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FUTURE PROSPECTS OF TURMERIC CULTIVATION USING FORECASTING TECHNIQUES IN TAMIL NADU INDIA

**Mahima Priyanka Neerugatti*, R.R.Kushwaha, Harshit Mishra,
Sandeep Gautamand Kaushlendra Srivastava**

Department of Agricultural Economics, Acharya Narendra Deva University of Agriculture and Technology,
Kumarganj, Ayodhya-224229 (U.P.), India

*Corresponding author E-mail: mahineerugatti@gmail.com

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ABSTRACT

Turmeric (*Curcuma longa*) is an economically and culturally significant spice crop in India, with Tamil Nadu playing an important role in its production. This study presents a forecast on area, production, and yield of turmeric in Tamil Nadu up to 2030, the best-fit ARIMA models were chosen based on their minimum AIC, RMSE, MAE, MAPE, and maximum R^2 values. Empirical results showed that the ARIMA (1,1,10) model was suitable for area, production and yield in Tamil Nadu, with a 95% accuracy level. The findings indicate that despite recent declines in observed area, production, and yield of turmeric in Tamil Nadu, the forecast suggests a potential recovery and upward trend in all three indicators by 2030. These projections provide valuable insights for policymakers, researchers, and stakeholders to plan sustainable and data-driven interventions to support turmeric farming in Tamil Nadu.

Key words: ARIMA, AIC, RMSE, MAE, MAPE and R^2 .

Introduction

Turmeric (*Curcuma longa*), a vital spice with extensive culinary, medicinal, and industrial applications, holds a significant position in India's agricultural economy. India is the world's largest producer, consumer, and exporter of turmeric, accounting for more than 62% of global trade (Kiruthika, 2013). In the year 2022–23, turmeric was cultivated across an area of 3.24 lakh hectares in India, yielding approximately 11.61 lakh tonnes of production. During the same period, India exported about 1.534 lakh tonnes of turmeric and its value-added products, generating export revenue worth USD 207.45 million through more than 380 registered exporters. The major export destinations include Bangladesh, the United Arab Emirates, the United States of America, and Malaysia. With the support of targeted initiatives and promotional strategies by the Spices Board, turmeric exports are projected to reach USD 1 billion by 2030 (Spices Board India, 2023).

Tamil Nadu has made notable contributions to

turmeric production, marked by a relatively stable growth trajectory. The state has traditionally emphasized improvements in yield and expansion of cultivated area, with major turmeric-producing districts such as Salem and Erode emerging as important cultivation hubs. Tamil Nadu's cultivation practices are largely efficiency-oriented, contributing to steady gains in productivity over the years. These patterns are shaped by a combination of regional agricultural policies, evolving market dynamics, and environmental factors. As the state continues to navigate the challenges posed by shifting agro-economic landscapes, a thorough understanding of the trends in area, production, and yield becomes critical for stakeholders seeking to ensure the long-term sustainability and profitability of turmeric farming. In this context, the present study aims to assess the future prospects of turmeric cultivation in Tamil Nadu through the application of forecasting techniques.

Materials and Methods

The collected information is purely secondary. The

Table 1: Different ARIMA Model for area, under Turmeric in Tamil Nadu.

Tamil Nadu					
AREARIMA	R ²	RMSE	MAPE	MAE	AIC
ARIMA (0,1,0)	0.589	9.137	24.402	4.908	505.116
ARIMA (0,1,1)	0.645	8.115	26.299	5.124	490.966
ARIMA (0,1,2)	0.669	7.970	27.862	5.260	490.501
ARIMA (0,1,3)	0.697	7.457	27.378	5.068	484.079
ARIMA (0,1,4)	0.729	6.941	25.515	4.611	478.982
ARIMA (0,1,5)	0.730	6.930	25.282	4.581	480.860
ARIMA (0,1,6)	0.735	6.865	26.031	4.730	481.387
ARIMA (0,1,7)	0.736	6.855	26.075	4.711	483.262
ARIMA (0,1,8)	0.739	6.816	26.047	4.711	484.332
ARIMA (0,1,9)	0.740	6.807	26.057	4.632	485.937
ARIMA (0,1,10)	0.740	6.805	26.044	4.631	487.931
ARIMA (1,1,0)	0.665	7.935	27.534	5.189	487.921
ARIMA (1,1,1)	0.664	7.932	27.678	5.212	489.876
ARIMA (1,1,2)	0.681	7.835	27.964	5.190	490.327
ARIMA (1,1,3)	0.725	6.997	26.216	4.727	479.872
ARIMA (1,1,4)	0.734	6.892	25.392	4.616	480.322
ARIMA (1,1,5)	0.737	6.848	25.606	4.640	481.421
ARIMA (1,1,6)	0.737	6.837	26.106	4.714	482.942
ARIMA (1,1,7)	0.737	6.836	26.109	4.724	484.931
ARIMA (1,1,8)	0.739	6.814	26.034	4.683	486.130
ARIMA (1,1,9)	0.740	6.806	26.053	4.632	487.935
ARIMA (1,1,10)	0.763	6.556	26.589	4.707	489.299

information on area, Production and Yield of turmeric for the period 1954-2023 were collected from www.Indiastat.com.

Box-Jenkins models

With the formulation of Box-Jenkins approach of modelling in the 1970s gave time series forecasting a huge boost, which was boosted even more by the development of computer software. The underlying premise of this methodology is that the series current value is in some way related to its previous value.

Given a time series of data X_t , the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. The model consists of two parts, an autoregressive (AR) part and a moving average (MA) part. The model are referred as:

- **Autoregressive model:** ARIMA stands for Autoregressive Integrated Moving Average. The term *Integrated* means that any trend in the data has been removed, usually by differencing. If the data series does not show a significant trend, we can directly use an ARMA model instead of ARIMA.

The notation AR(p) is used for the *autoregressive* model of order p . It means the current value of the series

Table 2: Model Validation and forecasting of Area (000' hectare) under Turmeric in Tamil Nadu.

Tamil Nadu		
Year	Observed	Predicted
2016	29.31	40.32
2017	18.08	17.3
2018	23.46	26.4
2019	18.43	14.84
2020	20.89	16.72
2021	24.17	17.25
2022	24.75	24.13
2023	24.81	27.7
2024	-	41.73
2025	-	40.78
2026	-	47.39
2027	-	44.62
2028	-	44.44
2029	-	40.11
2030	-	39.73

depends on its previous p values. The AR(p) model is written as:

$$Y_t = c + \sum_{i=1}^p \phi_i Y_{t-i} + \varepsilon_t$$

Where: Y_t = current value of the series

c = constant term c

ϕ_i = parameters of the model

Y_{t-i} = past values of the series

ε_t = random error term at time t

Stationarity

Box and Jenkins (1976), Anderson (1976), Judge *et al.*, (1982), Chatfield (1984), and Pankratz (1983) pointed out that for the process to be strictly stationary, the joint distribution function describing the process must be

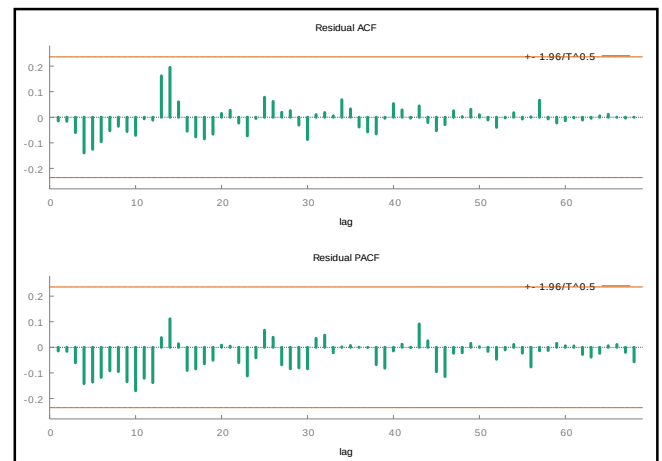
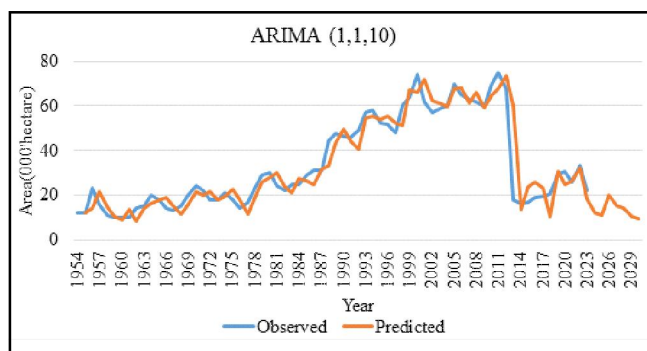
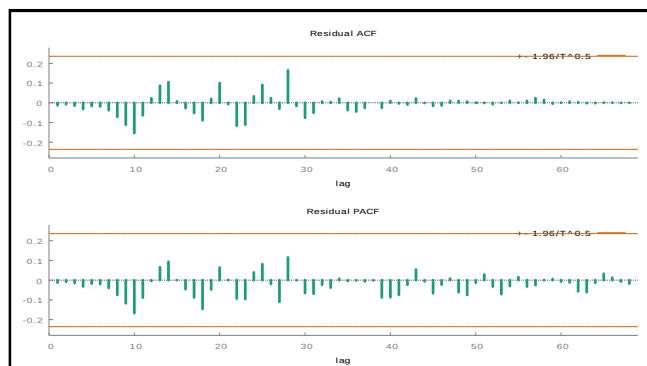
**Fig. 1:** ACF and PACF graphs of residuals for the best fitted models of Area under turmeric in Tamil Nadu.

Table 3: Different ARIMA Model for Production under turmeric in Tamil Nadu.

Tamil Nadu					
Production ARIMA	R ²	RMSE	MAPE	MAE	AIC
ARIMA (0,1,0)	0.4567	62.2630	31.2710	30.4180	769.9430
ARIMA (0,1,1)	0.5259	54.3100	34.6700	31.8760	753.4006
ARIMA (0,1,2)	0.5381	54.1070	35.2180	32.4320	754.8213
ARIMA (0,1,3)	0.5810	49.9080	36.8160	30.4000	749.2081
ARIMA (0,1,4)	0.6104	48.1000	35.7670	30.5360	745.8695
ARIMA (0,1,5)	0.6105	48.0940	35.6470	30.5910	747.8130
ARIMA (0,1,6)	0.6108	48.0810	35.3860	30.4910	749.6833
ARIMA (0,1,7)	0.6151	47.8130	35.9190	30.6980	751.1879
ARIMA (0,1,8)	0.6168	47.7080	35.9220	30.7490	753.0767
ARIMA (0,1,9)	0.6156	47.7830	35.8350	30.7600	754.9408
ARIMA (0,1,10)	0.6158	47.7860	35.1930	30.4830	756.8014
ARIMA (1,1,0)	0.5445	53.9590	35.1130	32.3530	752.4660
ARIMA (1,1,1)	0.5434	53.7620	35.5310	32.6070	753.9757
ARIMA (1,1,2)	0.5456	53.7490	35.5500	32.6550	755.9417
ARIMA (1,1,3)	0.6035	48.5430	35.0920	30.2310	746.9049
ARIMA (1,1,4)	0.6105	48.0950	35.3980	30.5860	747.8009
ARIMA (1,1,5)	0.6105	48.0970	35.5750	30.5750	749.7952
ARIMA (1,1,6)	0.6123	47.9890	35.6830	30.6730	751.4902
ARIMA (1,1,7)	0.6159	47.7660	35.9640	30.7370	753.1511
ARIMA (1,1,8)	0.6167	47.7160	35.9180	30.7590	755.0506
ARIMA (1,1,9)	0.6156	47.7880	35.7480	30.7250	756.9255
ARIMA (1,1,10)	0.6173	47.6860	35.2730	30.3850	758.5473

**Fig. 2:** Recorded and forecasted Area under turmeric in Tamil Nadu.**Fig. 3:** ACF and PACF graphs of residuals for the best fitted models of Production under turmeric in Tamil Nadu.

invariant with respect to time, where $F(z_t, \dots, z_{t+k}) = F(z_{t+s}, \dots, z_{t+s+k})$ for s and all k . This strong stationarity condition implies that the mean, variance, and covariance are constant. However, most economic time series exhibit trends or growth over time, leading to changes in the mean and, consequently, resulting in non-stationarity. To analyze such data effectively, it becomes essential to transform non-stationary series into stationary ones. This is typically accomplished through differencing or other forms of transformation. In many practical cases, first-order differencing is sufficient to attain stationarity, after which the series tends to exhibit a stable mean, although the variance may remain unaffected.

Pankratz (1983) cautioned against excessive differencing, as over-differencing can introduce artificial patterns into the data and may compromise the predictive accuracy of time series models. Hence, while differencing is a useful technique for stabilizing a time series, it should be applied judiciously to avoid distortion in model estimation and forecasting.

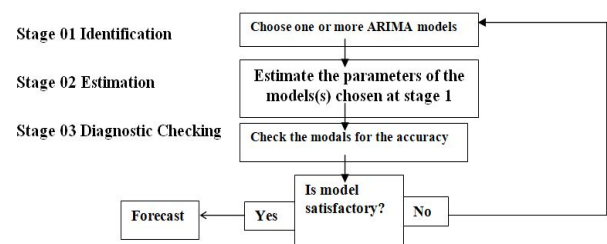
The stationary series case:

Stationary series (original or transformed) can be modelled using the following techniques: simple moving averaging, simple exponential smoothing, and Box-Jenkins (Box and Jenkins, 1976).

Autoregressive Moving Average model (ARMA)

The notation ARMA (p, q) refers to the model with p autoregressive terms and q moving average terms. This model contains the AR(p) and MA(q) models.

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Diagnostic checking

In this stage allows you to see if the model you've chosen matches the data pretty enough. One easy test of the chosen model is to verify if the residuals calculated from this model are white noise; if they are, the particular fit can be accepted; if not, the procedure must be restarted, making the Box Jenkins Methodology an iterative process. The study uses data from 1950 to 2024

Table 4: Model Validation and forecasting of Production (000' metric tons) under Turmeric in Tamil Nadu.

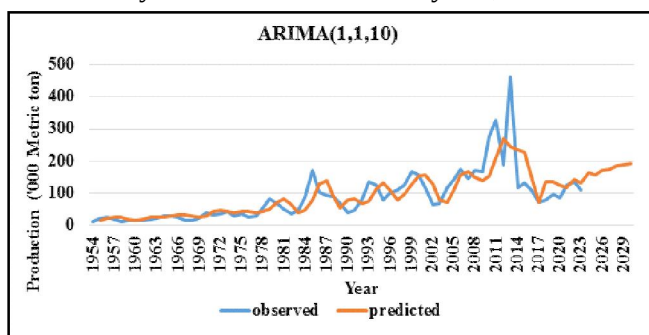
Tamil Nadu		
Year	Observed	Predicted
2016	112.6	121.91
2017	73.13	71.27
2018	79.84	85.41
2019	96.25	105.85
2020	86.51	93.55
2021	124.9	118.44
2022	136.4	144.26
2023	111.7	123.35
2024	-	165.17
2025	-	156.58
2026	-	172.64
2027	-	174.72
2028	-	183.84
2029	-	187.37
2030	-	192.58

to estimate ARIMA equations for all parameters and predicts up to 2030.

Forecasting

ARIMA's success in predicting is one of the reasons for its popularity. The fundamental box-jenkins approach for forecasting the values of a time series is as follows.

- First, check for stationarity. The autocorrelation function (ACF) and partial autocorrelation (PACF) can be computed, or a normal root analysis can be used.
- If the time series isn't stationary, divide it by one or more to attain stationarity.
- The stationary time series' ACF and PACF are then calculated to determine if the series is fully autoregressive, solely moving average, or a combination of the two.
- Finally, the preliminary model is estimated.
- This model's residuals are investigated to see if they are white noise. If they are, the tentative

**Fig. 4:** Recorded and forecasted Production (000' metric ton) under turmeric in Tamil Nadu.

model is most likely a decent approximation of the stochastic process at hand. If they aren't, the procedure is restarted from the beginning. As a result, the Jenkins approach in the box is iterative. The final model used can be used to forecast.

Diagnostic checks of the fitted models are made through ACF and PACF graphs of the residuals. If the residuals are white noise, then only model is taken from forecasting purpose.

Results and Discussion

Modelling and forecasting

After the evaluation of trend of each and every series, our next goal is to forecast the series for the year to come. Box–Jenkins methodology was employed, as indicated in the material and method. Data from 1954 to 2015 was used to create the model, and data from 2016 to 2023 was used to validate it. The best fitting models are used to forecast the series in the future. The ACF and PACF graphs from the original series clearly reveal that none of them are steady in nature, and that first order differencing is insufficient to make them so. It was discovered that ARIMA models ranging from (0, 1, 0) to (1, 1, 10) are appropriate for predicting and forecasting turmeric production behavior, starting with the model-building technique mentioned in the material and method (Srivastava *et al.*, 2022) and (Srivastava *et al.*, 2023) .

The study then uses the differenced series to estimate ARIMA equations for all parameters using data from 1954 to 2023 and provides forecasts up to 2030, through Gretl software and MS Excel. ARIMA models were tested, and the best models were chosen among the competing models based on the smallest value of RMSE, MAE, MAPE, AIC, and the highest value of R^2 (Srivastava *et al.*, 2022) , but basic objectives were not followed and the best fitted model was selected based on the model which satisfy the majority of the objective.

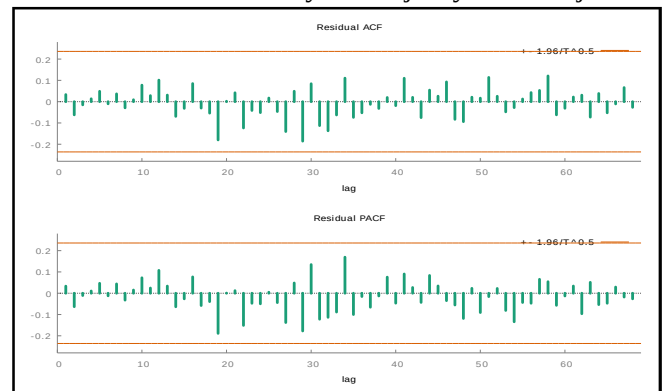
**Fig. 5:** ACF and PACF graphs of residuals for the best fitted models of Yield under Turmeric in Tamil Nadu.

Table 5: Different ARIMA Model for Yield (Kg./Hectare) under turmeric in Tamil Nadu.

Tamil Nadu					
YieldARIMA	R ²	RMSE	MAPE	MAE	AIC
ARIMA (0,1,0)	0.2949	1029.8000	13.4200	621.3100	1157.1330
ARIMA (0,1,1)	0.3469	890.2900	13.2270	607.3100	1139.5220
ARIMA (0,1,2)	0.3439	887.6900	13.1680	601.5600	1141.1980
ARIMA (0,1,3)	0.3507	878.9000	13.2400	604.1300	1141.9120
ARIMA (0,1,4)	0.3504	878.7100	13.3110	606.8600	1143.8840
ARIMA (0,1,5)	0.3780	849.9200	13.3350	603.5600	1143.9010
ARIMA (0,1,6)	0.3785	849.8900	13.1880	598.5400	1145.7810
ARIMA (0,1,7)	0.3772	863.4100	13.5720	616.1500	1147.7670
ARIMA (0,1,8)	0.4021	851.7800	13.0240	589.0200	1148.1330
ARIMA (0,1,9)	0.4002	851.0800	13.2110	596.8300	1150.0280
ARIMA (0,1,10)	0.4083	828.7300	13.1040	585.4000	1150.6650
ARIMA (1,1,0)	0.4084	827.3800	13.4440	585.6650	1140.9254
ARIMA (1,1,1)	0.3434	885.6000	13.0630	595.5200	1140.9240
ARIMA (1,1,2)	0.3643	859.8300	12.7340	580.5300	1140.7350
ARIMA (1,1,3)	0.3682	856.9800	12.9830	591.5000	1142.4560
ARIMA (1,1,4)	0.3801	858.0500	13.2360	608.0200	1144.1050
ARIMA (1,1,5)	0.3782	849.9900	13.2490	600.7300	1145.8290
ARIMA (1,1,6)	0.4037	831.8400	13.2490	600.7800	1146.4020
ARIMA (1,1,7)	0.3922	859.1900	13.5380	614.5700	1149.2020
ARIMA (1,1,8)	0.4013	851.4100	13.1160	593.0700	1150.0740
ARIMA (1,1,9)	0.3987	850.8200	13.2530	597.8200	1151.9870
ARIMA (1,1,10)	0.4104	827.3500	13.1130	585.3900	1152.6130

However, residuals are also subjected to diagnostic checks using ACF and PACF graphs. The graph clearly illustrates that the acreage, production, and yield of turmeric in Tamil Nadu are expected to increase in the future. Inturmeric area, production and yield data none of the series are stationary in Tamil Nadu. Thus, first

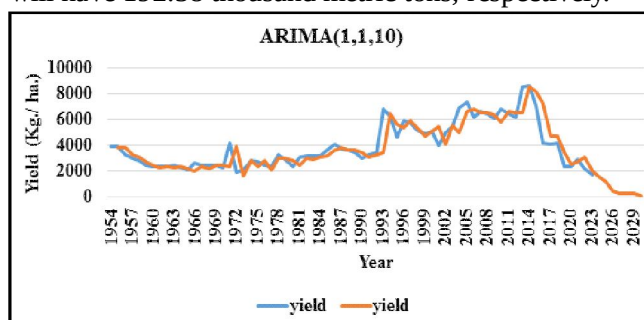
Table 6: Model Validation and forecasting of Production under turmeric in Tamil Nadu.

Tamil Nadu		
Year	Observed	Predicted
2016	3840	3957.84
2017	4045	4168.22
2018	3400	4455.27
2019	5222	4590.6
2020	4140	4569.94
2021	5170	5024.65
2022	5510	4709.86
2023	4500	5002.49
2024	-	5300.19
2025	-	5316.1
2026	-	4997.33
2027	-	5263.51
2028	-	5330.74
2029	-	5161.44
2030	-	5585.4

differencing with original data makes all the series stationary *i.e.* constant mean and constant variance.

The ACF and PACF plot of first difference, the value of area under turmeric in Andhra Pradesh and Tamil Nadu, is represented in Figure 1 which suggests that the tentative value of p and q that would be suitable for area under turmeric is $p=1$ and $q=10$ for Tamil Nadu. Thus, ARIMA (1,1,10) were shown to be the best ARIMA models for area under turmeric in Tamil Nadu. As shown in Table 1, the ARIMA (1,1,10) area under turmeric have the least RMSE, MAPE, MAE value and largest R² value in Tamil Nadu. So, the best fitting model is ARIMA (1,1,10) Tamil Nadu. From the Fig. 2 is clearly depicted that the area under turmeric is reducing. In 2023-2024 the area of turmeric Tamil Nadu 24.81 thousand hectares compared to 27.2 thousand hectares predicted. As shown in the table 2 for the years 2030-2031, Tamil Nadu would have 39.37 thousand hectares, respectively.

The ACF and PACF plot of first difference, the value of production under turmeric in Tamil Nadu, are represented in Fig. 3, which suggests that the tentative value of p and q that would be suitable for area under turmeric is $p=1$ and $q=10$ for Tamil Nadu. Thus ARIMA (1,1,10) was shown to be the best ARIMA models for production under turmeric in Andhra Pradesh and Tamil Nadu. As shown in Table 3, the ARIMA (1,1,10) production under turmeric the least RMSE value and largest R² value in Tamil Nadu. So, the best fitting model is ARIMA (1,1,10) in Tamil Nadu. From the Fig. 4 is clearly shown that the production is also decline with area. In 2023-2024 the production of turmeric in Tamil Nadu was 111.67 thousand metric ton, respectively, compared to 123.35 thousand metric tons predicted. As shown in the table 4 for the years 2030-2031, Tamil Nadu will have 192.58 thousand metric tons, respectively.

**Fig. 6:** Recorded and forecasted Yield under turmeric in Tamil Nadu.

The ACF and PACF plot of first difference, the value of yield under turmeric in Tamil Nadu, are represented in Fig. 5 which suggests that the tentative value of p and q that would be suitable for yield under turmeric is $p=1$ and $q=10$ for Tamil Nadu. Thus, ARIMA (1,1,10) was shown to be the best ARIMA models for yield under turmeric in and Tamil Nadu. As shown in Table 5, ARIMA (1,1,10) yield under turmeric has the least RMSE value and largest R^2 value in Tamil Nadu. So the best fitting model is ARIMA (1,1,10) in Tamil Nadu. From the Fig. 6 is clearly shown that the yield is also decline. In 2023-2024 the yield of turmeric in Tamil Nadu was 4500 Kg/ha respectively, compared to 5002.49 Kg/ha predicted. As shown in the table 6 for the years 2030-2031, Tamil Nadu will have 5585.4 Kg/ha respectively.

Conclusion

From the discussion reveal that all three variables that is area, production, and yield are exhibited non-stationary behavior initially, which was corrected through first-order differencing. Among various competing models, ARIMA (1,1,10) emerged as the best-fitting model for each indicator based on statistical diagnostics. Although recent years have shown a decline in the observed area under cultivation, production volume, and productivity levels, the forecasting results suggest a potential rebound in the coming years, with projected increases across all parameters by 2030. This trend indicates a positive outlook for turmeric cultivation in Tamil Nadu, provided that appropriate policy support, market stability, and agronomic innovations are ensured. The results underscore the importance of continuous

monitoring, forecasting, and timely intervention to enhance the resilience and profitability of turmeric farming in the region.

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