TREND AND FORECASTING OF MAJOR CEREALS PRODUCTION IN NEPAL: AN AUTOREGRESSIVE INTEGRATION MOVING AVERAGE APPROACH

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ABSTRACT

Paddy, maize and wheat are the major staple food crops grown and consumed in Nepal. But the country has been relying heavily on the import for meeting its demand in recent past. In this context, the study was carried out to analyze the pattern and prediction of paddy, maize and wheat production in Nepal. The time series data on production of paddy, maize and wheat in Nepal for the period of 1961/62 to 2023/24 were used to identify the trend, and the most widely used time series model, Autoregressive Integrated Moving Average (ARIMA), was applied for modelling and forecasting the production of selected three crops. The best fit ARIMA models for forecasting were found (1,1,1,) for paddy (3,1,1,) for maize and (1,1,1,) for wheat respectively. These models were further analyzed to validate for no significance autocorrelation among residuals. Although, the identified models were found more reliable in forecasting production trend of paddy, maize and wheat for 2025/26 to 2029/2030. Moreover, the increasing trend was projected for all the three crops through these best fit models. The forecasted value of paddy, maize and wheat for the year 2025/26 will 6497197 MT, 3319077 MT and 2360210 MT which will raise to 7047955 MT, 3666644 MT and 2878554 MT for the year 2029/30 respectively. The result from the study implies the increasing trend of paddy, maize and wheat in future which would play a vital role in designing production plan, food security, import reduction and maintain price stability in the market.

Keywords: *Box Jenkins model, Forecasting, Augmented Dickey Fuller test, Production*

INTRODUCTION

Main staple food in the world like maize, wheat and rice accounts around 90 percent of global food consumption (Gorska et al., 2021). Global food demand is increased due to the rapid increase in population subsequently sustainable environmental concern (Godfray et al., 2010; Noya. et al., 2018) It is projected that the world population will reach 9 billion by 2050, to feed this growing population food supply need to increase by approximately 70 percent (Godfray et al., 2010; Pye-Smith, 2011). However, the rate of production was increased with lower rate which is due to the dramatic decline of fertile land and availability of water (Hawkesford, 2013). Nepal is endowed of varied agroclimatic condition and geographic distribution. This benefited production of diversified crops in all part of Nepal such as Mountain, Hills and Terai. Terai region is known for food basket of Nepal. Major portion of cereals are produced in terai. In Nepal, paddy, maize and wheat sequentially have higher rank in production. Since the contribution of agriculture sector in Nepalese GDP is 24.09 percent in which paddy, maize and wheat accounts 12.81%, 6.63% and 5.87%, respectively (MoALD, 2025).

Table 1. Production status of major cereals of last five years in Nepal.

Crops	2019/20	2020/21	2021/22	2022/23	2023/24
Paddy (MT)	5550878	5621710	5130625	5486472	5724234
Maize (MT)	2835674	2997733	3106397	2976491	3193869
Wheat (MT)	2185289	2127276	2144568	2098462	2035559

(Source- MoALD, 2025)

Forecasting production and productivity of the agricultural products was common practices since past time. However, several statistical methods have been developed for forecasting different aspects of agricultural products (Hanke & Wichern, 2008). Most commonly used method for forecasting future aspects based on past observation is time series analysis (Enders, 2015; Ali et al., 2015), who analyze those different statistical models used in appropriate forecasting of agricultural productions. Among univariate time series data analysis method, the most popularly used technique is Autoregressive Integrated Moving Average (ARIMA) model, also known as the Box Jenkins approach (1970). Harris et al. (2012) used ARIMA model to forecast coffee production in Ghana using time series data from 1990 to 2010. Kumar and Anand (2014) analyzed the sugarcane production in India through ARIMA model from the data 2013 to 2017. Similarly, maize production was forecasted in India from 2017 to 2022 (Sharma et al., 2018; Poudel, 2024), forecasted area production and yield of maize in Nepal from 1963/64 to 2022/23.

Nepalese economy is dominated by agricultural sector, according to the Agricultural Census 2021, 57.3 percent of population is involved in agriculture. Cereals play a vital role in Nepalese food habit because cereals are the main source of nutrition. The growing population threatens the country for food insufficiency in such case country need to forecast their demand and supply of agricultural products. The future prediction of agricultural commodities is vital for controlling import/ export as well as price stability of any country (Badmus & Ariyo, 2011). This study analyzed the status of production of major cereals and the production forecasting model ARIMA will estimate the future production through which researcher and policy maker will identify the gap between future demand and supply of major cereals and recommend for the future action.

METHODOLOGY

The study was conducted by using time series data of production of rice, maize and wheat in Nepal from the year 1961/62 to 2023/24. The production data were collected through Statistical Information in Nepalese Agriculture published by Ministry of Agricultural and Livestock Development in the year 2025. The data were analyzed through MS Excel and SPSS for production trend throughout the time period and forecasting future value.

The data were analyzed and forecasted for the time period 2029/30 using Box Jenkins technique. Box Jenkins method (1970) called ARIMA (p, d, q) model consists of three components Autoregressive (AR) (p), integrated which indicate lag of differenced (d) and moving average (MA) (q). The aim of using ARIMA model was for identifying the stochastic process of the time series and forecast future value accurately (Verbeek, 2004). The stochastic process is stationary and satisfy following condition.

$$E(Yt) = \mu;\ E\ [(Yt - \mu)^2] = \sigma 2;\ Cov\ (Yt,\ Y_{t+k}) = \gamma(k)$$

The given equation implies that the mean, variance and autocovariance are unchanged due to change in time origin.

The equation of ARIMA model is presented as

$$Y_t = \mu + \sum_{i=1}^{p} \theta_i Y_{t-i} + \sum^{q}_{j=1} \alpha_j \varepsilon_{t-j} + \varepsilon_t$$

Where, Yt is assume variable at a given time t, μ is the mean series, $\theta 1 \ldots\ldots \theta p$ are parameter of AR model, $\alpha 1 \ldots\ldots \alpha q$ are the parameters of MA model and $\varepsilon t, \ldots \varepsilon t\text{-}1, \ldots.$ $\varepsilon t\text{-}q$ are white noise residuals.

Model prediction and validation

ARIMA model was used for the model prediction and validation of production of major cereals paddy, maize and wheat in Nepal. Before selecting the appropriate ARIMA model, the time series data must be tested for stationary, which is generally done using the Augmented Dickey- Fuller (ADF) test. The differencing of ‘d’ order was done until the series become stationary as denoted by the ADF test. Afterward, Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) were plotted to observed whether spikes showed significance or non-significance. Subsequently, ARIMA model was used to identify appropriate order (p, d, q) for each time series data of production of paddy, maize and wheat. The future prediction was then done using the selected best fit models. However, some studies had applied the ARIMA model to forecast the increasing trend of wheat, barley and maize production in Turkey for the period 2016 to 2025 (Celik, 2016). Similarly, positive trend in the area, production and yield of maize was forecasted in Nepal from 2023/24 to 2029/30 (Poudel, 2024). Amin at al., (2014) used the ARIMA model of order (0,2,1) for area and production and (0,2,1) for productivity respectively implies the best model accuracy for further prediction.

RESULTS AND DISCUSSION

Trend analysis of major cereals production in Nepal.

The trend analysis of paddy, maize and wheat production revealed the positive and increasing scenario form the year 1961/62 to 2023/24. The R square value and equation revealed the paddy production was increased approximately on an average 62812 mt/yr. In addition, an R-square value of 87.6 indicates a perfect relationship between paddy production and time horizon shown in Figure1. Similarly, maize production was grown consistently and steadily that means its annual average production was about 35963 mt. The R square value indicates 84.24 percent of variation had strong relationship between maize production and time period shown in Figure 2. Wheat production was observed most consistent and predictable growth pattern among these three cereals. The production of wheat was increased by 35574 mt/yr and the R square value indicates perfect relationship between production and time which was 97.03 percent shown in Figure 3. The result observed among three crops shows the perfect and predictable trend.

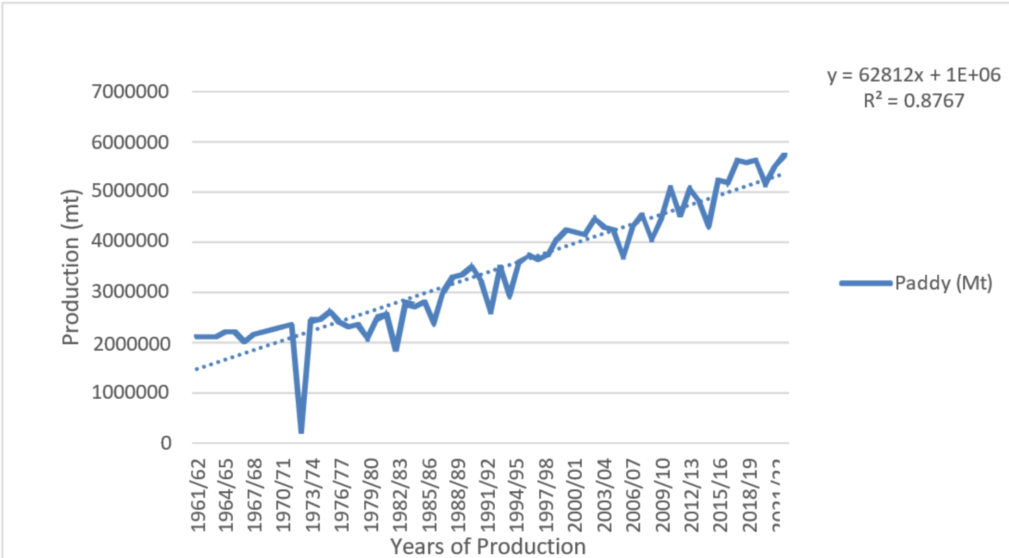


Figure 1. Trend of paddy production in Nepal from 1961/62 to 2023/24

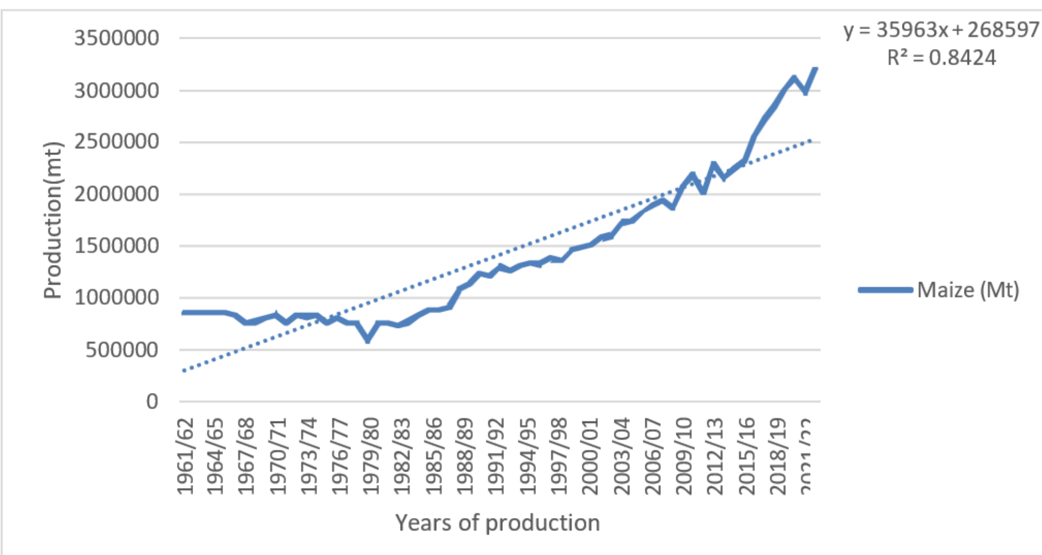


Figure 2. Trend of maize production in Nepal from 1961/62 to 2023/24

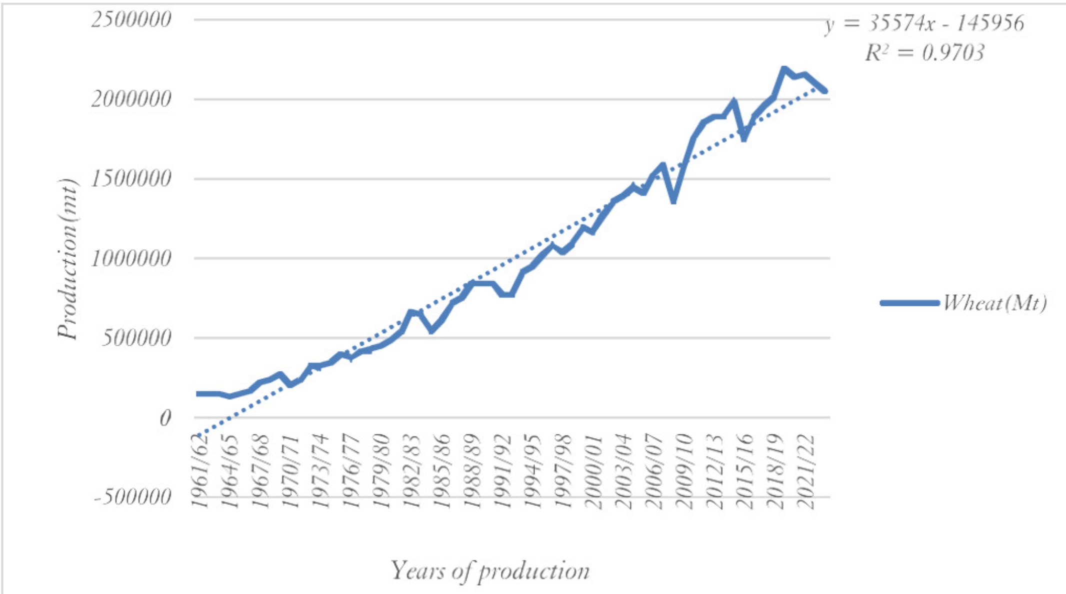


Figure 3. Trend of wheat production in Nepal from 1961/62 to 2023/24

Developing ARIMA model

The long- term increasing trend of three major crops paddy, maize and wheat was observed while inserted in sequence chart shown in the Figure 4(a), (b) and (c). Paddy production indicates relatively stable growth pattern as compare to maize and wheat. Since increasing trend was consistent with gradual improvement in use of hybrid seed, fertilizers, technology and cultivated land. Similar upward trend in cereal production had observed in other developing countries (FAO, 2022).

The best fit ARIMA model then identified by testing different order (p, d, q). Here the time series data was made stationary using natural differencing then the stationary of the time series data was checked through the first order differencing of the original data. Regarding time series data of production of paddy, maize and wheat, the first order differencing led to the stationary because the first differencing indicated stability in variance which were seen in the Figure 5(a), 5(b) and 5(c) for paddy, maize and wheat respectively. First order differencing is usually sufficient for agricultural production data as these contain stochastic trend by affecting different factors (Gujarati and Porter, 2009). Consequently, the visual result of the stationary condition was also confirmed by checking Augmented Dickey Fuller (ADF) test shown in the Table 2. The clear upward trend observed in all the three crops shows stochastic trend. The higher p- values and greater

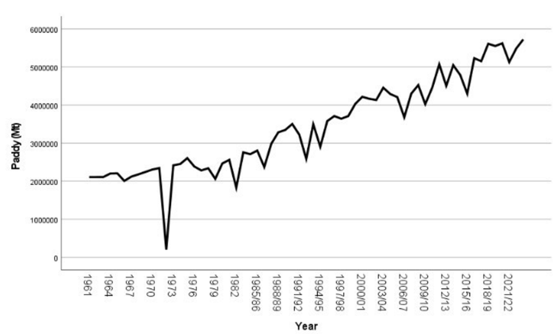
ADF statistics, which exceed the critical values, confirm that the series becomes non-stationary in their original form. However, first order differencing significantly converted the data into stationary series, as depicted in Table 3. After the series was stabilized, the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) were plotted which helped to find the degree of desired model.

Table 2. Augmented Dickey Fuller (ADF) test for major crops

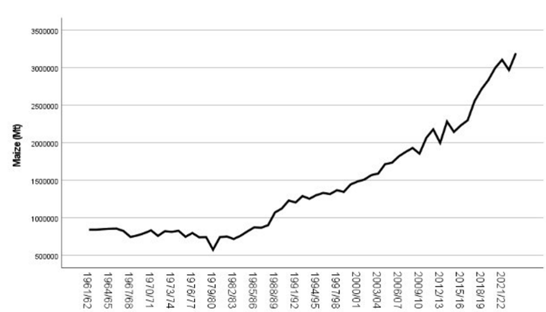
Crops	ADF statistics	p-value	Critical value (5%)
Paddy	-0.42	0.903	-2.91
Maize	+1.15	0.995	-2.91
Wheat	-0.18	0.941	-2.91

Table 3. ADF test result at First order differencing for major crops

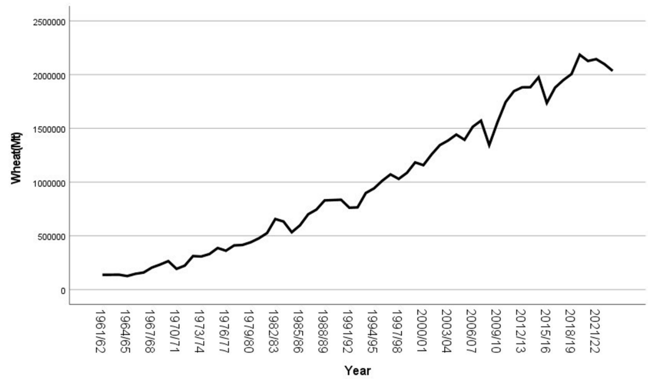
Crops	ADF statistics	p-value	Critical value (5%)
Paddy	-8.45	<0.001	-2.91
Maize	+7.12	<0.001	-2.91
Wheat	-6.89	<0.001	-2.91



(a) Trend of paddy production

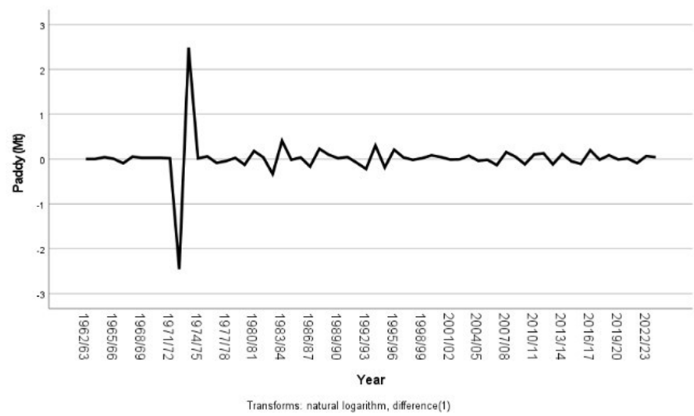


(b) Trend of maize production

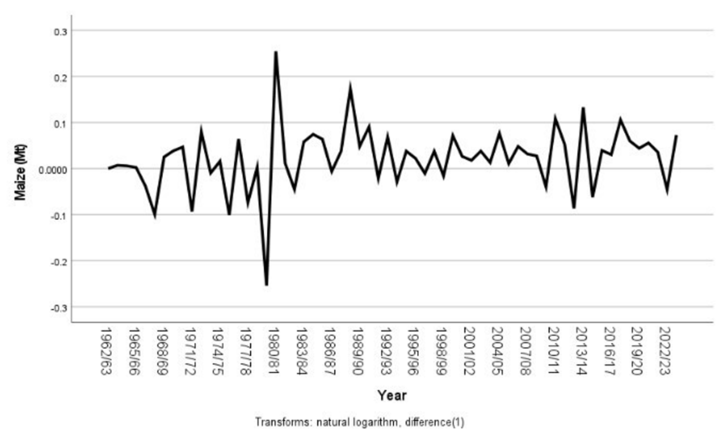


(c) Trend of wheat production

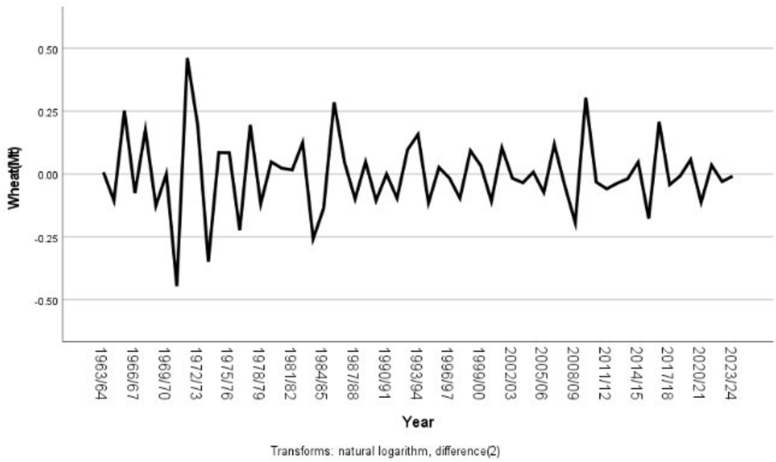
Figure 4. Trend of paddy, maize and wheat production from1961/62 to 2023/24



(a) First order differencing of paddy production



(b) First order differencing of maize production

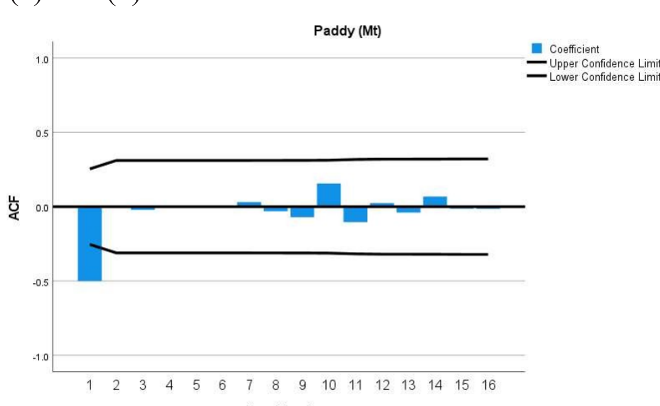


(c) First order differencing of wheat production data

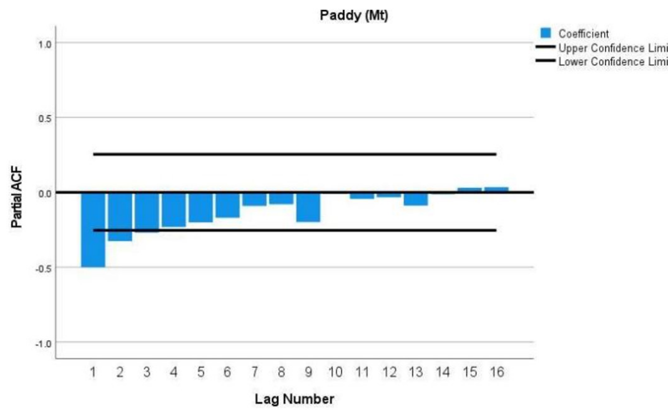
Figure 5. First order differencing of trend data for paddy, maize and wheat crops from1961/62 to 2023/24

Estimation of ARIMA (p, d, q) value using ACF and PACF

The identification of best ARIMA model for production of all three cereal crops were carried out using Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) for the above differenced series. The ACF was seen gradually tailed off whereas significant spikes at lower legs of PACF were observed in paddy indicated in Figure 6 (a) and (b), this indicates presence of both autoregression and moving average. Similarly, significant spikes were visible in both ACF and PACF at early lags in maize shown in Figure 7 (a) and (b), which suggest relatively higher order of p and q. Although simple pattern of ACF and PACF for wheat crop indicates lower order ARIMA model shown in Figure 8 (a) and (b).

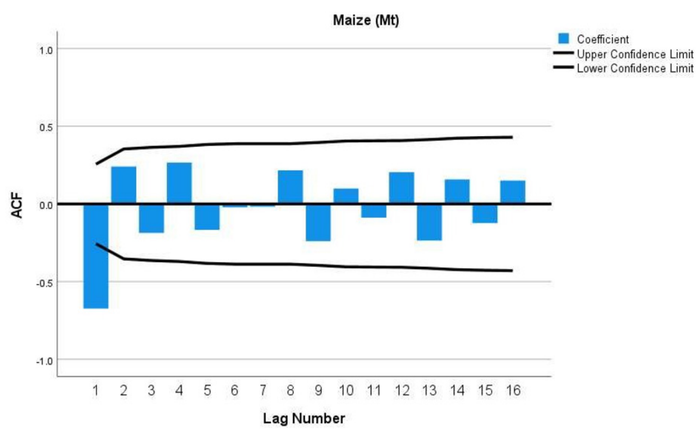


(a) Autocorrelation Function (ACF)

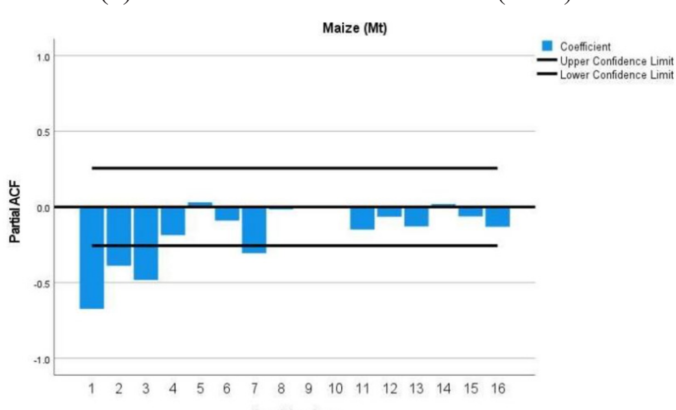


(b) Partial Autocorrelation Function (PACF)

Figure 6. Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) of paddy production time series data from1961/62 to 2023/24

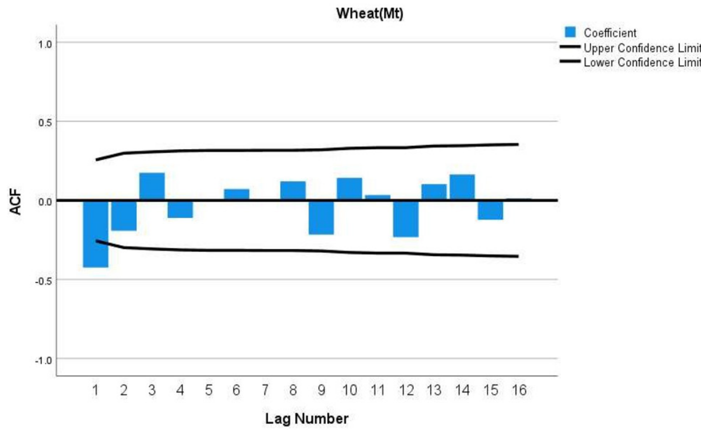


(a) Autocorrelation Function (ACF)

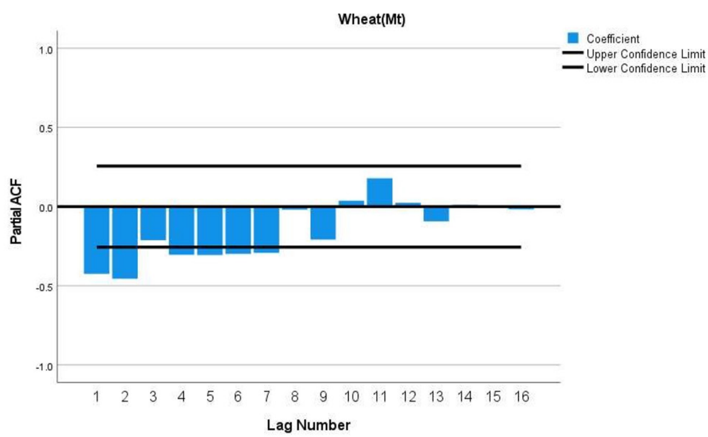


(b) Partial Autocorrelation Function (PACF)

Figure 7. Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) of maize production time series data from1961/62 to 2023/24.



(a) Autocorrelation Function (ACF)



(b) Partial Autocorrelation Function (PACF)

Figure 8. Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) of wheat production time series data from1961/62 to 2023/24

Different ARIMA model were tested with reference to the decaying of autocorrelation function and partial autocorrelation function for production of paddy, maize and wheat which was given in the Table 4. However, the best suited model selected for forecasting future trend was based basically on the following criteria.

Table 4. Description of different parameters for selection ARIMA model (Montgomery et al., 2015)

Model description	
Fit Statistics	**Remarks**
R^2 value	Value should be close to 1
RMSE	Low value indicates good model fit
MAPE	Lowest value indicates good fit
Normalized BIC	Least value is best
Model significance (p- Value) Ljung Box	greater than.05 to accept H0; residuals are white noise

Since the different ARIMA model (p, d, q); ARIMA (1,1,1), ARIMA (2,1,1), ARIMA (3,1,1) were tested with reference to the decaying level of ACF and PACF among these, the best model for forecasting paddy production was selected as ARIMA (1,1,1). The selection was based on the lowest Bayesian Information Criterion (BIC) value, lowest Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) value as presented in Table 5. Although the R^2 value was same for all the model and p- Value (Ljung Box) was higher for ARIMA (1,1,1). Similar evidence of Sivapathasundaram and Bogahawatte, 2012; estimated best fit model ARIMA (2, 1, 0) for paddy production in Sri Lanka. Although research was conducted in Bangladesh for Aus, Aman and Boro rice production, the best fit model identified ARIMA (4,1,1), ARIMA (2,1,1) and ARIMA (2, 2, 3) respectively (Awal & Siddique, 2011).

Table 5. Description of different ARIMA model for paddy

Statistics	ARIMA (1,1,1)	ARIMA (2,1,1)	ARIMA (3,1,1)
R^2 value	0.974	0.974	0.974
RMSE	13393.933	13536.927	13537.857
MAPE	4.644	4.651	4.651
Normalized BIC	19.073	19.163	19.163
p- Value (Ljung Box)	0.950	0.923	0.923

Different ARIMA model (p, d, q); ARIMA (2,1,2), ARIMA (3,1,1), ARIMA (4,1,1) were tested with reference to the decaying level of ACF and PACF. Among these, the best model for forecasting maize production was selected as ARIMA (3,1,1). The selection was based on the highest R^2 value which is near to 1, lowest BIC value, lowest RMSE value as presented in table 6. Higher p- value (Ljung Box) indicates residual independence at the 5% level. The study conducted in India revealed that the ARIMA (2,1,0) model was the best fit model for maize production and for forecasting future maize production (Sharma et al., 2018). Similarly, in case of Andhra Pradesh ARIMA (1,1,0) was found best suited model for maize production forecasting (Ramesh, Bhattacharyya & Biswas, 2014).

Table 6. Description of different ARIMA model for maize

Statistics	ARIMA (2,1,2)	ARIMA (3,1,1)	ARIMA (4,1,1)
R^2 value	0.986	0.987	0.986
RMSE	86952.772	86239.210	89.31.025
MAPE	4.567	4.657	4.769
Normalized BIC	23.079	23.063	23.193
p- Value (Ljung Box)	0.487	0.169	0.879

Similarly, different ARIMA model (p, d, q); ARIMA (1,1,1), ARIMA (2,1,1), ARIMA (3,1,1) were tested with reference to the decaying level of ACF and PACF. The best model for forecasting wheat production was selected as ARIMA (1,1,1). The selection was based on the lowest BIC value, lowest MAPE value as presented in Table 7. Although, the R^2 value was same for two model as lower value. ARIMA (1,2,2) model was identified on the basis of low BIC and low MAPE value in case of wheat forecasting in Pakistan (Amin et al., 2014). Similar research was conducted in India and found ARIMA (1,1,0) best fit for wheat production forecasting (Nath et al., 2019).

Table 7. Description of different ARIMA model for wheat

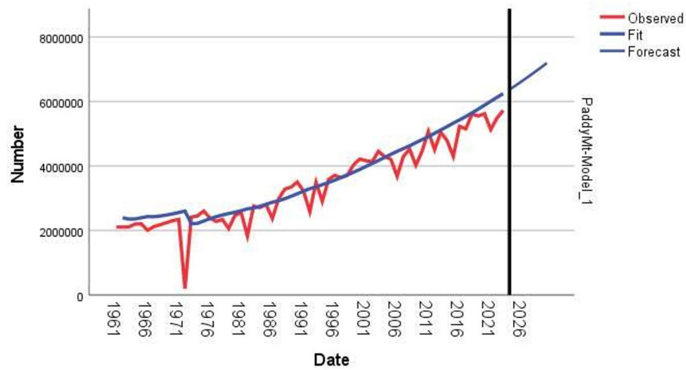
Statistics	ARIMA (1,1,1)	ARIMA (2,1,1)	ARIMA (3,1,1)
R^2 value	0.980	0.980	0.981
RMSE	93728.419	95855.702	93199.058
MAPE	7.205	7.214	7.263
BIC	23.096	23.207	23.218
p- Value (Ljung Box)	0.140	0.192	0.058

Production forecasting of major cereals

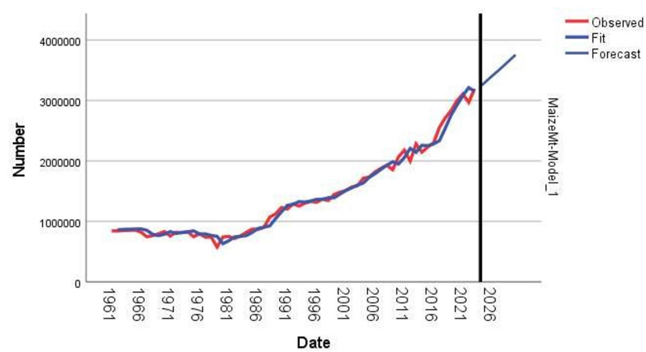
The forecasting of production for longer period do not give the accurate and reliable measure because time lags allow different factors to work on it. However, in this study the prediction was done up to 2029/30 year. In order to forecast the production of paddy, maize and wheat, appropriate model was used such as ARIMA (1,1,1) for paddy production, ARIMA (3,1,1) for maize production and ARIMA (1,1,1) for wheat production. Furthermore, ARIMA (0,2,1) model used for area and production but, ARIMA (0,2,0) was identified as the best fit for vegetable production forecasting on Nepal by Thapa (2022). The forecasted values of production of paddy, maize and wheat from 2025/26 to 2029/30 are presented in Table 8. The forecasted value was seen increasing trend in all the three crops. The estimated production of paddy will be increased by 8.47 % from the year 2025/26 to 2029/30, similarly maize and wheat production will increase by 10.47 % and 21.96% respectively. The positive growth of estimated value of food grain production was found in research conducted in Odisha, India (Dash et al., 2017). However, wheat production is estimated to have a greater impact on food security compare to other cereal crops as indicated by the estimated growth rate. The graph highlighted the trend of observed value, fit value and forecast value for production of three major crops. Among these maize and wheat shown best fitted and consistent increasing trend whereas slightly separated trend was seen in case of paddy production where observed value moved slightly varied way over fit value as observed in Figure 9 (a), (b), (c).

Table 8. Forecasted value of paddy, maize and wheat production for 2025/26 to 2029/30

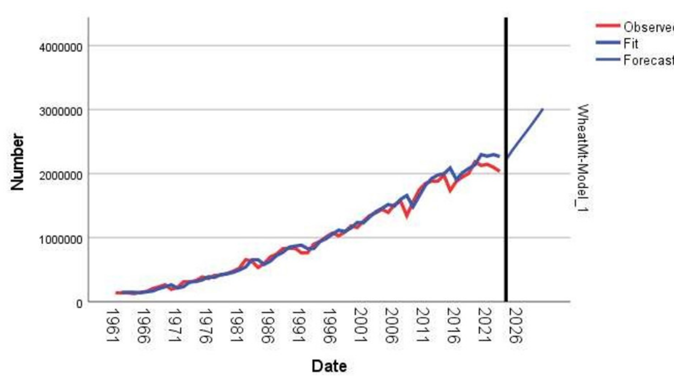
Year	Production forecast (Mt)		
	Paddy	Maize	Wheat
2025/26	6497197	3319077	2360210
2026/27	6630737	3407290	2490380
2027/28	6766993	3490154	2617232
2028/29	6906046	3577919	2745807
2029/30	7047955	3666644	2878554



(a) Figure represents forecasting of paddy



(b) Figure represents forecasting of maize



(c) Figure represents forecasting of wheat

Figure 10. Observed value, fitted value and forecasted value of paddy, maize and wheat production

Nepal continues to confront food deficit as depicted by its massive dependence on food imports. According to FAOSTAT data, growth rate of cereals crop production in Nepal was only 0.2% in 2023 whereas rate of population growth stood at 0.9% according to the census 2021.Thus the population growth rate was higher than food production. Such inequality contributes to persistent poverty, food deficit in various part of the country and a raising reliance on food imports. To address these challenges, country needs to expand major cultivation area and production of major cereals. Nevertheless, the predicted value of major cereals indicates positive and increasing trend in overall food production.

CONCLUSION

This study analyzed the production trend of major cereals in Nepal; paddy, maize and wheat over a 63 years period (1961/62to 2023/24). The result revealed an overall increasing trend in production of these cereals. For predicting future production, the Autoregressive Integrated Moving Average (ARIMA) model was applied, and the most suitable models were identified as ARIMA (1,1,1) for paddy, ARIMA (3,1,1) for maize and ARIMA (1,1,1) for wheat crops. These models provided reliable forecast of cereals production for the period from 2025/26 - 2029/30. The forecast result further indicated a continuous upward trend in the production of all three crops. Specifically, paddy, maize and wheat production are projected to increase by 8.47%, 10.47% and 21.96% respectively during the forecast period. The upward increasing trend in the predicted value of production suggests a positive contribution to food security, poverty reduction and indicates the potential to reduce the volume of cereals import in Nepal.

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