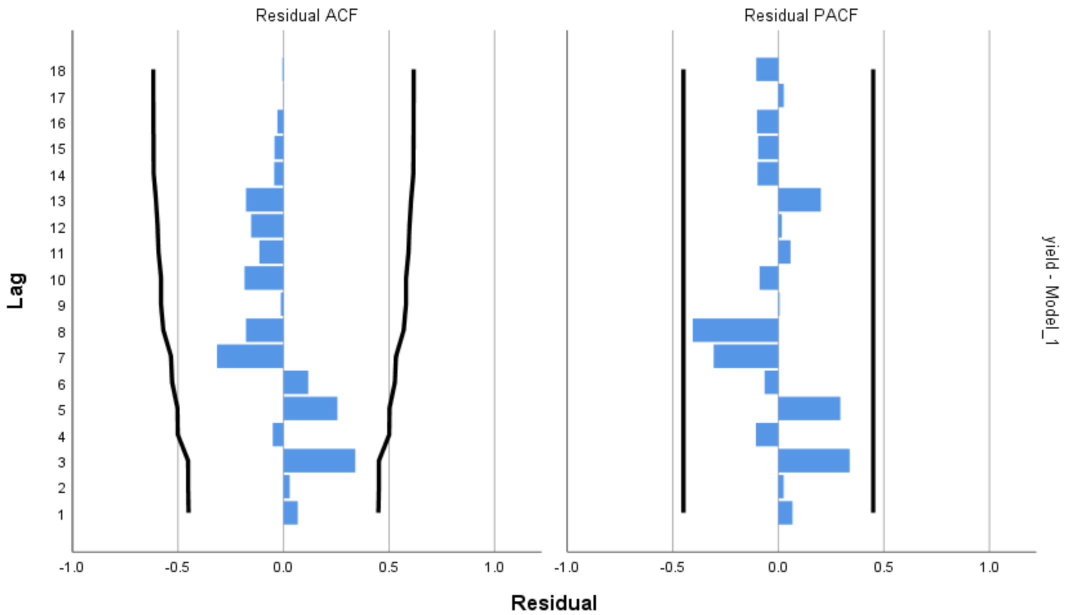

Fig.6: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for yield of foodgrain

Forecasting

Table 14.Forecasting of foodgrains yield

Years	Forecast (Kg/ha)	Upper confidence limit	Lower confidence limit
2021-22	2597.62	3052.28	2142.95
2022-23	2693.78	3210.27	2177.28
2023-24	2721.61	3240.91	2202.31
2024-25	2753.18	3285.65	2220.70
2025-26	2817.47	3349.55	2285.38

The model ARIMA (2,1,1) was used to forecast the yield of foodgrains for the period 2021-22 to 2025-26. It has been found that yield of foodgrains would increase from 2597.62 Kg/ha to 2817.47 Kg/ha in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.2 Total cereals

3.2.1 Forecasting of area of cereals in Bihar

Trend estimates

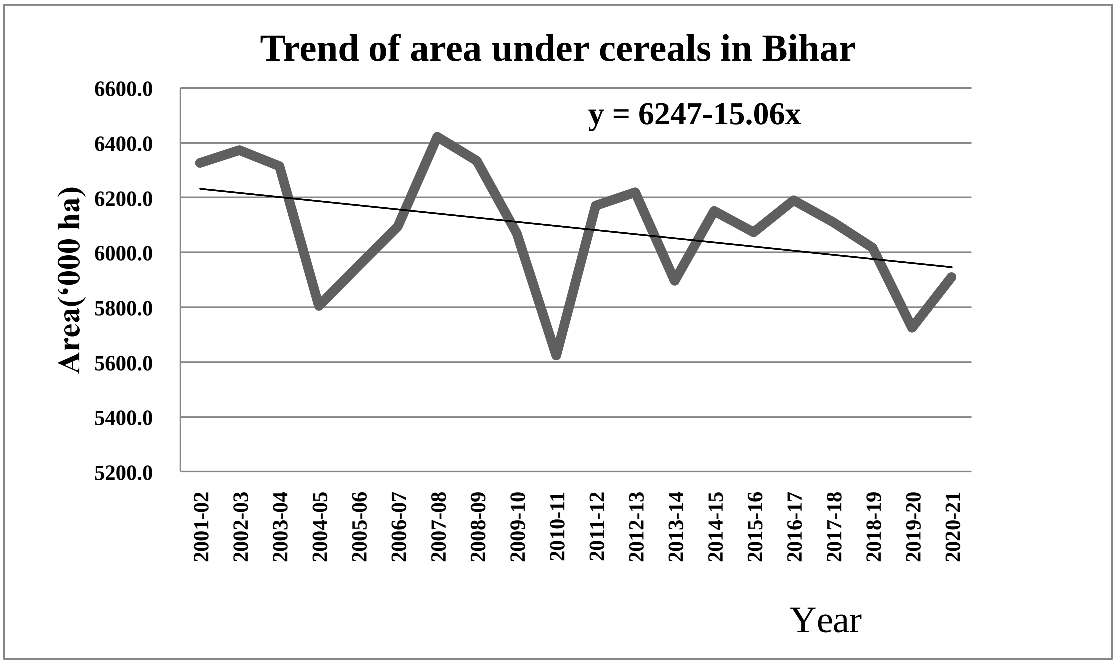

Fig.7: Graph of trend value of cereals area ('000 ha) in Bihar

The trend value of area of cereals has been plotted in Fig.7. This plot is showing that area of cereals is decreasing in linear trend. Maximum area under cereals in Bihar was 6421 thousand hectare in 2007-08 and minimum area under cereals in Bihar was 5623.5 thousand hectare in the year 2019-20.

The fitted trend equation was obtained as-

$$y = 6247-15.06x$$

Where, y was area in thousands hectare and x was years.

Table 15. Selection of best model for area of cereals in Bihar

Models	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.06	225.34	2.58	11.28
ARIMA (0,1,1)	-0.04	230.24	2.77	11.18
ARIMA (1,1,1)	-0.01	233.32	2.68	11.37
ARIMA (2,1,0)	-0.26	260.83	2.97	11.59
ARIMA (2,1,1)	**0.15**	**220.09**	**2.49**	**11.10**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of cereals ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.15 and 2.49 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the area of cereals in Bihar.

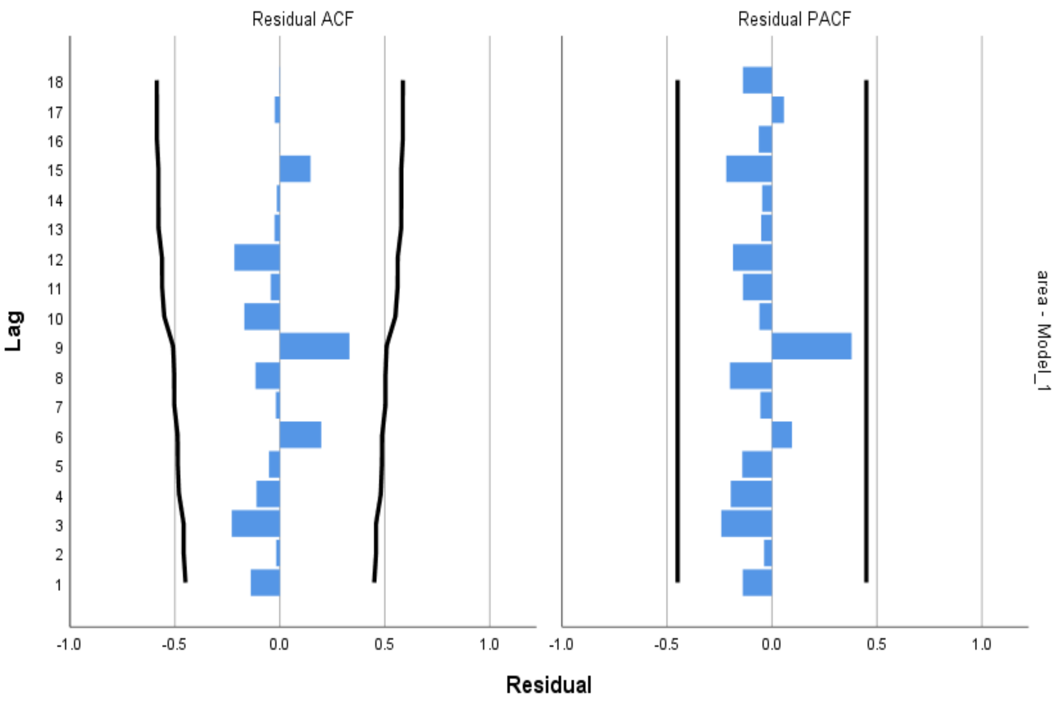

Fig.8: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for area of cereals

Forecasting

Table 16. Forecasting of area under cereals in Bihar

Years	Forecast (000'ha)	Upper confidence limit	Lower confidence limit
2021-22	6062.07	6497.57	5626.58
2022-23	6004.53	6456.91	5552.15
2023-24	5912.49	6383.77	5441.21
2024-25	5901.46	6376.48	5426.45
2025-26	5923.95	6402.99	5444.91

The model ARIMA (2,1,1) was used to forecast the area of cereals for the period 2021-22 to 2025-26. It has been found that area under cereals would decrease from 6062.07 million hectare to 5923.95 million hectare in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.2.2 Forecasting of production of cereals in Bihar

Trend estimation

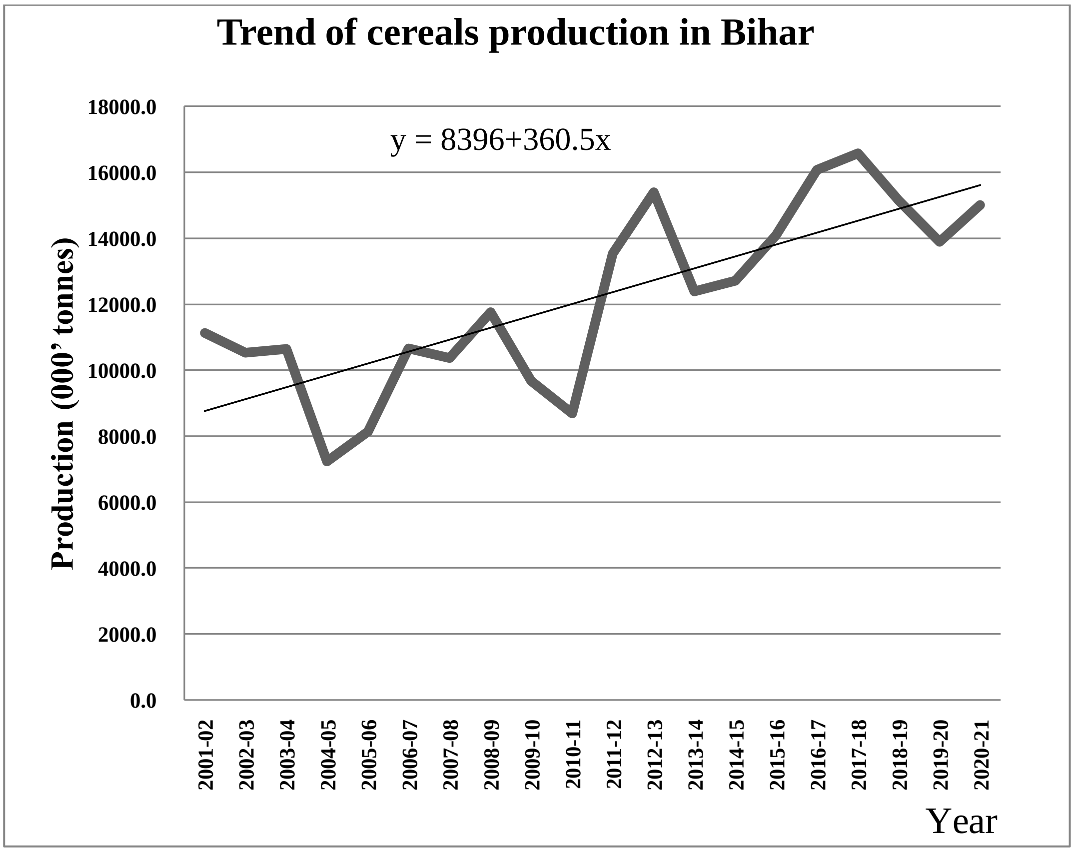

Fig.9: Graph of trend value of cereals production (000' tonnes) in Bihar

The trend value of production of cereals has been plotted in Fig.9. This plot is showing that production of cereals was increasing in linear trend. Minimum production of cereals in Bihar was 7237.5 thousand tonnes in the year 2004-05 and maximum production of cereals in Bihar was 16582.7 thousand tonnes in 2017-18.

The fitted trend equation was obtained as-

$$y= 8396+360.5x$$

Where, y was production in thousands tonnes and x was years.

Table 17. Selection of best fit model for cereals production in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.59	1832.61	11.84	15.47
ARIMA (0,1,1)	0.53	1954.50	13.69	15.46
ARIMA (1,1,1)	0.59	1887.37	13.10	15.55

ARIMA (2,1,0)	0.63	1791.83	11.17	15.44
ARIMA (2,1,1)	**0.66**	**1762.72**	**11.74**	**15.36**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For production of cereals ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.66 and 11.74 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the cereals production in Bihar.

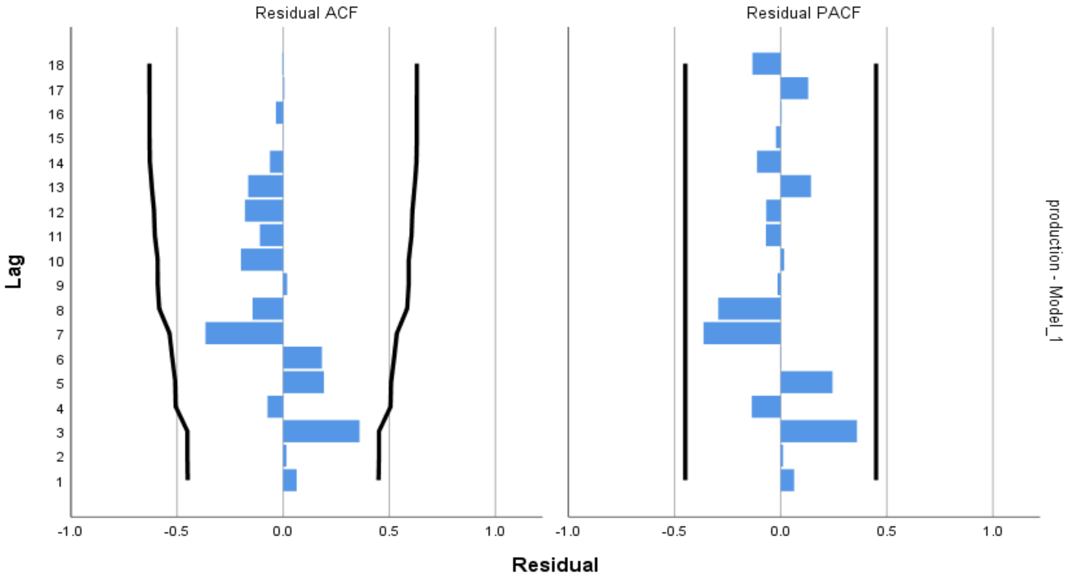

Fig.10: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for cereals production

Forecasting

Table.18 Forecasting of cereals production in Bihar

Years	Forecast (000'tonnes)	Upper confidence limit	Lower confidence limit
2021-22	16607.4	20028.42	13186.38

2022-23	17178.31	20996.28	13360.33
2023-24	17042.26	20929.92	13154.6
2024-25	17100.72	21118.13	13083.31
2025-26	17596.88	21612.15	13581.6

The model ARIMA (2,1,1) was used to forecast the production of cereals for the period 2021-22 to 2025-26. It has been found that production of cereals would increase from 16607.4 thousand tonnes to 17596.88 thousand tonnes. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.2.3 Forecasting of yield of cereals in Bihar

Trend estimation

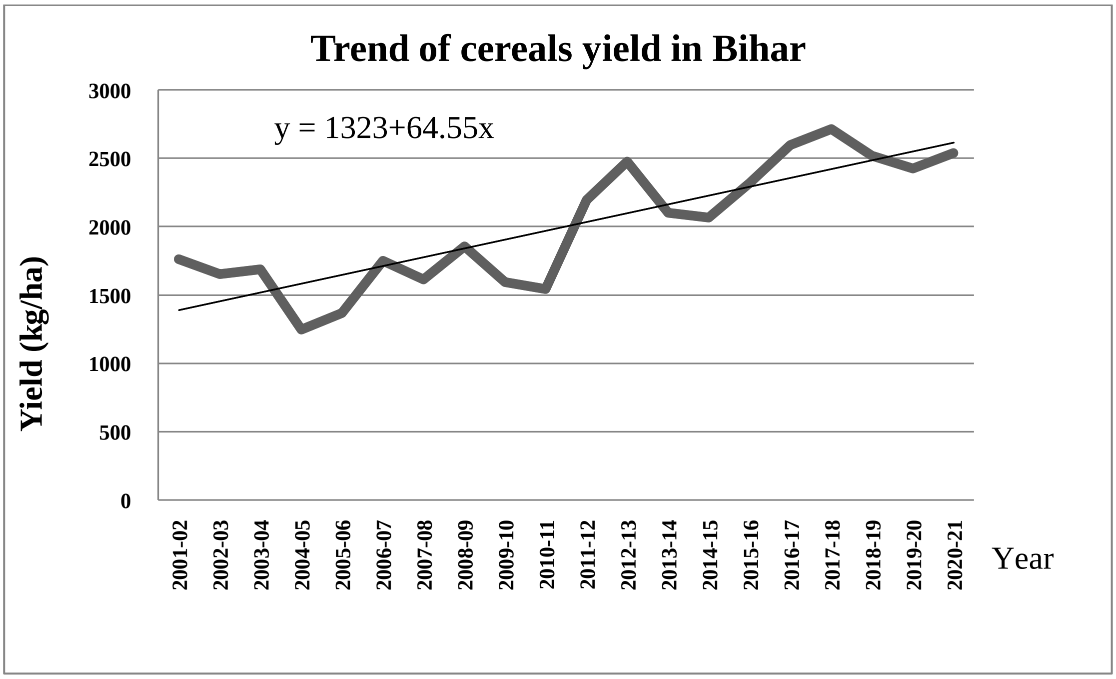

Fig.11: Graph of trend value of cereals yield (Kg/ha) in Bihar

The trend value of yield of cereals has been plotted in Fig.11. This plot is showing that yield of cereals is increasing in linear pattern. Minimum yield of cereals in Bihar was 1247 Kg/ha in the year 2004-05 and maximum yield of cereals in Bihar was 2714 Kg/ha in 2017-18.

The fitted trend equation was obtained as-y= 1323+64.55x

Where, y was yield in kg/ha and x was years.

Table19. Selection of best fit model for cereals yield in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.67	270.88	11.51	11.65
ARIMA (0,1,1)	0.66	272.38	11.69	11.52
ARIMA (1,1,1)	0.71	259.64	11.18	11.58
ARIMA (2,1,0)	0.73	251.07	9.44	11.51
ARIMA (2,1,1)	**0.75**	**251.06**	**9.86**	**11.47**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For yield of cereals ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.75 and 9.86 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the cereals yield in Bihar.

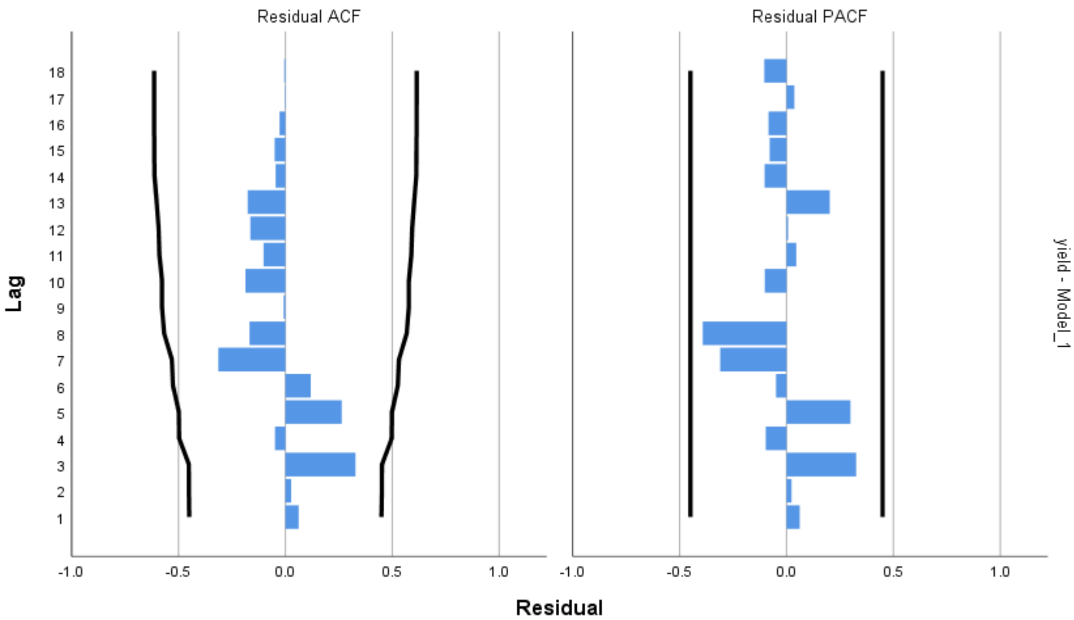

Fig.12: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for cereals yield

Forecasting

Table 20.Forecasting of cereals yield

Years	Forecast (Kg/ha)	Upper confidence limit	Lower confidence limit
2021-22	2710.42	3202.02	2218.83
2022-23	2808.21	3364.82	2251.61
2023-24	2845.36	3403.82	2286.9
2024-25	2884.3	3453.79	2314.82
2025-26	2949.71	3518.7	2380.72

The model ARIMA (2,1,1) was used to forecast the yield of cereals for the period 2021-22 to 2025-26. It has been found that yield of cereals would increase from 2710.42 Kg/ha to 2949.71 Kg/ha in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.3 Total pulses

3.3.1 Forecasting of area of pulses in Bihar

Trend estimates

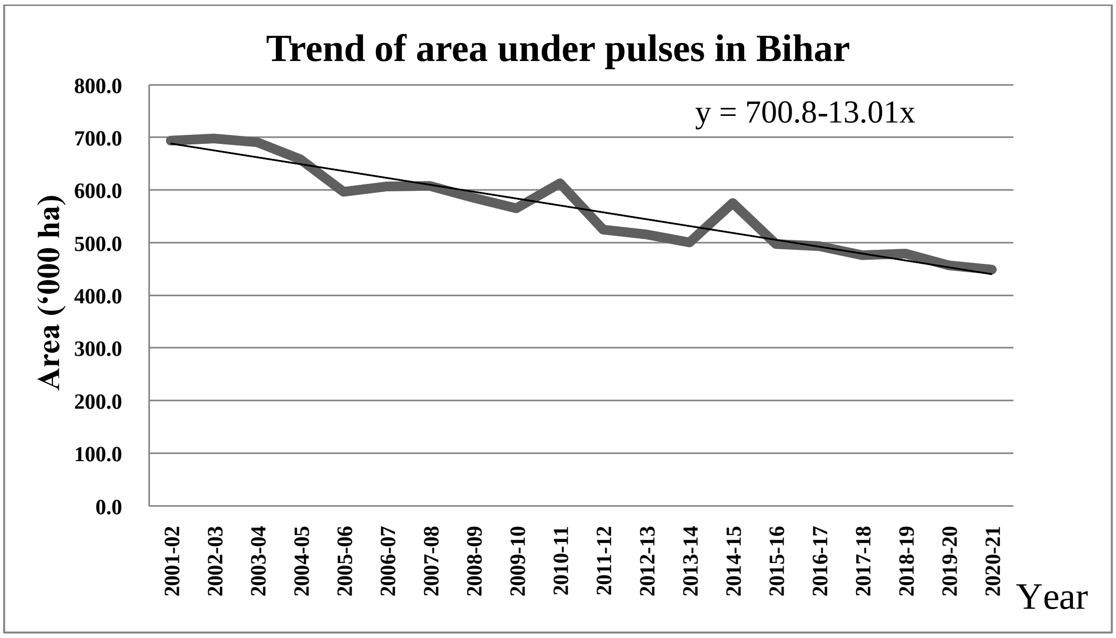

Fig.13: Graph of trend value of pulses area ('000 ha) in Bihar

The trend value of area of pulses has been plotted in Fig.13. This plot is showing that area of pulses is decreasing in linear pattern. Maximum area under pulses in Bihar was in 2001-02 it was 694.2 thousand hectare and minimum area under pulses in Bihar was 448.93 thousand hectare in the year 2020-21.

The fitted trend equation was obtained as-

$y = 700.8-13.01x$

Where y was area in thousands hectare and x was years.

Table 21. Selection of best model for area of pulses in Bihar

Models	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.67	48.9	6.0	8.23
ARIMA (0,1,1)	0.87	28.7	3.7	7.02
ARIMA (1,1,1)	**0.87**	**29.2**	**3.6**	**7.21**
ARIMA (2,1,0)	0.83	33.9	3.9	7.51
ARIMA (2,1,1)	0.87	29.9	3.8	7.42

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of pulses ARIMA (1,1,1) was the best fit model. Its R-square and MAPE value was 0.87 and 3.6 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (1,1,1) model was suitable for predicting the area under pulses in Bihar.

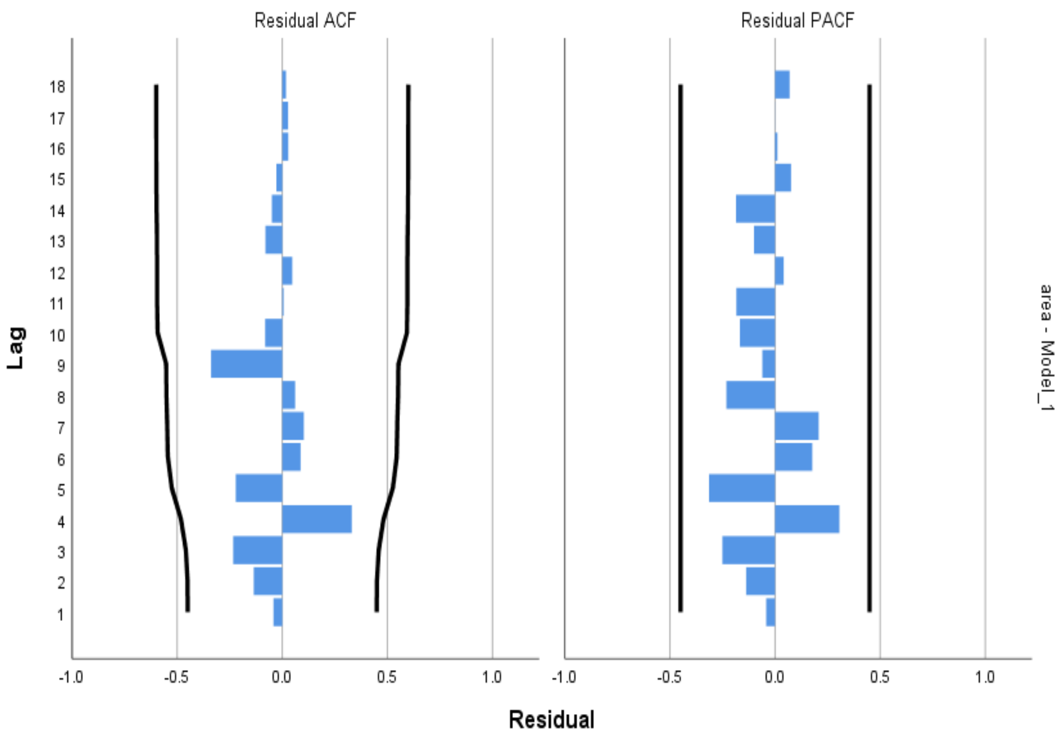

Fig.14: Residual ACF and PACF plots of the best fitted ARIMA (1,1,1) model confirms the adequacy of the model for area of pulses

Forecasting

Table 22. Forecasting of area under pulses in Bihar

Years	Forecast (000'ha)	Upper confidence limit	Lower confidence limit
2021-22	426.77	486.14	367.41
2022-23	413.77	473.12	354.42
2023-24	400.69	460.04	341.34
2024-25	387.61	446.96	328.26
2025-26	374.53	433.87	315.18

The model ARIMA (1,1,1) was used to forecast the area of pulses for the period 2021-22 to 2025-26. It has been found that area of pulses would decrease from 426.77 thousand hectare to 374.53 thousand hectare in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.3.2 Forecasting of production of pulses in Bihar

Trend estimation

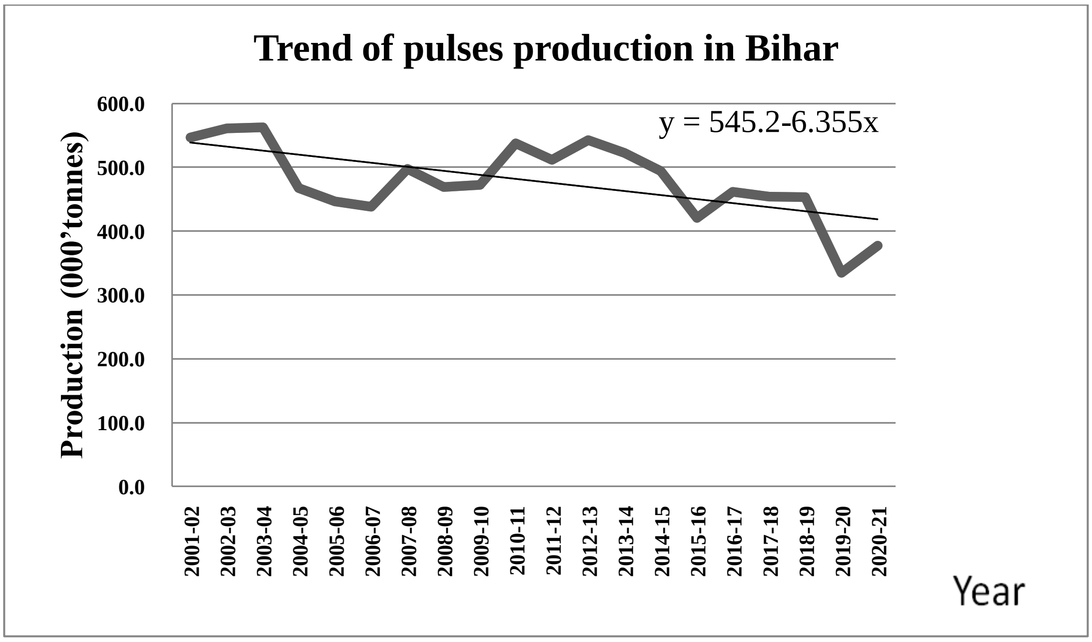

Fig.15: Graph of trend value of pulses production (000' tonnes) in Bihar

The trend value of production of pulses has been plotted in Fig.15. This plot is showing that production of pulses is decreasing by linear trend. Minimum production of pulses in Bihar was 334.4 thousand tonnes in the year 2019-20 and maximum production of pulses in Bihar was 562.6 thousand tonnes in 2003-04.

The fitted trend equation was obtained as-

$y=545.2 - 6.355x$

Where y was production in thousand tonnes and x was years.

Table 23. Selection of best fit model for pulses production in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.37	50.09	7.54	8.27
ARIMA (0,1,1)	0.38	47.98	7.61	8.05
ARIMA (1,1,1)	**0.44**	**47.10**	**7.31**	**8.17**
ARIMA (2,1,0)	0.37	49.73	7.61	8.27

ARIMA (2,1,1)	0.44	48.64	7.31	8.38

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For production of pulses ARIMA (1,1,1) was the best fit model. Its R-square and MAPE value was 0.44 and 7.31 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (1,1,1) model was suitable for predicting the pulses production in Bihar.

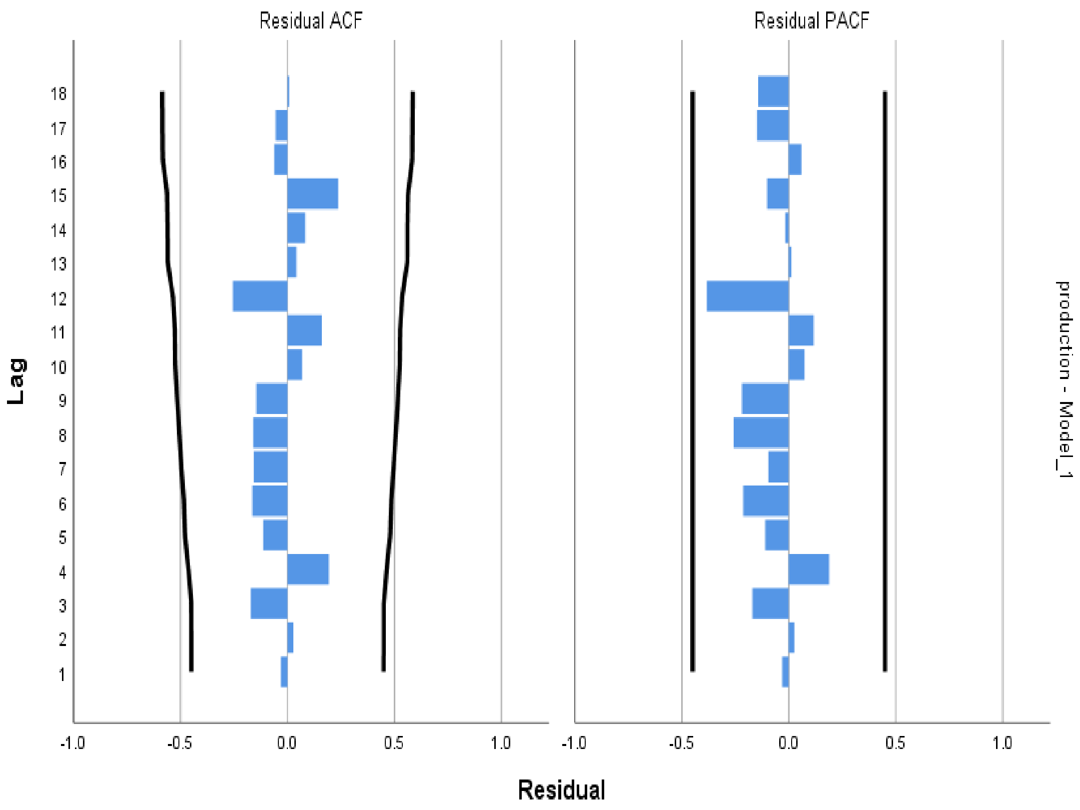

Fig.16: Residual ACF and PACF plots of the best fitted ARIMA (1,1,1) model confirms the adequacy of the model for pulses production

Forecasting

Table 24. Forecasting of pulses production in Bihar

Years	Forecast (000'tonnes)	Upper confidence limit	Lower confidence limit
2021-22	384.75	482.33	287.16
2022-23	386.02	499.75	272.29
2023-24	383.64	502.94	264.33
2024-25	379.21	500.71	257.72
2025-26	373.66	496.08	251.23

The model ARIMA (1,1,1) was used to forecast the production of pulses for the period 2021-22 to 2025-26. It has been found that production of pulses would increase from 384.75 thousand tonnes to 386.02 thousand tonnes first after that it would decrease to 373.66 thousand tonnes. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.3.3 Forecasting of yield of pulses in Bihar

Trend estimation

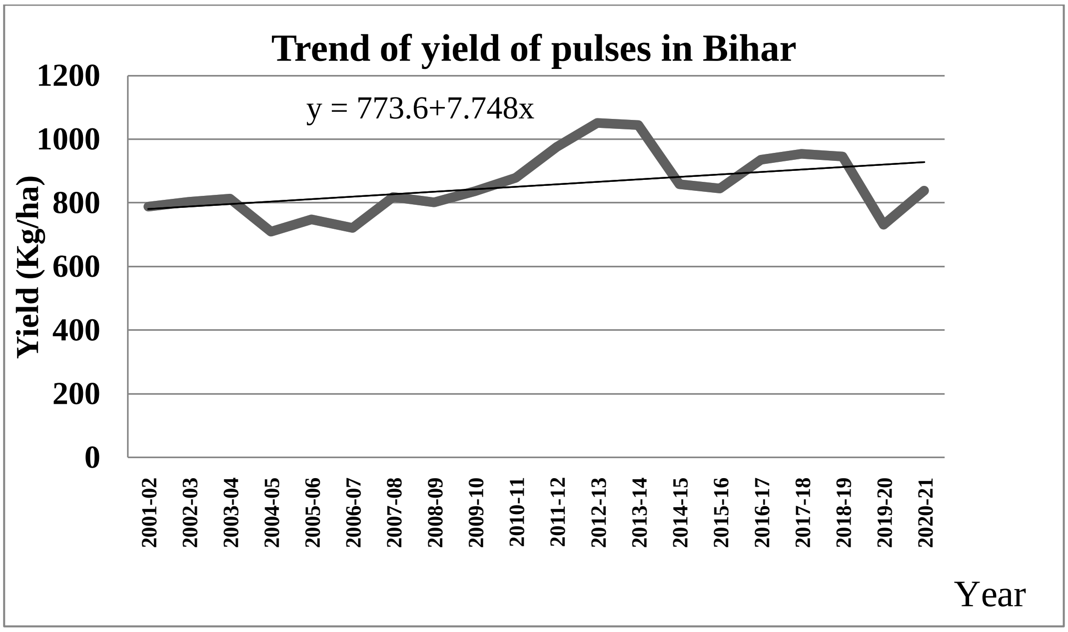

Fig.17: Graph of trend value of pulses yield (Kg/ha) in Bihar

The trend value of yield of pulses has been plotted in Fig.17. This plot is showing that yield of pulses is increasing in linear fashion. Minimum yield of pulses in Bihar was731 Kg/ha in the year 2019-20 and maximum yield of pulses in Bihar was 1052 Kg/ha in 2012-13.

The fitted trend equation was obtained as-

$$y=773.6+7.748x$$

Where y was yield in kg/ha and x was years.

Table 25. Selection of best fit model for pulses yield in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	**0.39**	**83.20**	**7.37**	**9.29**
ARIMA (0,1,1)	0.26	90.36	7.44	9.31
ARIMA (1,1,1)	0.36	86.48	7.02	9.38
ARIMA (2,1,0)	0.28	91.75	7.63	9.50
ARIMA (2,1,1)	0.39	87.48	6.87	9.56

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For yield of pulses ARIMA (1,0,1) was the best fit model. Its R-square and MAPE value was 0.39 and 7.37 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (1,0,1) model was suitable for predicting the pulses yield in Bihar.

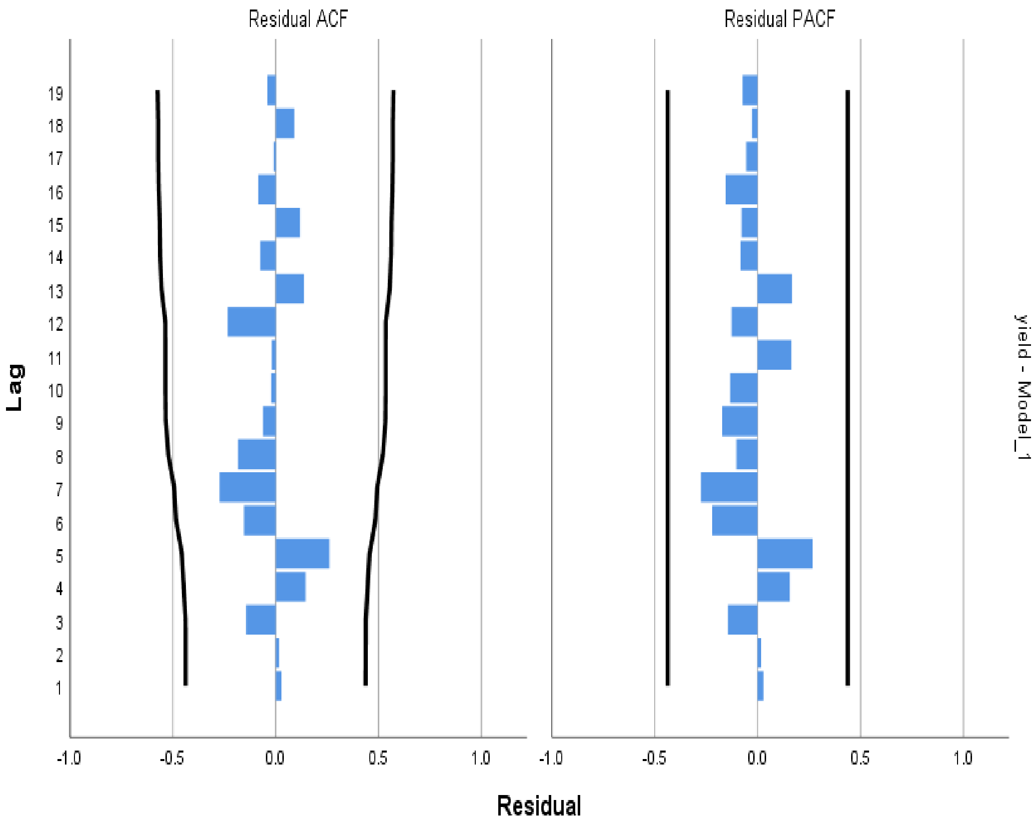

Fig.18: Residual ACF and PACF plots of the best fitted ARIMA (1,0,1) model confirms the adequacy of the model for yield of pulses

Forecasting

Table 26.Forecasting of pulses yield

Years	Forecast (kg/ha)	Upper confidence limit	Lower confidence limit
2021-22	855.03	1029.44	680.61
2022-23	853.37	1062.30	644.44
2023-24	852.50	1069.95	635.04
2024-25	852.04	1071.78	632.30
2025-26	851.80	1072.16	631.44

The model ARIMA (1,0,1) was used to forecast the yield of pulses for the period 2021-22 to 2025-26. It has been found that yield of pulses would decrease from 855.03 Kg/ha to 851.80 Kg/ha in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.4 Rice

3.4.1 Forecasting of area of rice in Bihar

Trend estimate

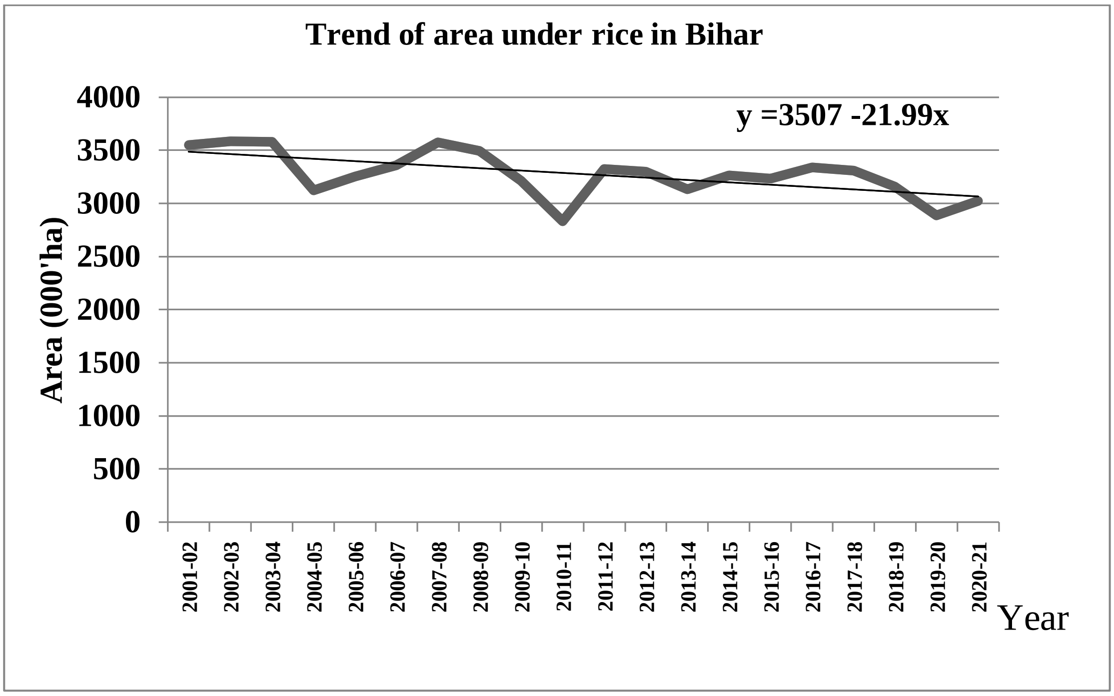

Fig.19: Graph of trend value of area under rice (000'ha) in Bihar

The trend value of area of rice has been plotted in Fig.19. This plot is showing that area of rice is decreasing in linear fashion. Maximum area under rice in Bihar was 3584.7 thousand hectare in 2002-03 and minimum area under rice in Bihar was 2832.5 thousand hectare in the year 2010-11.

The fitted trend equation was obtained as-

$y = 3507-21.99x$

Where y was area in thousands hectare and x was years.

Table 27. Selection of best model for area of rice in Bihar

Models	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.21	203.47	4.84	11.08
ARIMA (1,1,1)	0.22	198.46	4.29	11.04
ARIMA (0,1,1)	0.18	197.43	4.50	10.88

ARIMA (2,1,0)	0.34	187.84	3.95	11.09
ARIMA (2,1,1)	0.34	187.84	3.95	11.09

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of rice ARIMA (2,1,0) was the best fit model. Its R-square and MAPE value was 0.34 and 3.95 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,0) model was suitable for predicting the area under rice in Bihar.

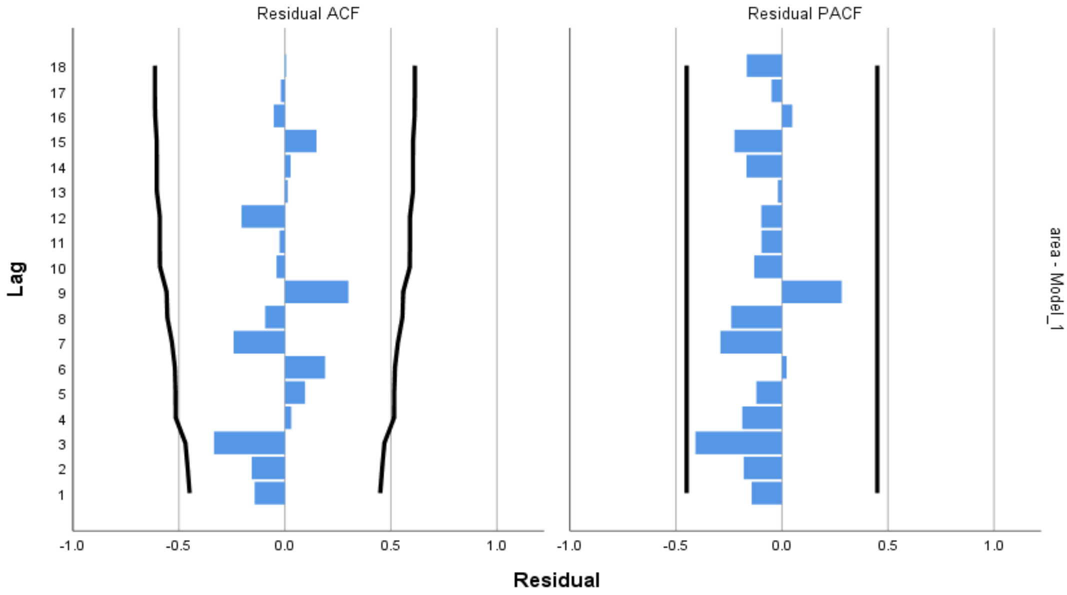

Fig.20: Residual ACF and PACF plots of the best fitted ARIMA (2,1,0) model confirms the adequacy of the model for area of rice

Forecasting

Table 28. Forecasting of area under rice in Bihar

Years	Forecast (000'ha)	Upper confidence limit	Lower confidence limit
2021-22	3035.80	3507.39	2584.20

2022-23	2945.18	3534.06	2356.31
2023-24	2910.5	3538.33	2282.68
2024-25	2907.78	3596.59	2218.98
2025-26	2874.44	3635.43	2113.44

The model ARIMA (2,1,0) was used to forecast the area of rice for the period 2021-22 to 2025-26. It has been found that area of rice would decrease from 3035.80 thousand hectare to 2874.44 thousand hectare in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.4.2 Forecasting of production of rice in Bihar

Trend estimation

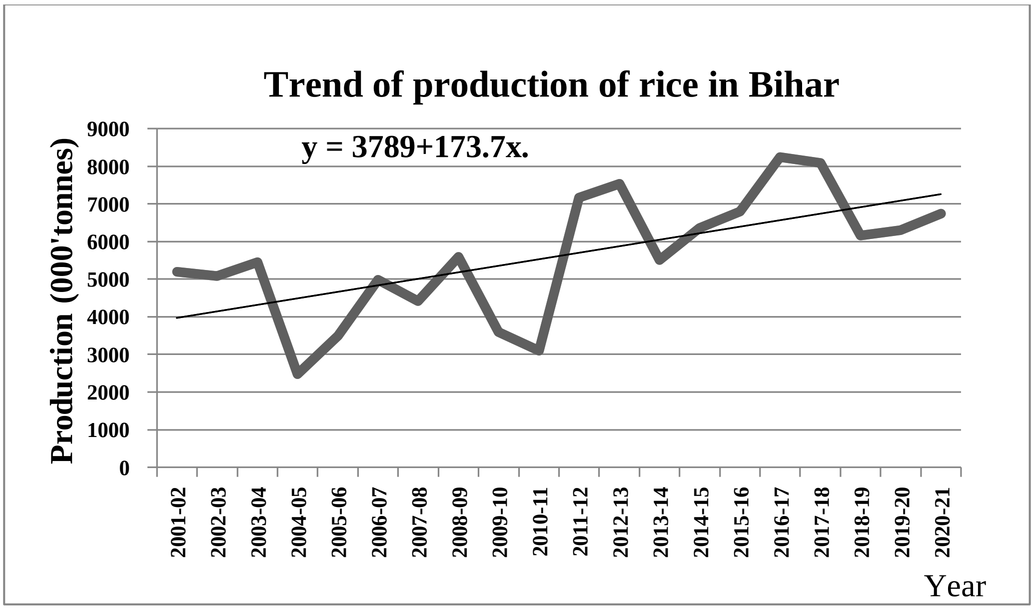

Fig.21: Graph of trend value of rice production (000'tonnes) in Bihar

The trend value of production of rice has been plotted in Fig.21. This plot is showing that production of rice is increasing in linear fashion. Minimum production of rice in Bihar was 2472.2 thousand tonnes in the year 2004-05 and maximum production of rice in Bihar was 8239.26 thousand tonnes in 2016-17 it was.

The fitted trend equation was obtained as-

$y=3789+173.7x$

Where y was production in thousand tonnes and x was years.

Table 29. Selection of best fit model for rice production in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA(1,0,1)	**0.43**	**1292.50**	**18.77**	**14.77**
ARIMA(1,1,1)	0.34	1432.30	23.48	14.99
ARIMA(0,1,1)	0.30	1434.29	24.57	14.84
ARIMA(2,1,0)	0.34	1428.40	20.47	14.99
ARIMA(2,1,1)	0.41	1399.89	22.17	15.10

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For production of rice ARIMA (1,0,1) was the best fit model. Its R-square and MAPE value was 0.43 and 18.77 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (1,0,1) model was suitable for predicting the rice production in Bihar.

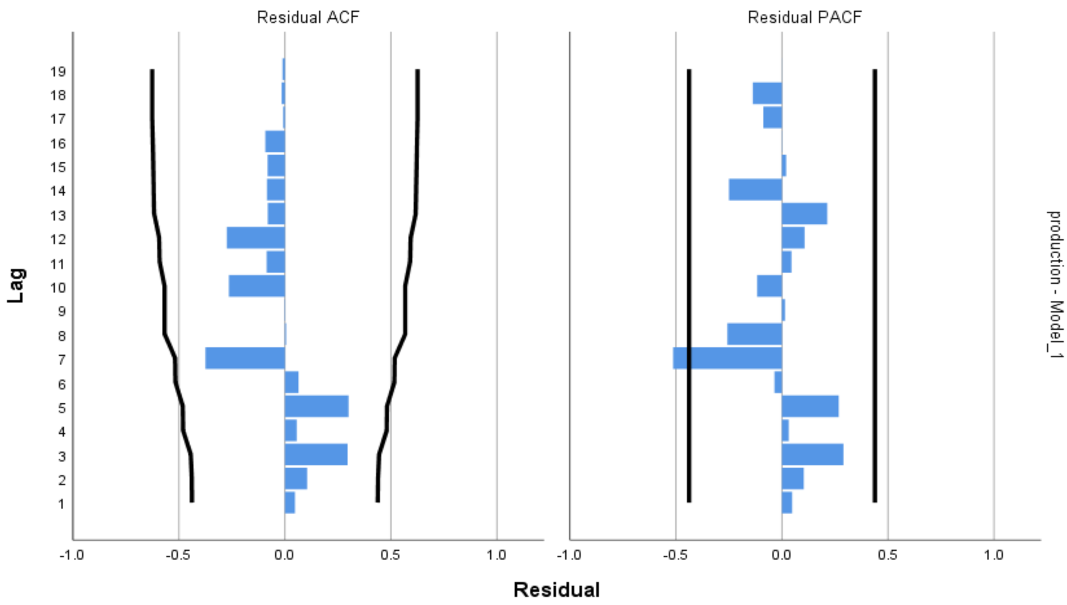

Fig.22: Residual ACF and PACF plots of the best fitted ARIMA (1,0,1) model confirms the adequacy of the model for rice production

Forecasting

Table 30. Forecasting of rice production in Bihar

Years	Forecast (000'tonnes)	Upper confidence limit	Lower confidence limit
2021-22	6305.43	8912.13	3698.73
2022-23	5642.8	9173.70	2111.9
2023-24	5669.25	9201.43	2137.07
2024-25	5668.20	9200.38	2136.02
2025-26	5668.24	9200.42	2136.06

The model ARIMA (1,0,1) was used to forecast the production of rice for the period 2021-22 to 2025-26. It has been found that production of rice would decrease from 6305.43 thousand tonnes to 5668.24 thousand tonnes in the year 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.4.3 Forecasting of rice yield in Bihar

Trend estimation

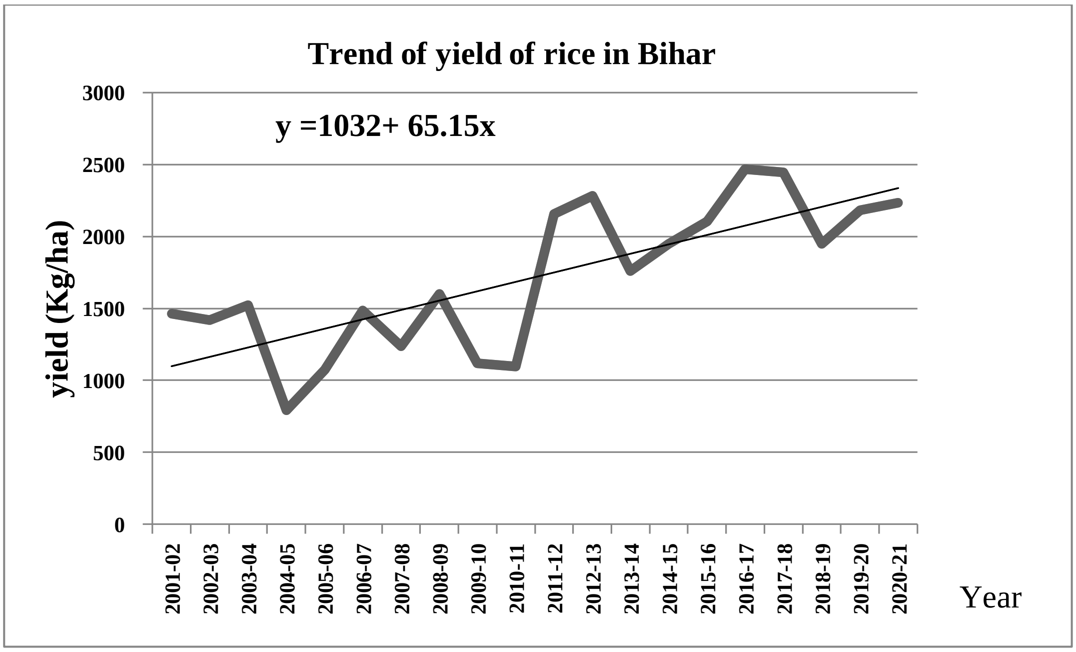

Fig.23: Graph of trend value of rice yield (Kg/ha) in Bihar

The trend value of yield of pulses has been plotted in Fig.23. This plot is showing that yield of rice is increasing in linear trend. Minimum yield of rice in Bihar was 792 Kg/ha in the year 2004-05 and maximum yield of pulses in Bihar was 2467 Kg/ha in 2016-17.

The fitted trend equation was obtained as-

y= 1032+65.15x

Where y was yield in kg/ha and x was years.

Table 31. Selection of best fit model for rice yield in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.44	398.03	20.20	12.42
ARIMA (1,1,1)	0.53	372.82	19.22	12.30
ARIMA (0,1,1)	0.50	372.65	20.05	12.15
ARIMA (2,1,0)	0.53	374.57	16.73	12.31
ARIMA (2,1,1)	0.566	371.77	18.92	12.45
ARIMA (2,1,2)	**0.64**	**351.21**	**15.54**	**12.49**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For yield of rice ARIMA (2,1,2) was the best fit model. Its R-square and MAPE value was 0.64 and 15.54 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,2) model was suitable for predicting the rice yield in Bihar.

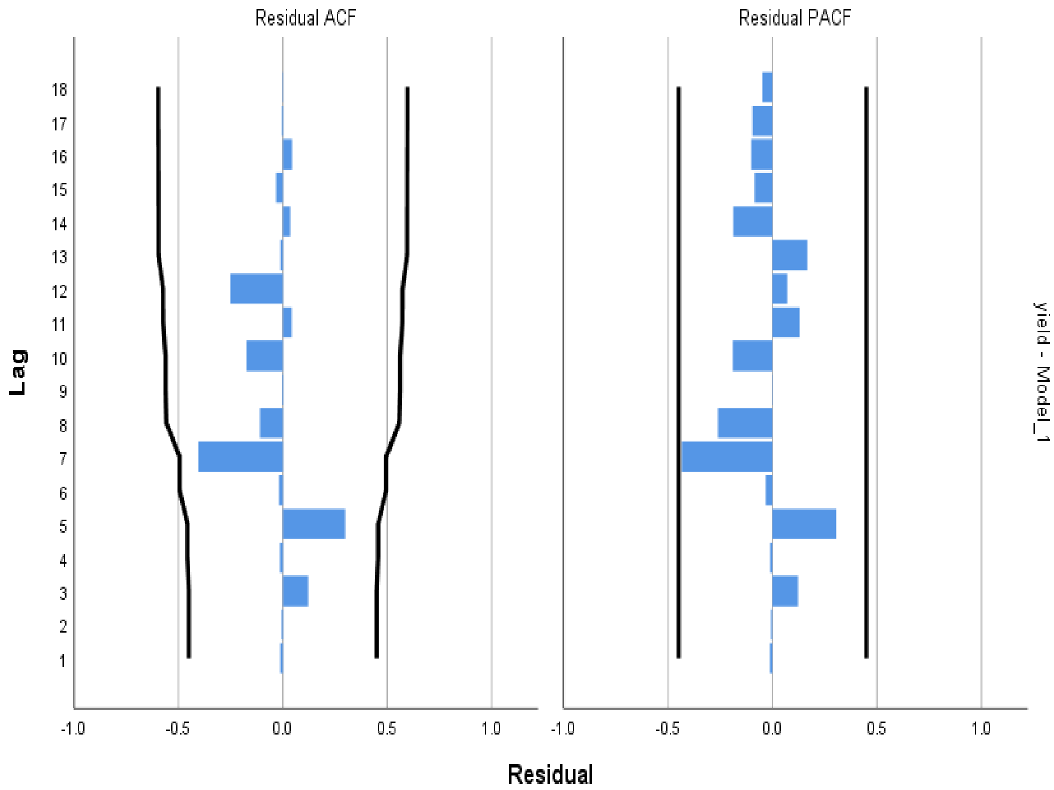

Fig.24: Residual ACF and PACF plots of the best fitted ARIMA (2,1,2) model confirms the adequacy of the model for yield of rice

Forecasting

Table 32 Forecasting of rice yield

Years	Forecast (kg/ha)	Upper confidence limit	Lower confidence limit
2021-22	2287.54	2974.34	1600.73
2022-23	2477.02	3304.18	1649.87
2023-24	2499.12	3338.85	1659.39
2024-25	2562.71	3404.00	1721.41
2025-26	2628.90	3471.01	1786.79

The model ARIMA (2,1,2) was used to forecast the yield of rice for the period 2021-22 to 2025-26. It has been found that yield of rice would increase from 2287.54 Kg/ha to 2628.90 Kg/ha in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.5 Maize

3.5.1 Forecasting of area under maize in Bihar

Trend estimate

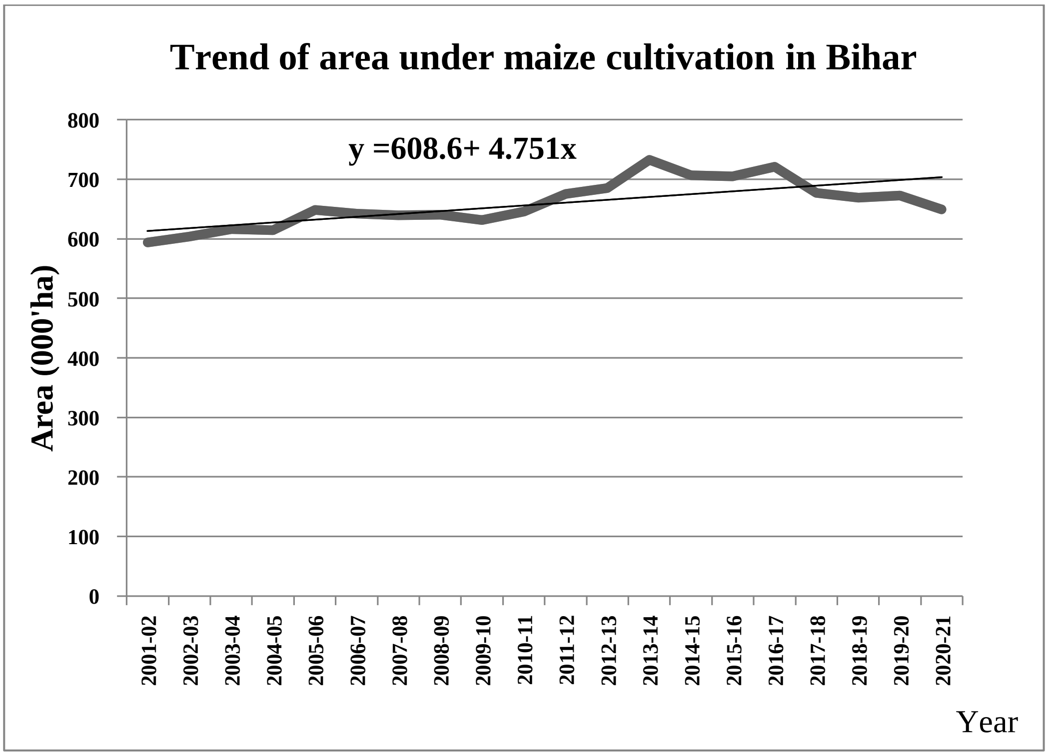

Fig.25: Graph of trend value of area of maize (000'ha) in Bihar

The trend value of area of maize has been plotted in Fig.25. This plot is showing that area of maize is increasing in linear fashion. Maximum area under maize in Bihar was 732.3 thousand hectare in 2013-14 and minimum area under maize in Bihar was 594.3 thousand hectare in the year 2001-02.

The fitted trend equation was obtained as-

y =608.6 + 4.751x

Where y was area in thousands hectare and x was years.

Table 33. Selection of best model for area of maize in Bihar

Models	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,0,1)	0.64	24.26	2.48	6.82
ARIMA (1,1,1)	0.67	22.20	2.26	6.66
ARIMA (0,1,1)	0.66	21.85	2.37	6.47

ARIMA (2,1,0)	0.66	22.43	2.42	6.68
ARIMA (2,1,1)	0.67	22.88	2.29	6.88
ARIMA (2,1,2)	**0.78**	**19.36**	**1.92**	**6.70**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For area of maize ARIMA (2,1,2) was the best fit model. Its R-square and MAPE value was 0.78 and 1.92 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the area under maize in Bihar.

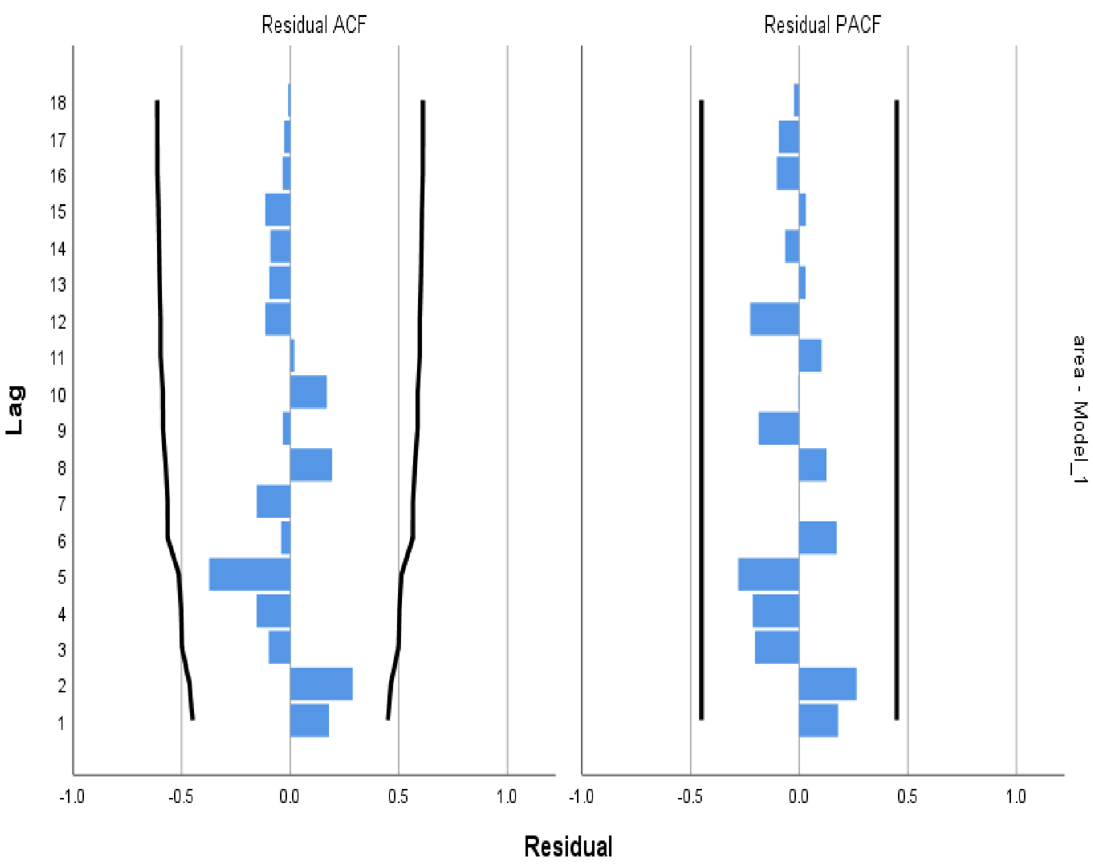

Fig.26: Residual ACF and PACF plots of the best fitted ARIMA (2,1,2) model confirms the adequacy of the model for area of maize

Forecasting

Table 34. Forecasting of area under maize in Bihar

Years	Forecast (000'ha)	Upper confidence limit	Lower confidence limit
2021-22	670.60	709.96	631.24
2022-23	666.91	724.28	609.53
2023-24	661.40	728.88	593.91
2024-25	683.15	762.59	603.72
2025-26	668.24	756.83	579.65

The model ARIMA (2,1,2) was used to forecast the area of maize for the period 2021-22 to 2025-26. It has been found that area of maize would decrease from 670.60 thousand hectare to 668.24 thousand hectare. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.5.2 Forecasting of maize production in Bihar

Trend estimation

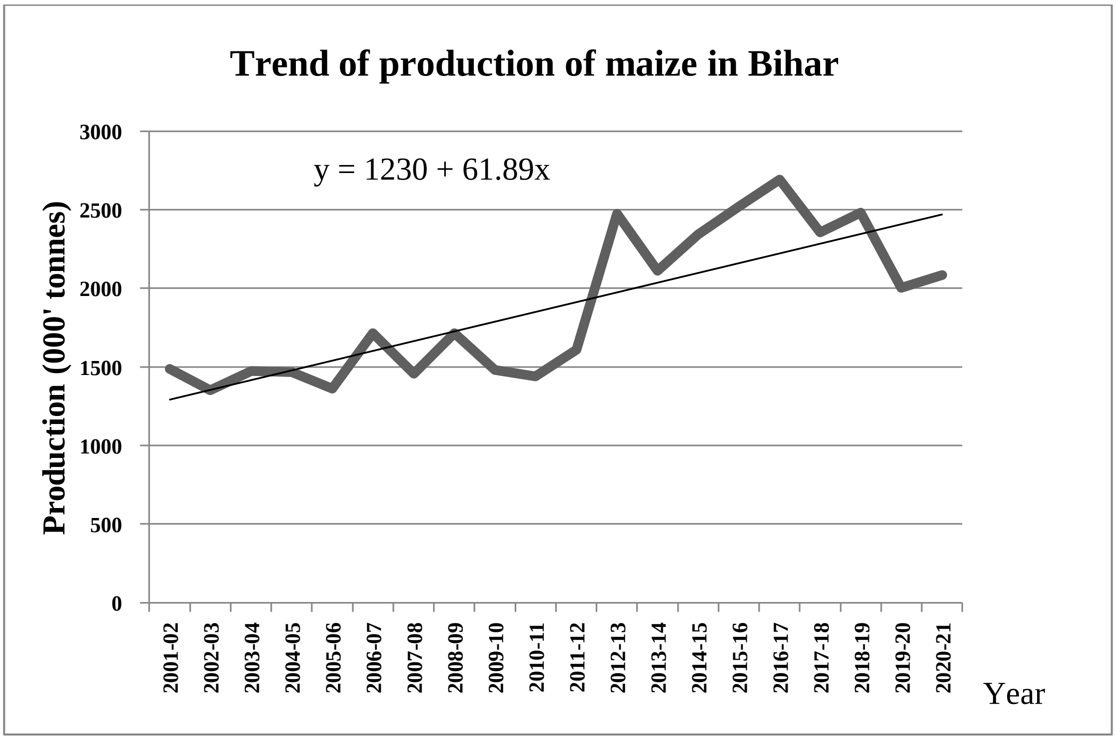

Fig.27: Graph of trend value of maize production (000'tonnes) in Bihar

The trend value of production of maize has been plotted in Fig.27. This plot is showing that production of maize is increasing in linear pattern. Minimum production of maize in Bihar was 1349.8 thousand tonnes in the year 2002-03 and maximum production of maize in Bihar was 2690.29 thousand tonnes in the year 2016-17.

The fitted trend equation was obtained as-

$y= 1230 + 61.89x$

Where y was production in thousand tonnes and x was years.

Table 35. Selection of best fit model for maize production in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA(1,0,1)	0.60	305.44	11.44	11.89
ARIMA(0,1,1)	0.61	296.81	10.76	11.69
ARIMA(1,1,1)	0.64	293.13	11.03	11.82
ARIMA(2,1,0)	0.62	303.04	10.24	11.89
ARIMA(2,1,1)	**0.63**	**309.30**	**10.03**	**12.08**

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For production of maize ARIMA (2,1,1) was the best fit model. Its R-square and MAPE value was 0.63 and 10.03 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (2,1,1) model was suitable for predicting the maize production in Bihar.

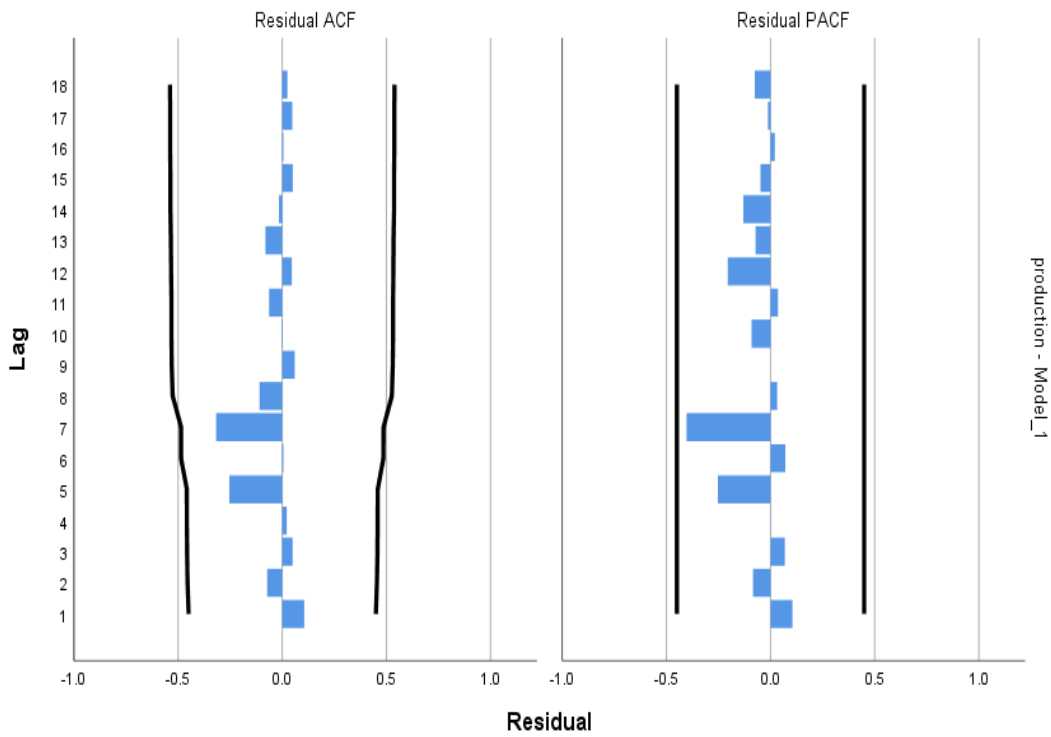

Fig.28: Residual ACF and PACF plots of the best fitted ARIMA (2,1,1) model confirms the adequacy of the model for maize production

Forecasting

Table 36. Forecasting of maize production in Bihar

Years	Forecast (000'tonnes)	Upper confidence limit	Lower confidence limit
2021-22	2048.13	2703.55	1392.71
2022-23	2154.19	2904.73	1403.66
2023-24	2107.86	3011.31	1204.41
2024-25	2218.05	3218.57	1217.54
2025-26	2170.06	3278.09	1062.04

The model ARIMA (2,1,1) was used to forecast the production of maize for the period 2021-22 to 2025-26. It has been found that production of maize would increase from 2048.13 thousand tonnes to 2170 thousand tonnes in 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

3.5.3 Forecasting of yield of maize in Bihar

Trend estimation

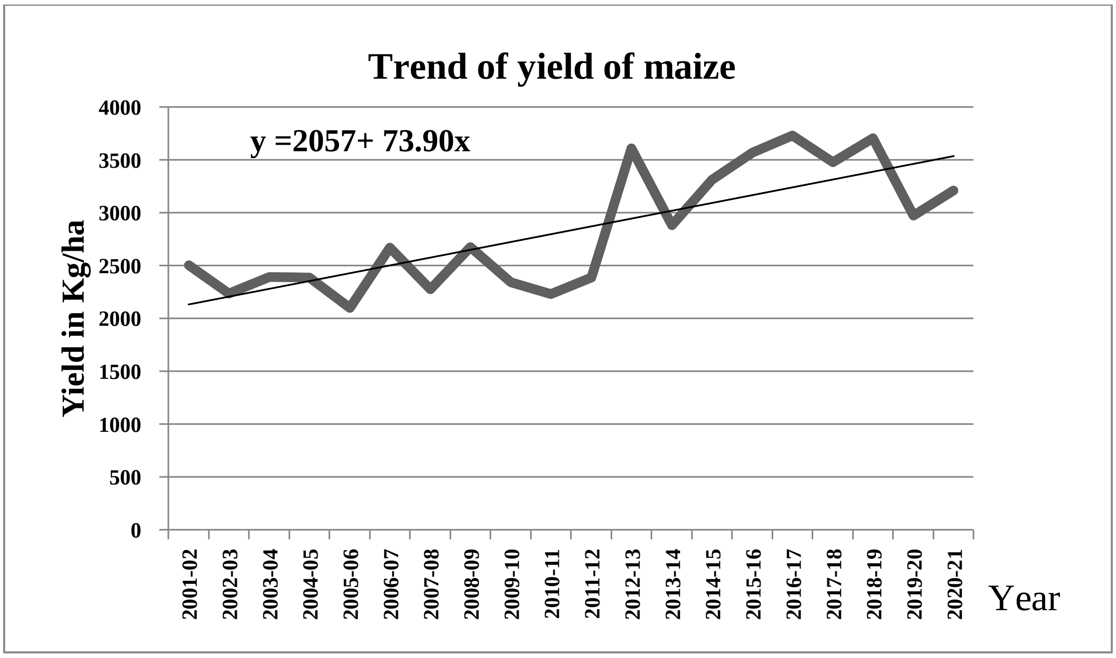

Fig.29: Graph of trend value of maize yield (Kg/ha) in Bihar

The trend value of yield of maize has been plotted in Fig.29. This plot is showing that yield of maize is increasing in linear pattern. Minimum yield of maize in Bihar was 2098 Kg/ha in the year 2005-06 and maximum yield of maize in Bihar was 3732 kg/ha in the year 2016-17.

The fitted trend equation was obtained as-

$y=2057+ 73.90x$

Where y was yield in kg/ha and x was years.

Table 37. Selection of best fit model for maize yield in Bihar

Model	R-Square	RMSE	MAPE	Normalized BIC
ARIMA (1,1,0)	**0.51**	**413.63**	**9.42**	**12.36**
ARIMA (1,0,1)	0.49	423.95	10.76	12.55
ARIMA (0,1,1)	0.52	410.76	10.62	12.34
ARIMA (1,1,1)	0.52	422.00	9.67	12.55
ARIMA (2,1,0)	0.52	422.95	9.46	12.56

ARIMA (2,1,1)	0.56	416.02	10.26	12.68

For selection of best fit model value of R-square, RMSE, MAPE and Normalized Bayesian information criteria was computed. The model which had highest R-square value and lowest MAPE value was taken as best fit model. For yield of maize ARIMA (1,1,0) was the best fit model. Its R-square and MAPE value was 0.51 and 9.42 respectively.

Diagnostic checking

The model was verified with checking residual of model. It was observed by Residual of ACF and PACF that there was not any systemic pattern. Various autocorrelations with lags up to 18 were estimated for this purpose. It had established that the ARIMA (1,1,0) model was suitable for predicting the maize yield in Bihar.

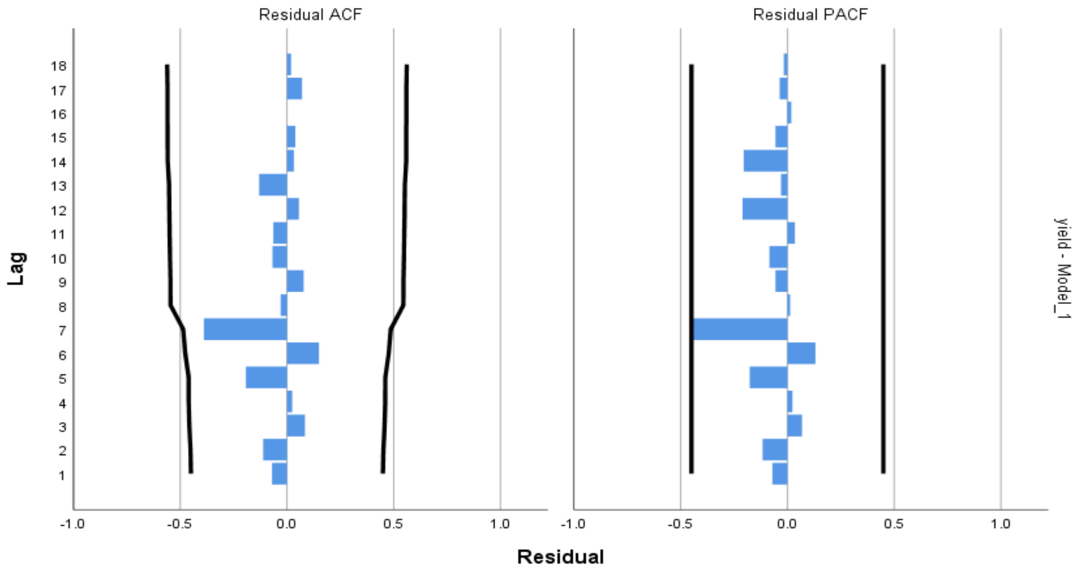

Fig.30: Residual ACF and PACF plots of the best fitted ARIMA (1,1,0) model confirms the adequacy of the model for yield of maize

Forecasting

Table 38.Forecasting of maize yield

Years	Forecast (kg/ha)	Upper confidence limit	Lower confidence limit
2021-22	3150.71	4019.78	2281.64
2022-23	3240.10	4209.75	2270.45
2023-24	3253.88	4422.25	2085.51
2024-25	3305.85	4592.89	2018.51

2025-26	3338.53	4757.03	1920.03

The model ARIMA (1,1,0) was used to forecast the yield of maize for the period 2021-22 to 2025-26. It has been found that yield of maize would increase from 3150.71 Kg/ha to 3338.53 Kg/ha in the year 2025-26. This model had demonstrated a good performance in terms of explained variability and predicting power.

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CHAPTER - V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Bihar stands at seventh position in foodgrains production in the country. It had produced 15.38 million tonnes in the year 2020-21 from an area of 6.36 million hectare. Production of cereals was 15 million tonnes from which rice accounts for 6.74 million tonnes and maize accounts for 2.08 million tonnes of production but pulses contribute only 0.38 million tonnes. The study has been conducted with three objectives i.e.i) to analyze the temporal patterns of production-growth and decomposition of its components. ii) to examine the cropping intensity, yield and change in yield under changing land use dimensions and iii) to forecast the area, production and productivity of Food grains using various model of time series. The study was based on secondary data which was collected from Directorate of Economics and Statistics, Govt. of India. Software package SPSS was used to forecast the area, production and yield of foodgrains.

It was observed that growth rate in area of foodgrains was negative in every decades during the whole study period. Production and yield of foodgrains was showing positive growth rate except in second decade (2001-02 to 2010-11) in which growth rate in production of foodgrains was negative. For cereals also negative growth rate in area was observed in all the three decades. Production was showing positive growth rate in first and third decade but it was showing negative growth rate in second decade. In pulses negative growth rate for area as well as for production was observed in every decade. As a major food crops in Bihar i.e. rice was studied and found that growth rate in area of rice was negative in three decades under study. Growth rate in production of rice was showing positive growth rate in first decade and it was showing negative growth rate in second and third decade due to area effect. Yield of rice was showing positive growth rate in first and third decade and it was showing negative growth rate in second decade. Growth rate in area of maize was negative in first and third decade but it was positive for second decade. Production of maize was showing positive growth rate in all the decade due to yield effect. Yield of maize was showing positive growth rate in first and third decade but it had sown negative growth rate in second decade.

The instability in area of foodgrains was highest in first decade followed by second and third decades. In production of foodgrains maximum instability was observed in second decade followed by first and third decade and its yield was also showing maximum instability in second decade followed by first and third decade. Similar pattern was observed in cereals also, highest instability in area was observed in first decade followed by second and third decade and for production and yield maximum instability was observed in second decade followed by first and third decade. For pulses scenario was different highest instability in area production and yield was observed in first decade followed by second and third decade. Among cereals area of rice was showing maximum instability in first decade followed by second and third decade. For production of rice maximum instability was observed in second decade followed by first and third decade and yield of rice was showing maximum instability in first decade followed by second and third decade. For maize area was showing highest instability in first decade followed by second and third decade, production was showing highest instability in third decade followed by first and second decade and its yield was showing highest instability in third decade followed by second and first decade.

The decomposition analysis revealed that production of food grains was mainly affected by yield effect except in second decade in which it was majorly affected by area effect. Production of cereals was also contribution of yield effect was more in every decade. But for pulses area effect was contributing majorly in change in production. For rice and maize also yield effect was majorly contributing in total production in all the decade but in third decade area of rice was majorly (156%) contributing in production change.

Variation in gross cropped area, net sown area, forest area, fallow land and cropping intensity were observed for 18 years (2001-02 to 2018-19) after bifurcation of Jharkhand and Bihar. It was found that net area sown and gross cropped area had been decreased by 8.77% and 6.21% respectively during the last 18 years. Forest area, fallow land and cropping intensity had been increased by 18.64%, 59.68% and 2.79% respectively due to concentrated efforts of various stake holders.

Yield of major food crops in Bihar was observed for 18 years from 2001-02 to 2018-19 and it was found that productivity is increasing day by day. Maximum change in yield was observed in oilseeds (48.74%) followed by maize (48.08%) and wheat (45.18%) and minimum change in yield was observed for pulses (20.05%)

followed by rice (32.96%) and total cereals (43.0%). Total change in foodgrains was 44.35%.

The trend analysis of data of area, production and yield of foodgrains was showing decreasing trend in area and production and yield was showing positive and increasing trend. The autoregressive (p) and moving average (q) parameters were identified based on significant spike in plot of PACF and ACF of various time series model. Forecasting was made for upcoming years from 2021-22 to 2025-26. The model which had minimum value of RMSE, MAPE and BIC was taken as best fit model. ARIMA (2,1,1) model was best fitted model for the area, production and yield of foodgrains. The forecasted result showed that area of foodgrains would decrease from current area of 6.4 million hectare to 6.2 million hectare in 2025-26. The production would increase to 17.99 million tonnes in 2025-26 from its current production level of 17.06 million tonnes because yield would increase from 2597.62 kg/ha to 2817.47 kg/ha.

Forecasting of area, production and productivity of cereals were showing similar trend as of foodgrains. ARIMA (2,1,1) was also found as the best fit model to for area, production and yield of cereals. The forecasted value of area, production and yield of cereals revealed that area of cereals would decrease from 6.06 million hectare in 2021-22 to 5.92 million hectare in 2025-26 and production of cereals would increase from 16.6 million tonnes in 2021-22 to 17.5 million tonnes in 2025-26 and yield of cereals would further increase from 2710.42 Kg/ha in 2021-22 to 2949.71 Kg/ha in 2025-26.

For forecasting the area and production of pulses ARIMA (1,1,1) was the best fit model. Area of pulses was showing decreasing trend. Forecasted value for area of pulses revealed that would decrease in near future. Area of pulses would decrease from 0.42 million hectares in 2021-22 to 0.37 million hectares in 2025-26. Its production was also showing decreasing trend. Pulse production would increase (0.386 million tonnes) first after that it will decrease (0.373 million tonnes). For yield of pulses ARIMA (1,0,1) was the best fit model. Pulses yield is going to decrease in coming year from 855.03 kg/ha to 851.8 kg/ha.

The best fit model for area of rice was ARIMA (2,1,0) which revealed that area under rice cultivation would decrease from 3.04 million hectare in 2021-22 to 2.87 million hectare in 2025-26. For production of rice best fit model was ARIMA

(1,0,1) model which had forecasted that production of rice would decrease from 6.3 million tonnes in 2021-22 to 5.6 million tonnes in 2025-26. But yield of rice would increase from 2287.5 Kg/ ha in 2021-22 to 2628.9 Kg/ha in 2025-26. It was revealed by forecasting through ARIMA (2,1,2) model.

For area of maize ARIMA(2,1,2) was the best fit model which revealed that area under maize cultivation would first increase from 0.67 million hectares in 2021-22 to 0.68 million hectares in 2022-23 but after that it would decrease to 0.66 million hectare in 2025-26. Best fit model for production of maize was ARIMA (2,1,1) model which had forecasted that production would increase from 2.04 million tonnes in 2021-22 to 2.17 million tonnes 2025-26. Yield of maize would also increase from 3150.71 Kg/ha in 2021-22 to 3338.53 Kg/ha in 2025-26 as it was forecasted through best fitted ARIMA (1,1,0) model.

Suggestions and policy implications

Though the production of foodgrains in Bihar increased a lot from 11.68 million tonnes in 2001-02 to 15.38 million tonnes during 2020-21, still the State is able to meet only 86% of its requirement. Rest, 14% of its requirement is met up through bringing foodgrains from outside the State. There is a need to adopt the high yielding varieties and improved production technology to increase the production of foodgrains to make Bihar self-sufficient in foodgrain production. Fallow lands should be used for production of pulses as Bihar is highly deficient in pulse production. Using residual moisture (after rice and maize cultivation) fallow lands may be used for cultivation of pea (using zero tillage) to boost pulse production in the State. There is a huge scope to increase the cropping intensity in Bihar as most of the lands are lying vacant after cultivation of paddy and maize. Awareness may be created to cultivate short duration variety of rice and maize to grow other additional crops to increase cropping intensity. The cropping intensity in Bihar is 143% which may be increased further. If cropping intensity becomes 175% to 180% which is achievable through using existing seed and production technologies, Bihar would become self reliant in food production. There is a need for concentrated efforts from various line departments to work together to make Bihar not only food secure but to make Bihar nutritionally secure also.

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