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Deepak Behra
Department of Agricultural
Statistics and Social Sciences
(L), Indira Gandhi Krishi
Vishwavidhyalaya, Raipur,
Chhattisgarh, India

MK Pradhan
Professor, Department of
Agricultural Statistics and
Social Sciences (L), Indira
Gandhi Krishi
Vishwavidhyalaya, Raipur,
Chhattisgarh, India

Tejeshwar
Department of Agricultural
Statistics and Social Sciences
(L), Indira Gandhi Krishi
Vishwavidhyalaya, Raipur,
Chhattisgarh, India

Priyanka Sahu
Department of Agricultural
Statistics and Social Sciences
(L), Indira Gandhi Krishi
Vishwavidhyalaya, Raipur,
Chhattisgarh, India

Forecasting area, production and productivity of fieldpea (*Pisum sativum*) in India: A comparative assessment of polynomial, ARIMA and ANN models

Deepak Behra, MK Pradhan, Tejeshwar and Priyanka Sahu

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Abstract

Fieldpea (*Pisum sativum*) is an important pulse crop, and reliable forecasts of its cultivated area, production and productivity can support agricultural planning and resource management. The present study evaluates alternative statistical and machine-learning approaches for forecasting these three indicators for India. Annual data for 1980-2021 were used, sourced from the Indian Institute of Pulses Research and agricultural statistics sources of the Government of India. Linear, quadratic and cubic polynomial trends were examined, followed by Autoregressive Integrated Moving Average (ARIMA) and Artificial Neural Network (ANN) models. Model performance was assessed using goodness of fit and forecasting-error measures, including R^2 , MAPE, MAE, RMSE and AIC where reported. The area series was best represented by a quadratic trend, whereas production and productivity were better represented by cubic trends. The series used for ARIMA modelling were made stationary through first-order differencing. The selected ARIMA specifications were ARIMA(0,1,0) for area, ARIMA(0,1,1) for production and ARIMA(0,1,0) for productivity. The corresponding MAE values were 57.39, 67.18 and 95.60, while RMSE values were 83.28, 90.41 and 117.67, respectively. The best ANN architectures were (5-5-1), (4-4-1) and (4-2-1) for area, production and productivity, respectively. Overall, the thesis comparison indicates that ARIMA provided the stronger forecasting performance for the annual fieldpea series, while ANN provided a useful complementary framework for nonlinear pattern representation.

Keywords: Fieldpea, *Pisum sativum*, agricultural forecasting, time series, ARIMA, artificial neural network, trend analysis, India, productivity

1. Introduction

Pulses are important components of the Indian food system and are major sources of dietary protein, particularly for populations relying substantially on plant-based foods. The thesis notes the continuing importance of pulses for food security and identifies fieldpea (*Pisum sativum*) as an important cool-season crop. It also highlights the need for better planning of pulse production in the context of variability in agricultural production.

Agricultural area, production and productivity are interrelated but do not necessarily exhibit identical temporal patterns. Long-term changes may arise from changes in cultivated area, productivity, technological progress and crop-management practices. Consequently, a forecasting framework should be able to represent both systematic trend and temporal dependence.

Previous studies summarized in the thesis have applied ARIMA and ANN methods to agricultural production, prices and yields. The thesis also cites comparative work showing that model performance can differ by crop, location and time-series structure. This provides a rationale for evaluating alternative models rather than assuming that one forecasting method is universally superior.

The objective of the present paper is therefore to synthesize and publish the thesis analysis as a focused comparison of polynomial trend, ARIMA and ANN models for Indian fieldpea area, production and productivity. The specific objectives are to: (i) characterize the long-term trends; (ii) identify suitable ARIMA and ANN forecasting models; (iii) compare predictive performance using the reported error measures; and (iv) provide five-year post-sample forecasts based on the selected models.

Corresponding Author:
Deepak Behra
Department of Agricultural
Statistics and Social Sciences
(L), Indira Gandhi Krishi
Vishwavidhyalaya, Raipur,
Chhattisgarh, India

2. Materials and Methods

2.1 Data source and study period

The analysis was conducted for India using annual secondary data for fieldpea area, production and productivity covering 1980-2021. The thesis identifies the Indian Institute of Pulses Research (IIPR), the Agricultural Statistics Division/Directorate of Economics and Statistics, the Department of Agriculture and Cooperation, the Ministry of Agriculture and Farmers Welfare, and APEDA among the data sources used or cited in the analysis.

Variable	Unit
Area	million hectares/reported series in the thesis tables
Production	million tonnes/reported series in the thesis tables
Productivity	kg ha ⁻¹

For publication, the exact source attribution and unit convention should be checked against the original statistical tables/data files before journal submission because the thesis uses different unit descriptions in different sections.

2.2 Trend models

Linear, quadratic and cubic polynomial models were fitted to describe the temporal trend. The general forms reported in the thesis were: $Y_t = a + bt + et$; $Y_t = a + bt + ct^2 + et$; and $Y_t = a + bt + ct^2 + dt^3 + et$, respectively. Model suitability was assessed using R^2 , RMSE and MAE.

The quadratic model was selected for area, while cubic models were selected for production and productivity. The selected equations reported in the thesis were: area, $Y_t = 341.91 + 25.746t - 0.37362t^2$; production, $Y_t = 145.17 + 52.205t - 1.9073t^2 + 0.02665t^3$; and productivity, $Y_t = 453.16 + 84.969t - 4.5628t^2 + 0.073114t^3$.

2.3 ARIMA modelling

ARIMA models were developed following the Box-Jenkins framework. Stationarity was examined using the Augmented Dickey-Fuller (ADF) test. The thesis reports that all three original series were non-stationary and became stationary after first-order differencing, giving $d = 1$. Candidate p and q orders were considered using ACF and PACF diagnostics, followed by parameter estimation and comparison of candidate models using AIC and forecasting-error measures. The selected models were ARIMA(0,1,0) for area, ARIMA(0,1,1) for production and ARIMA(0,1,0) for

productivity. The thesis reports MAPE, MAE and RMSE for the selected models and uses these measures, together with AIC and R^2 where reported, to assess performance.

2.4 Artificial Neural Network modelling

ANN models were developed as multilayer feed-forward networks using back-propagation learning. The thesis reports use of a sigmoid activation function in the hidden layer and comparison of alternative network structures. The best-performing architectures were selected using reported error measures and R^2 .

Series	Selected ANN architecture	MAE	RMSE	R^2
Area	5-5-1	98.23	108.37	0.74
Production	4-4-1	111.19	137.31	0.67
Productivity	4-2-1	110.23	104.51	0.74

3. Results

3.1 Descriptive statistics

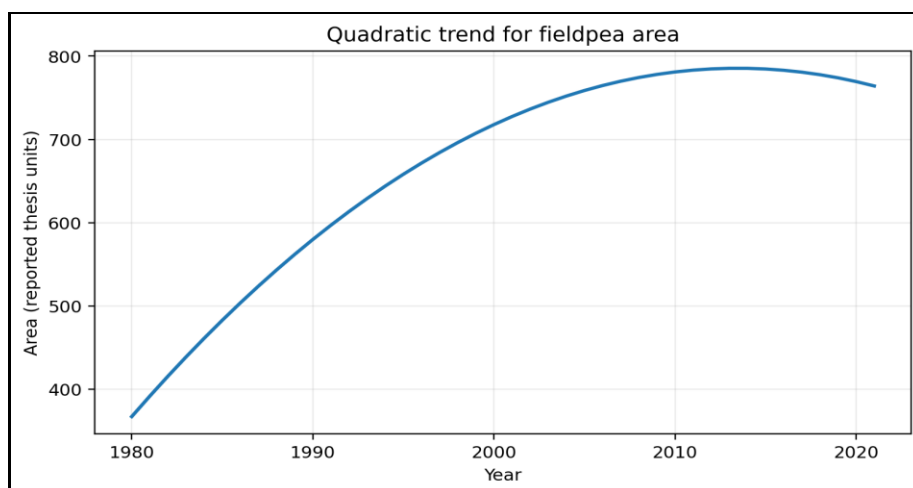
The thesis reports substantial variability across all three fieldpea series. The coefficients of variation were 24.0% for area, 32.0% for production and 19.6% for productivity. The reported means were 667.85 for area, 623.09 for production and 919.952 for productivity in the units used in the thesis.

Statistic	Area	Production	Productivity
Mean	667.85	623.09	919.952
Minimum	410	230	470
Maximum	1060	1010	1440
Standard deviation	160.35	199.17	180.001
Coefficient of variation	24.0%	32.0%	19.6%

3.2 Trend analysis

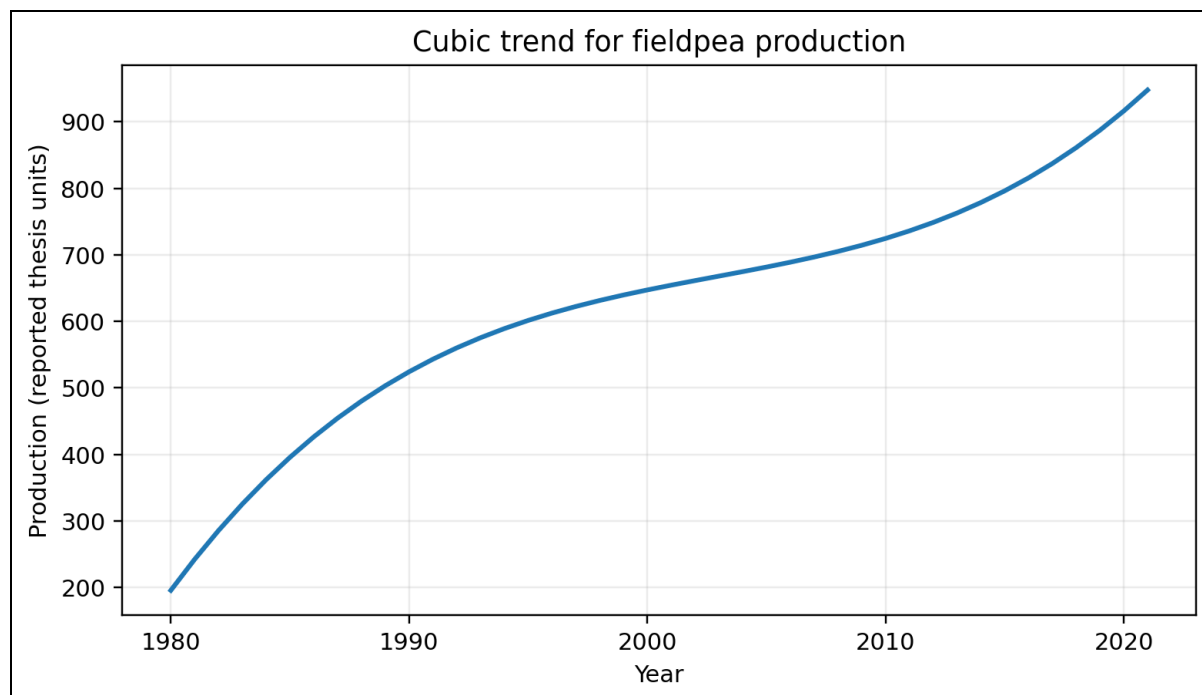
The quadratic model gave the best overall trend description for fieldpea area, with $R^2 = 0.65$, RMSE = 93.28 and MAE = 70.59. For production, the cubic model was selected, with $R^2 = 0.81$, RMSE = 79.76 and MAE = 60.59. For productivity, the cubic model was selected, with $R^2 = 0.75$, RMSE = 93.53 and MAE = 65.28. These results indicate that the three series do not share the same simple linear growth pattern.

Series	Selected trend	R^2	RMSE	MAE
Area	Quadratic	0.65	93.28	70.59
Production	Cubic	0.81	79.76	60.59
Productivity	Cubic	0.75	93.53	65.28



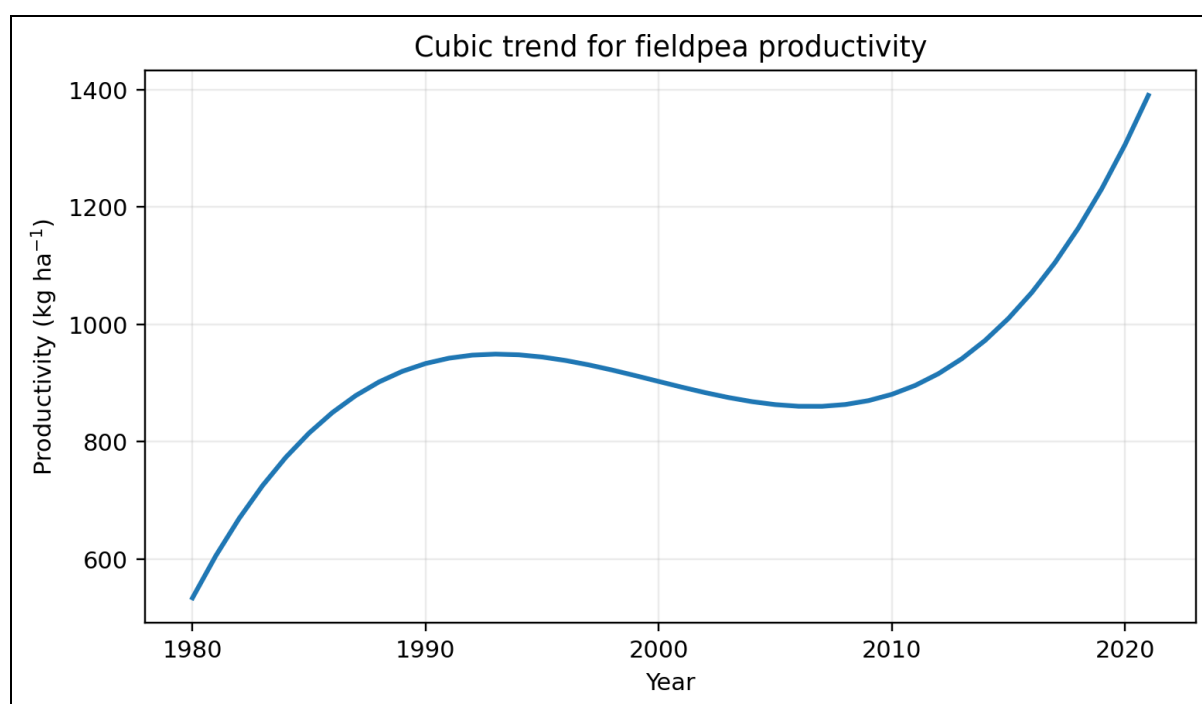
Fitted values are generated from the quadratic equation reported in the thesis.

Fig 1: Reported quadratic trend for fieldpea area.



Fitted values are generated from the cubic equation reported in the thesis.

Fig 2: Reported cubic trend for fieldpea production.



Fitted values are generated from the cubic equation reported in the thesis.

Fig 3: Reported cubic trend for fieldpea productivity.

3.3 ARIMA results

The ADF results reported in the thesis indicate non-stationarity in the original area, production and productivity series. First-order differencing produced stationary series. For area, the ADF statistic changed from -2.4567 ($p = 0.3936$) in levels to -3.4791 ($p = 0.05$) after first differencing. For production, the corresponding values were -2.2303 ($p = 0.4828$) and -4.3689 ($p = 0.01$).

For area, ARIMA(0,1,0) was selected, with MAPE = 8.26, MAE = 57.39 and RMSE = 83.28. For production, ARIMA(0,1,1) was selected, with MAPE = 10.52, MAE = 67.18 and RMSE = 90.41. For productivity, ARIMA(0,1,0)

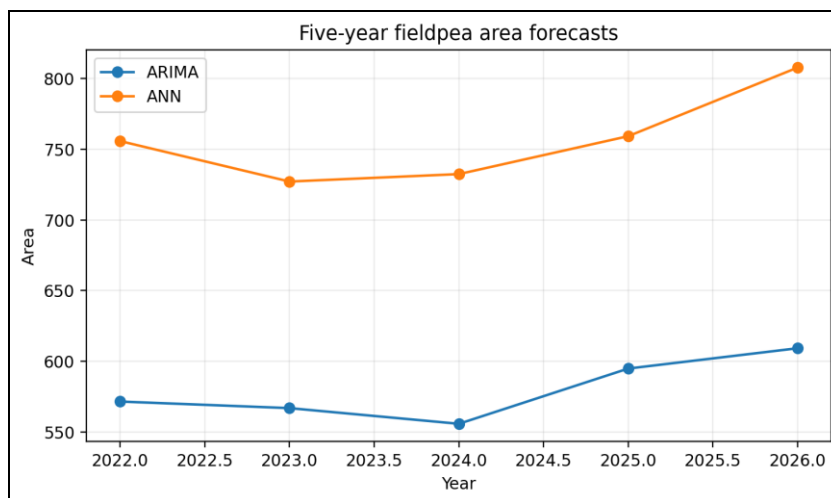
was selected, with MAPE = 10.23, MAE = 95.60 and RMSE = 117.67.

Series	Best ARIMA	MAPE	MAE	RMSE	R ² (comparison table)
Area	ARIMA(0,1,0)	8.26	57.39	83.28	0.75
Production	ARIMA(0,1,1)	10.52	67.18	90.41	0.80
Productivity	ARIMA(0,1,0)	10.23	95.60	117.67	0.87

3.4 Five-year ARIMA forecasts

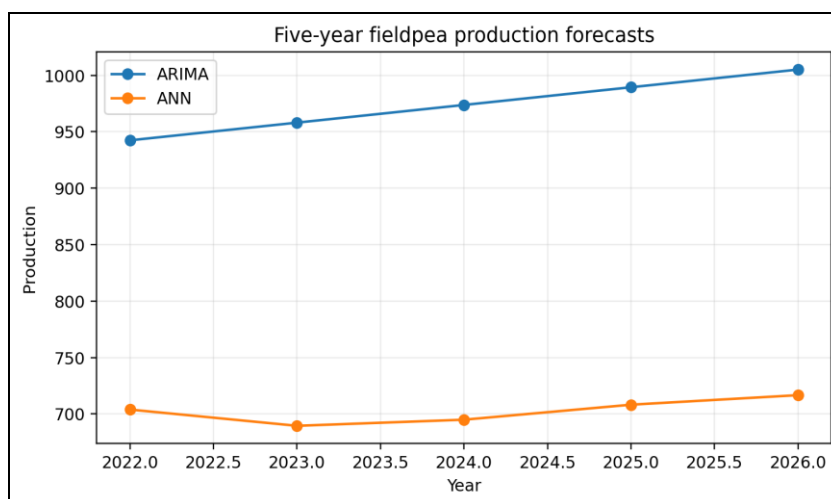
The selected ARIMA models were used in the thesis to generate five-year post-sample forecasts for 2022-2026. The reported point forecasts are summarized below.

Year	Area	Production	Productivity (kg ha ⁻¹)
2022	571.45	942.35	875.60
2023	566.80	958.02	745.70
2024	555.70	973.70	758.60
2025	594.80	989.37	759.50
2026	609.18	1005.04	978.30



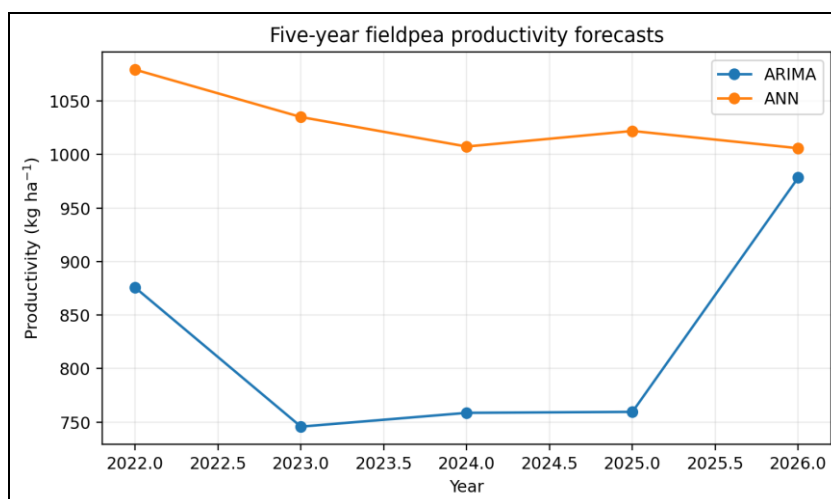
Forecasts for 2022-2026 as reported in the thesis.

Fig 4: Five-year forecast comparison for fieldpea area.



Forecasts for 2022-2026 as reported in the thesis.

Fig 5: Five-year forecast comparison for fieldpea production.



Forecasts for 2022-2026 as reported in the thesis.

Fig 6: Five-year forecast comparison for fieldpea productivity.

3.5 ANN results

The ANN comparison identified architecture 5-5-1 as the best model for area, 4-4-1 for production and 4-2-1 for productivity. The selected area network had MAE = 98.23, RMSE = 108.37 and $R^2 = 0.74$. The selected production network had MAE = 111.19, RMSE = 137.31 and $R^2 = 0.67$. The selected productivity network had MAE = 110.23, RMSE = 104.51 and $R^2 = 0.74$.

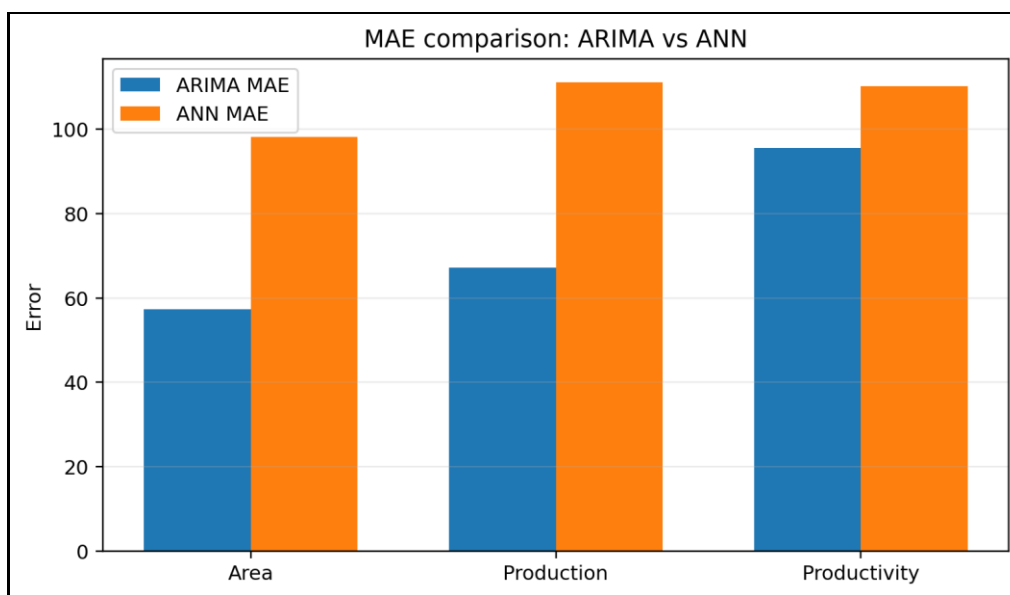
The corresponding ANN point forecasts for 2022-2026 were 755.79, 727.16, 732.43, 759.27 and 807.84 for area; 703.87, 689.48, 694.89, 708.18 and 716.63 for production; and 1079.22, 1034.96, 1007.39, 1021.96 and 1005.82 kg ha⁻¹ for

productivity.

3.6 Comparative model performance

The direct comparison reported in the thesis shows that ARIMA produced lower MAE and RMSE than the selected ANN model for area and production, and a higher R^2 for all three variables. For productivity, the ANN RMSE (104.51) was lower than the ARIMA RMSE (117.67), but the ARIMA model had lower MAE (95.60 versus 110.23) and substantially higher R^2 (0.87 versus 0.74). On the combined comparison reported by the thesis, ARIMA was therefore identified as the preferred forecasting approach.

Aspect	ARIMA model	MAE	RMSE	R^2	ANN model	MAE	RMSE	R^2
Area	(0,1,0)	57.39	83.28	0.75	(5-5-1)	98.23	108.37	0.74
Production	(0,1,1)	67.18	90.41	0.80	(4-4-1)	111.19	137.31	0.67
Productivity	(0,1,0)	95.60	117.67	0.87	(4-2-1)	110.23	104.51	0.74



Lower MAE indicates lower average absolute forecasting error.

Fig 7: MAE comparison of selected ARIMA and ANN models.

4. Discussion

The results demonstrate that Indian fieldpea area, production and productivity exhibit distinct temporal behaviour. The quadratic area trend suggests a nonlinear change in cultivated area over the study period, whereas cubic specifications provided the strongest fit for production and productivity. The difference among selected trend orders is important because it indicates that production and productivity cannot be adequately represented solely by changes in cultivated area.

The ARIMA results further indicate that the three annual series contain substantial persistence or trend-related non-stationarity that can be reduced through first-order differencing. The selected specifications are relatively parsimonious: ARIMA(0,1,0) for area and productivity and ARIMA(0,1,1) for production. This parsimony, together with the reported error measures, contributed to the stronger performance of ARIMA in the thesis comparison.

ANN models were able to represent nonlinear patterns and produced competitive fits. However, the selected ANN models did not outperform ARIMA on the overall set of comparison measures. This finding is consistent with the thesis interpretation that conventional time-series models can be advantageous when annual agricultural series have

relatively stable temporal structure. At the same time, ANN remains potentially useful as a complementary model when stronger nonlinear behaviour or additional explanatory variables are introduced.

The five-year forecasts illustrate meaningful differences between the modelling approaches. Because the study is based on annual observations and the thesis uses a univariate forecasting framework, these forecasts should be interpreted as model-based projections conditional on historical patterns rather than as forecasts incorporating weather, prices, policy changes or other external shocks.

5. Conclusion

This study compared polynomial trend, ARIMA and ANN approaches for forecasting fieldpea area, production and productivity in India using annual data from 1980 to 2021. Area was best represented by a quadratic trend, whereas production and productivity were best represented by cubic trends. After first-order differencing, ARIMA(0,1,0), ARIMA(0,1,1) and ARIMA(0,1,0) were selected for area, production and productivity, respectively.

The selected ANN architectures—5-5-1 for area, 4-4-1 for production and 4-2-1 for productivity—also provided useful predictive performance. Nevertheless, the thesis comparison

identified ARIMA as the more reliable overall forecasting framework for the annual fieldpea series. The results support the use of ARIMA as a practical baseline for agricultural planning, while ANN can be retained as a complementary method for nonlinear modelling.

For applied planning, the forecasts can provide an initial quantitative reference for future fieldpea area, production and productivity. However, future studies should validate the models using an explicitly defined hold-out period and, where data permit, compare univariate ARIMA and ANN with hybrid or exogenous-variable models incorporating weather, prices, input use and other agronomic factors.

6. Study limitations and publication notes

The manuscript is derived directly from the submitted thesis and therefore preserves its reported data, models and results. Before journal submission, the following items should be checked against the original analysis files: (i) exact units of area and production; (ii) the precise data source and retrieval dates for each series; (iii) the train/test or validation design used for ANN; (iv) residual diagnostic statistics for the selected ARIMA models; (v) exact definitions of the reported R^2 values; and (vi) the apparently inconsistent wording in the thesis describing some ARIMA parameter components. These checks are important for reproducibility and should be completed before submission.

The paper also intentionally avoids adding new empirical claims or external references that were not established in the thesis. Journal-specific formatting, reference verification, figure preparation and plagiarism/similarity screening should be performed as a separate final submission stage.

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