



RESEARCH ARTICLE

Modelling and forecasting of turmeric in Andhra Pradesh

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Abstract

In India, turmeric holds a special place as both a spice and a medicinal crop, with South India being the leading region for its cultivation and trade. Given its economic importance, the present study examines developments in acreage, output and yield of turmeric in Andhra Pradesh from 1954 to 2023, using data collected from India stats and analyzed through GRETL and MS Excel. The compound annual growth rates (CAGR) were calculated across eight sub-periods to identify cultivation trends. The results indicate that from 1954 to 1993, turmeric area, production and yield showed a steady increase, but began declining thereafter, largely influenced by regional restructuring and the state bifurcation. Furthermore, for forecasting, the Box-Jenkins ARIMA methodology was applied, selecting models based on autocorrelation functions and criteria such as AIC, RMSE, MAE, MAPE (minimum) and R^2 (maximum) values. The ARIMA (1,1,10) model was deemed suitable for forecasting area and yield, while the ARIMA (1, 1, 9) model was appropriate for production, both achieving a 95 % accuracy level. Projections suggest a declining trend in turmeric cultivation, with area and production expected to decrease to 9.33 (000 ha) and 108.12 (000) MT, respectively, by 2030-31. These findings highlight the necessity for strategic interventions to stabilize and enhance turmeric farming in the region, providing a foundation for policymakers to address sustainability and productivity challenges.

Keywords: ARIMA; CAGR; forecasting; modelling; time series; turmeric

Introduction

India, widely recognised as the Spice Bowl of the World, has nurtured a thriving legacy of spice cultivation and trade since ancient times (1). Among its diverse array of spices, turmeric (*Curcuma longa* L.) holds exceptional prominence-praised not only as a culinary staple and natural colourant, but also for its wide-ranging medicinal benefits. The active compound curcumin, known for its anti-inflammatory, antioxidant, antimicrobial and anticancer properties, underpins turmeric's therapeutic appeal in traditional systems like Ayurveda and its growing validation in modern scientific research (2, 3).

India remains the largest producer, consumer and exporter of turmeric globally. In the 2023-24 agricultural year, turmeric was cultivated on approximately 305,000 hectares, yielding about 1.054 million tonnes, with an average productivity of 3.66 t/ha (4). Among the producing states, Telangana leads the country, contributing nearly 14.33 % of the national area and 24.75 % of production, with productivity levels reaching about 6.6 t/ha (5). Telangana's leadership in turmeric production is primarily due to its favorable warm climate, well-drained loamy soils and a strong, established agricultural base for this specific crop (6). Maharashtra, Tamil Nadu, Odisha and Karnataka also remain major contributors to turmeric output, collectively accounting for a substantial share of the national production (7). In contrast Andhra Pradesh was once a major producer as well in 2013-14, just before the states'

bifurcation, it ranked third in the country with nearly 151.9 thousand tonnes of production (8). After the split in 2014, however, turmeric cultivation in Andhra Pradesh declined sharply, falling to around 17 thousand ha and 121 thousand tonnes by 2015-16. The situation later improved, reaching about 74.7 thousand tonnes of production with area cultivation 26 thousand ha in 2021-22, with around 5.6 % of national output, but it again fell to about 22.4 thousand ha area with production 38 thousand tonnes in 2023-24 (4).

Despite turmeric's economic and medicinal relevance Andhra Pradesh currently experiences high variability in area, production and yield, driven by policy changes, market uncertainties and structural adjustments after bifurcation. This instability poses challenges for farmers, supply-chain actors and policymakers, particularly in crop planning, input management and marketing. Time-series models, particularly the Box-Jenkins ARIMA framework, are well-suited for capturing historical patterns and generating reliable short-term forecasts. To address this, the present study employs the Box-Jenkins ARIMA model to forecast the area, production and yield of turmeric in Andhra Pradesh. By providing evidence-based insights into future trends, this study aims to guide policymakers, researchers and farmers in formulating strategies to overcome production challenges and enhance the sustainability of turmeric cultivation (9, 10).

Materials and Methods

Data source

The information was collected from online databases. The data on the area, production and yield of turmeric for the last 69 yr, i.e., from 1954 to 2023. To analyse the data, we utilized the statistical software GRETL (Gnu Regression, Econometric and Time-series Library) and MS Excel.

Growth rate

Compound annual growth rate (CAGR) was estimated using the following functional form:

$$\ln Y = a + bt \quad (\text{Eqn. 1})$$

Where Y is the time series data of area, production, or yield of turmeric, for which the growth rate is calculated, ' t ' is the trend term and ' a ' is the constant coefficient. The slope coefficient ' b ' measures the relative change in Y for a given absolute change in the value of the explanatory variable ' t '. The compound annual growth rate can be calculated from the value.

$$\text{CAGR} = [\text{antilog}(b) - 1] \times 100 \quad (\text{Eqn. 2})$$

For analyzing the growth rate of time series data on area, production and yield, the study period was segmented into eight decadal periods the period I (1954-1963), period II (1964-1973), period III (1974-1983), period-IV (1984-1993), period-V (1994-2003), period-VI (2004-2013), period-VII (2014-2023) and period-VIII (1954-2023).

Modelling and forecasting

Box-Jenkins was used for forecasting the future values of dependent variables such as area, production and yield. The Box-Jenkins methodology is also referred to as the ARIMA methodology (11). The invention of the Box-Jenkins approach for modelling in the 1970s significantly advanced time series forecasting, further enhanced by the advent of computer software. The fundamental premise behind this technique is that the present value of the series is intrinsically linked to its historical values (12, 13).

It is first necessary to note that most time series are non-stationary and the ARIMA models refer only to a stationary time series (11). Since the ARIMA models refer only to a stationary time series, the first stage of the Box-Jenkins model is for reducing a non-stationary series to a stationary series by taking first-order differences. In general, an ARIMA model is characterised by the notation ARIMA (p, d, q) where p, d and q denote orders of auto-regression, integration (differencing) and moving average, respectively. It refers to the number of lags of the difference series is referred to as autoregressive and the lags within predicted data are

referred to as moving average (14).

Autoregressive model

ARIMA models stand for autoregressive integrated moving average model. Integrated means the trends have removed; if the series has no important trend, the models are known as ARMA models. The notation AR(p) refers to the autoregressive model of order p. The AR (p) model is written

$$X_t = c + \sum_{i=1}^p \alpha_i X_{t-i} + \mu_t \quad (\text{Eqn. 3})$$

Where α_i are the parameters of the model, c is a constant and μ_t is the noise (15)

Moving average model

The notation MA (q) refers to the moving average model of order q:

$$X_t = \mu + \sum_{i=1}^q \theta_i \varepsilon_{t-i} + \varepsilon_t \quad (\text{Eqn. 4})$$

Where the $\theta_1, \dots, \theta_q$ are the parameters of the model, μ is the expectation of X_t (often assumed to equal 0) and ' ε_t ' is an error term.

The stage shown in Fig. 1 can be used to fit time-series data to an ARIMA model.

The whole period under consideration (1954 - 2015) was distributed as model building for the period of 1954 - 2015 and as model validation for the period of 2016-2023 and forecast up to 2030. Models are compared based on the maximum value of the coefficient of determination (R^2) and the minimum value of root mean square error (RMSE), mean absolute percentage error (MAPE), mean absolute error (MAE) and akaike information criterion (AIC).

Results and Discussion

Growth trend analysis for turmeric in Andhra Pradesh

The growth in the area, production and yield of turmeric is examined to know the pattern of changes taking place in the turmeric in Andhra Pradesh. The period-wise annual compound growth rate in the area, production and yield of turmeric in Andhra Pradesh has been depicted in Table 1. In the early phase (period I: 1954-1963), growth rates for area, production and yield were all negative, with production declining at -7.4 % annually. This early decline is consistent with historical evidence indicating limited access to

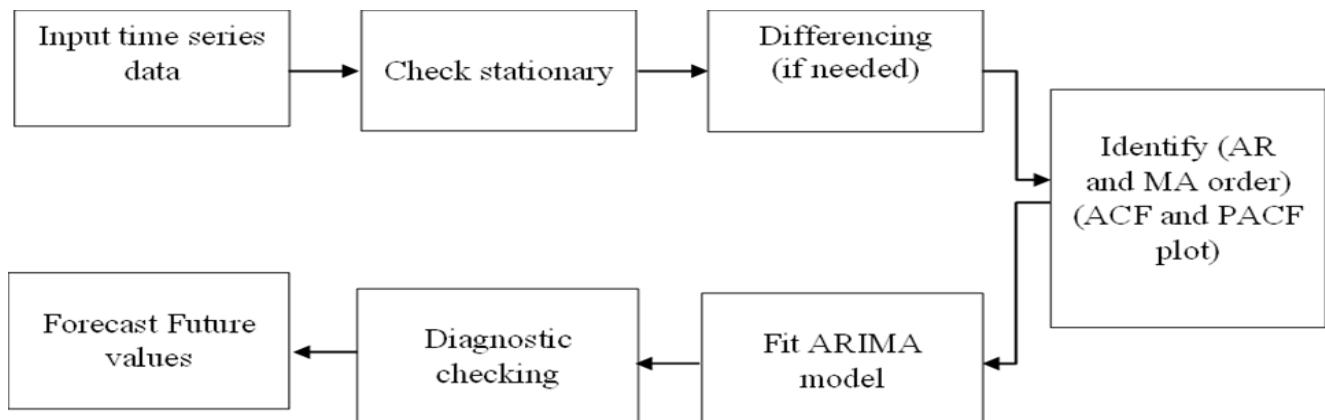


Fig. 1. Flow chart of Box-Jenkins.

Table 1. Growth rate of area, production and yield of turmeric in Andhra Pradesh from 1954 to 2023

| PERIOD | Area | Production | Yield |
|----------------------------|-------|------------|--------|
| Period-I (1954-1963) | -1.55 | -7.4 | -5.75 |
| Period-II (1964-1973) | 2.11 | 2.57 | 0.38 |
| Period-III (1974-1983) | 4.72 | 6.83 | 2.04 |
| Period-IV (1984-1993) | 9.06 | 12.29 | 2.98 |
| Period-V (1994-2003) | 1.72 | -0.12 | -1.79 |
| Period-VI (2004-2013) | -6.02 | -5.5 | 0.56 |
| Period-VII (2014-2023) | 6.63 | -9.05 | -14.98 |
| Period-VIII (1954-2023) | 1.82 | 2.93 | 1.09 |

improved inputs, poor irrigation coverage and the dominance of traditional farming practices during the mid-20th century (16). In period II (1964-1973), a positive shift occurred, with production growing at 2.57 % annually, largely due to an increase in area (2.11 %), while yield grew minimally (0.38 %). This recovery reflects the broader national improvement in spice cultivation during the green revolution era, largely due to enhanced extension services and gradual adoption of improved agronomic practices (6). This growth trend continued into periods III (1974-1983) and IV (1984-1993), with production rates improving to 6.83 % and 12.29 %, respectively, supported by positive contributions from area and yield, particularly in period IV where yield growth was 2.98 % which corresponds with nationwide technological improvements, increased fertilizer use and gradual integration of irrigation infrastructure in horticultural crops (6). During period V (1994-2003), production declined at -0.12 % annually, primarily driven by a decline in yield (-1.79 %), with a decline in area (1.72 %). In period VI (2004-2013), yield growth (0.56 %) sustained production increases despite a slight decline in area (-6.02 %). Similar stagnation was reported across Indian spice crops during the late 1990s, largely linked to climatic variability, rising input costs and increasing pest and disease pressures.

However, period VII (2014-2023) experienced positive growth in area and negative growth in production and yield, with an annual production decline of -9.05 %, largely due to the bifurcation of

Andhra Pradesh and Telangana in 2014, which resulted in the loss of major turmeric-growing regions to Telangana. This structural division significantly reduced cultivated area and disrupted supply chains, contributing to production instability in the reorganised state (8). Across the entire study period (1954-2023), the overall CAGR reflects moderate positive growth in area (1.82 %), production (2.93 %) and yield (1.09 %) as shown in Fig. 2, indicating a general upward trend in turmeric production despite distinct periods of expansion and contraction, particularly influenced by regional restructuring in recent years.

Modelling and forecasting

After the evaluation of the trend each series, our next goal is to forecast the series for the future years. Box-Jenkins methodology was employed, as indicated in the material and methods. Data from 1954 to 2015 were used to create the model and data from 2016 to 2023 were used to validate it. The best fitting models are used to forecast the area, production and yield series in the future. To forecast, first check the stationarity, in which the ACF and PACF graphs from the original series clearly reveal that none of them are steady in nature, but after first-order differencing are sufficient to make them stationary. So it was discovered that ARIMA models ranging from (0, 1, 0) to (1, 1, 10) are appropriate for forecasting the area production and yield of turmeric, starting with the model-building technique mentioned in the material and method.

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 the 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 , but basic objectives were not followed and the best-fitted model was selected based on the model that satisfies the majority of the objectives. 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 Andhra Pradesh are expected to decrease in the future were quite clearly in Fig. 3-5. In the turmeric area, production and yield data from none of the series are stationary in Andhra Pradesh. Thus, first differencing with the 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

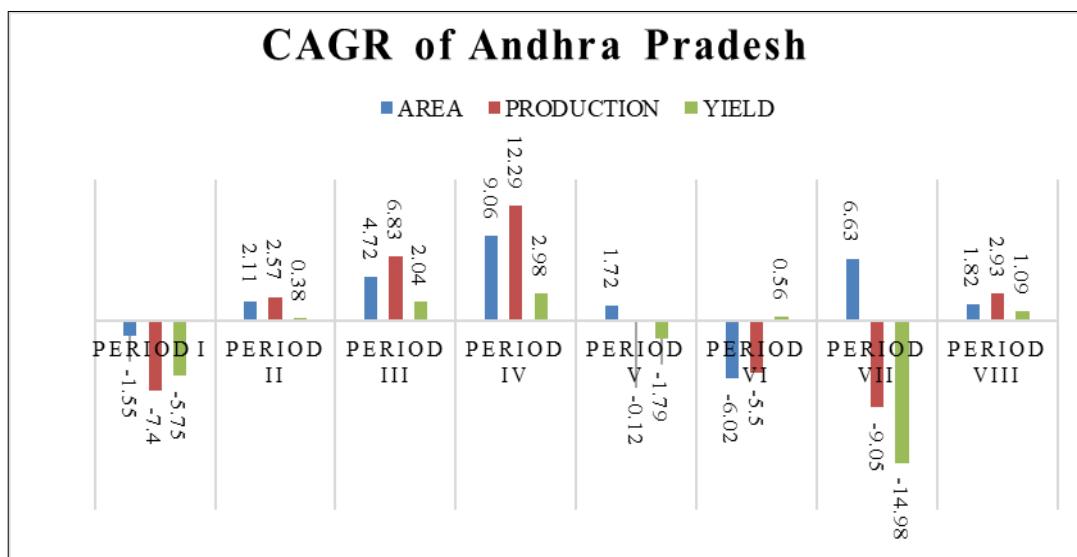


Fig. 2. Decadal growth trend in area production and yield of turmeric in Andhra Pradesh in 1954-2023.

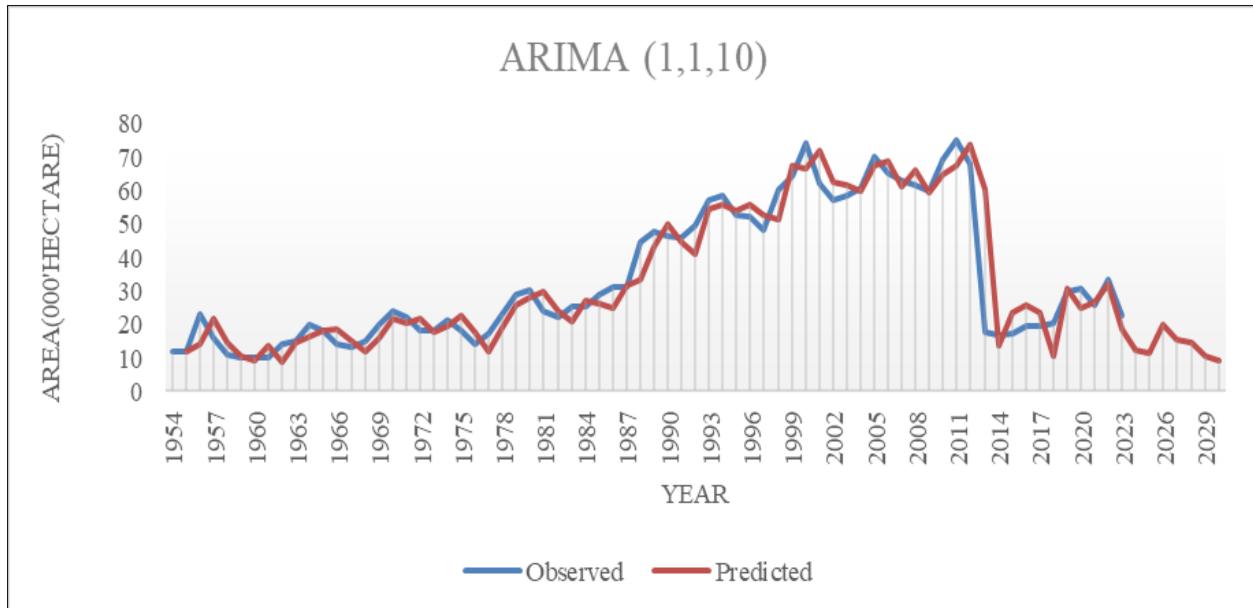


Fig. 3. Observed and forecasting area under turmeric in Andhra Pradesh.

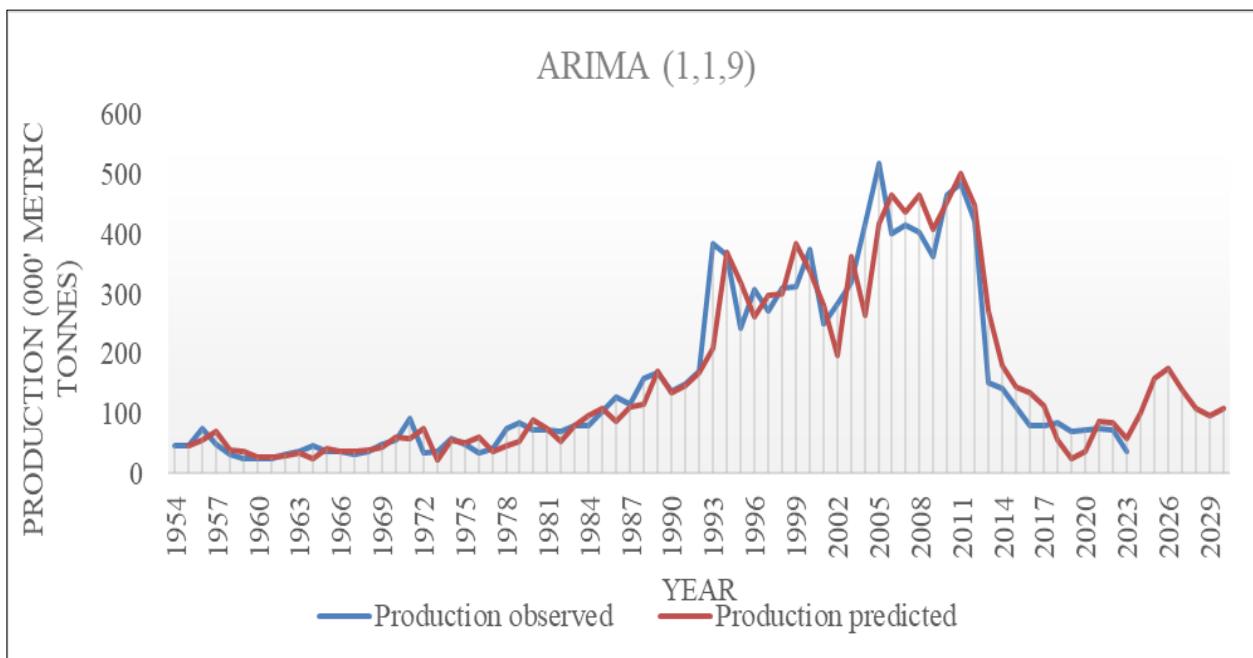


Fig. 4. Observed and forecasted production (000' MT) of turmeric in Andhra Pradesh.

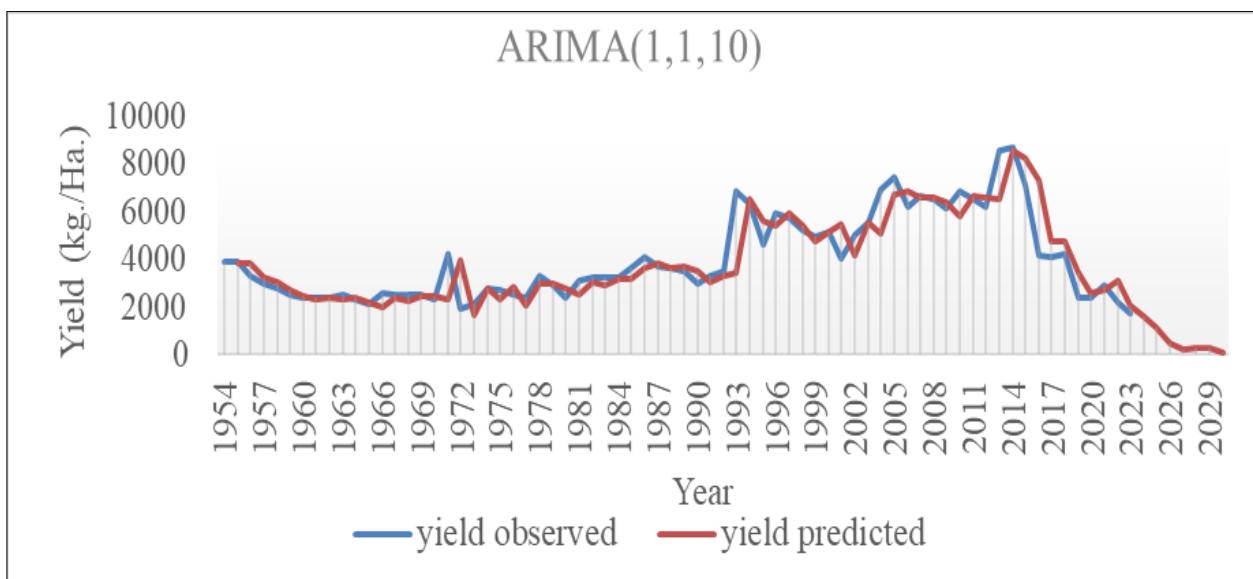


Fig. 5. Observed and forecasted yield under turmeric in Andhra Pradesh.

under turmeric in Andhra Pradesh, is represented in Fig. 6, which suggests that the tentative values of p and q that would be suitable for area under turmeric are $p=1$ and $q=10$ for Andhra Pradesh. Thus, ARIMA (1, 1, 10) was shown to be the best ARIMA model for the area under turmeric in Andhra Pradesh. The ARIMA (1, 1, 10) areas under turmeric have low RMSE, MAPE and MAE values in Andhra Pradesh, as shown in Table 2. So, the best-fitting model is ARIMA (1, 1, 10) in Andhra Pradesh. In 2023-2024, the area of turmeric in Andhra Pradesh was 22.37 thousand ha, respectively, compared to 18.65 thousand ha predicted. Andhra Pradesh will expect to have 9.33 thousand ha, as shown in Table 3 for the years 2030-2031.

The ACF and PACF plot of first difference, the value of production under turmeric in Andhra Pradesh, is represented in Fig. 7, which suggests that the tentative values of p and q that would be suitable for the area under turmeric are $p=1$ and $q=9$ for Andhra Pradesh. Thus, ARIMA (1, 1, 9) was shown to be the best ARIMA model for production under turmeric in Andhra Pradesh. As shown in Table 4, the ARIMA (1, 1, 9) production under turmeric had low RMSE, AIC values and maximum R^2 Value in Andhra Pradesh. So, the

Table 3. Model validation and forecasting of area (000' ha) under turmeric in Andhra Pradesh

| Year | Observed | Predicted |
|------|----------|-----------|
| 2016 | 19.18 | 25.87 |
| 2017 | 19.62 | 23.24 |
| 2018 | 20.36 | 10.39 |
| 2019 | 29.72 | 30.67 |
| 2020 | 30.52 | 24.94 |
| 2021 | 25.59 | 26.47 |
| 2022 | 33.42 | 32.12 |
| 2023 | 22.37 | 18.65 |
| 2024 | | 12.24 |
| 2025 | | 11.23 |
| 2026 | | 19.9 |
| 2027 | | 15.36 |
| 2028 | | 14.32 |
| 2029 | | 10.32 |
| 2030 | | 9.33 |

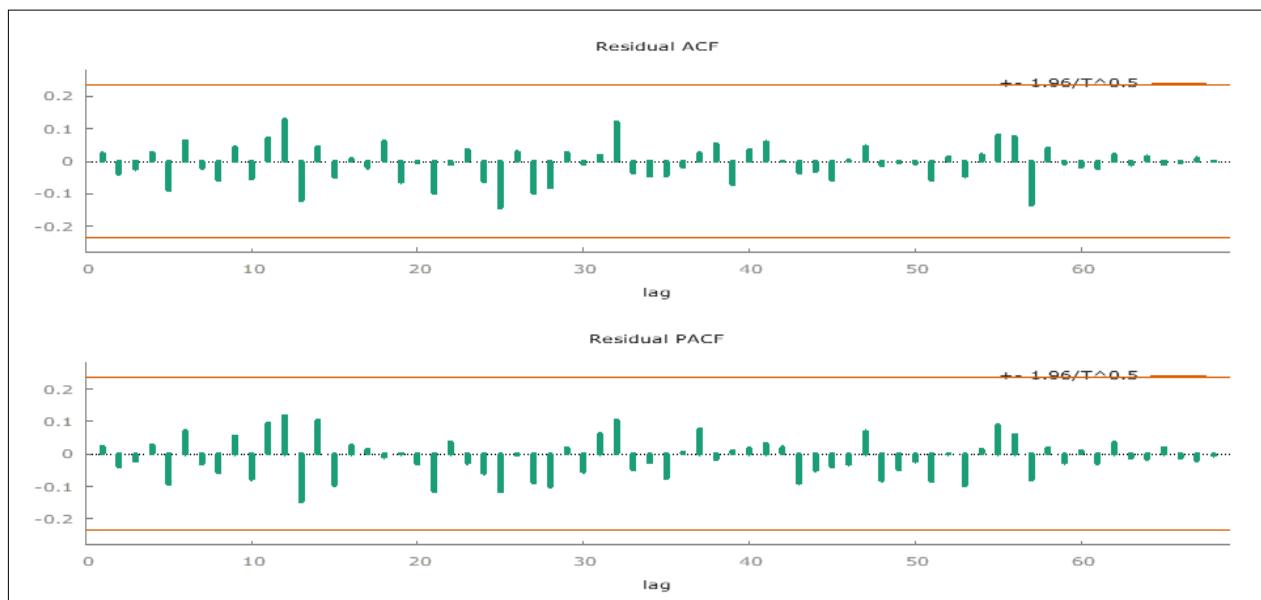


Fig. 6. ACF and PACF graphs of residuals for the best fitted models of the area under turmeric in Andhra Pradesh.

Table 2. Different ARIMA model for the area under turmeric in Andhra Pradesh

| AREA ARIMA | R ² | RMSE | MAPE | MAE | AIC |
|----------------|----------------|-------|--------|-------|----------------|
| ARIMA (0,1,0) | 0.847 | 7.950 | 17.313 | 4.639 | 485.903 |
| ARIMA (0,1,1) | 0.850 | 7.903 | 17.083 | 4.555 | 487.105 |
| ARIMA (0,1,2) | 0.849 | 7.847 | 17.134 | 4.516 | 488.165 |
| ARIMA (0,1,3) | 0.855 | 7.656 | 17.895 | 4.686 | 486.916 |
| ARIMA (0,1,4) | 0.855 | 7.652 | 17.734 | 4.631 | 488.838 |
| ARIMA (0,1,5) | 0.858 | 7.578 | 18.007 | 4.579 | 489.618 |
| ARIMA (0,1,6) | 0.858 | 7.569 | 18.070 | 4.596 | 491.477 |
| ARIMA (0,1,7) | 0.859 | 7.569 | 18.076 | 4.608 | 493.456 |
| ARIMA (0,1,8) | 0.860 | 7.542 | 17.673 | 4.489 | 495.102 |
| ARIMA (0,1,9) | 0.862 | 7.481 | 17.744 | 4.384 | 496.293 |
| ARIMA (0,1,10) | 0.864 | 7.428 | 17.454 | 4.353 | 497.472 |
| ARIMA (1,1,0) | 0.849 | 7.914 | 17.129 | 4.577 | 487.298 |
| ARIMA (1,1,1) | 0.850 | 7.895 | 17.126 | 4.553 | 488.964 |
| ARIMA (1,1,2) | 0.851 | 7.762 | 17.033 | 4.500 | 488.696 |
| ARIMA (1,1,3) | 0.855 | 7.654 | 17.804 | 4.657 | 488.882 |
| ARIMA (1,1,4) | 0.856 | 7.641 | 17.990 | 4.710 | 490.699 |
| ARIMA (1,1,5) | 0.859 | 7.570 | 18.081 | 4.601 | 491.488 |
| ARIMA (1,1,6) | 0.858 | 7.569 | 18.073 | 4.569 | 493.474 |
| ARIMA (1,1,7) | 0.861 | 7.548 | 17.835 | 4.565 | 495.188 |
| ARIMA (1,1,8) | 0.878 | 7.033 | 16.472 | 4.343 | 491.971 |
| ARIMA (1,1,9) | 0.878 | 7.034 | 16.463 | 4.344 | 493.966 |
| ARIMA (1,1,10) | 0.886 | 6.849 | 17.547 | 4.386 | 496.564 |

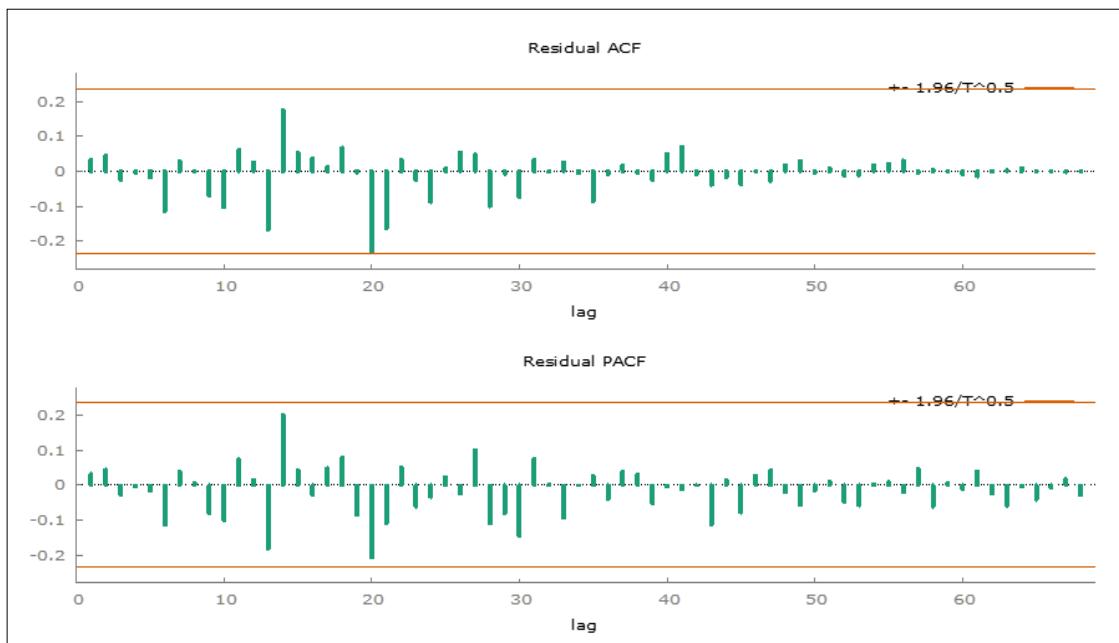


Fig. 7. ACF and PACF graphs of residuals for the best-fitted models of production under turmeric in Andhra Pradesh.

Table 4. Different ARIMA model for production under turmeric in Andhra Pradesh

| Production ARIMA | R ² | RMSE | MAPE | MAE | AIC |
|------------------|----------------|---------|---------|---------|----------|
| ARIMA (0,1,0) | 0.8424 | 57.8640 | 23.5880 | 32.7690 | 759.8304 |
| ARIMA (0,1,1) | 0.8422 | 57.8530 | 23.5680 | 32.6920 | 761.8050 |
| ARIMA (0,1,2) | 0.8434 | 57.2990 | 24.2080 | 32.9470 | 762.5164 |
| ARIMA (0,1,3) | 0.8437 | 57.1930 | 24.7120 | 33.5170 | 764.2638 |
| ARIMA (0,1,4) | 0.8437 | 57.1930 | 24.6940 | 33.5360 | 766.2625 |
| ARIMA (0,1,5) | 0.8499 | 56.3640 | 26.5670 | 33.9570 | 766.4311 |
| ARIMA (0,1,6) | 0.8499 | 56.3620 | 26.2010 | 33.9880 | 768.4258 |
| ARIMA (0,1,7) | 0.8558 | 55.6660 | 25.2850 | 33.5660 | 768.8868 |
| ARIMA (0,1,8) | 0.8893 | 48.4590 | 25.4960 | 31.6820 | 761.6305 |
| ARIMA (0,1,9) | 0.8900 | 47.8700 | 24.8120 | 30.7250 | 761.2258 |
| ARIMA (0,1,10) | 0.8901 | 47.8680 | 24.7510 | 30.7510 | 763.2002 |
| ARIMA (1,1,0) | 0.8423 | 57.8560 | 23.5690 | 32.7090 | 761.8115 |
| ARIMA (1,1,1) | 0.8432 | 56.7480 | 24.6290 | 33.0870 | 762.4368 |
| ARIMA (1,1,2) | 0.8435 | 57.2380 | 24.4970 | 33.2210 | 764.3687 |
| ARIMA (1,1,3) | 0.8437 | 57.1930 | 24.7100 | 33.5180 | 766.2637 |
| ARIMA (1,1,4) | 0.8468 | 56.9010 | 25.0690 | 33.8260 | 767.6154 |
| ARIMA (1,1,5) | 0.8495 | 56.3570 | 26.5460 | 34.0190 | 768.4060 |
| ARIMA (1,1,6) | 0.8498 | 56.2960 | 26.5670 | 34.0520 | 770.2545 |
| ARIMA (1,1,7) | 0.8586 | 55.1180 | 25.6120 | 33.6470 | 769.7424 |
| ARIMA (1,1,8) | 0.8895 | 47.8920 | 25.0270 | 30.6310 | 761.4822 |
| ARIMA (1,1,9) | 0.9041 | 44.8520 | 23.2520 | 29.0740 | 758.2617 |
| ARIMA (1,1,10) | 0.9038 | 44.7940 | 23.3120 | 29.1190 | 759.9181 |

best-fitting model is ARIMA (1, 1, 9) in Andhra Pradesh. In 2023-2024, the production of turmeric in Andhra Pradesh was 38.03 thousand MT compared to 57.67 thousand MT predicted. As shown in Table 5 for the years 2030-2031 andhra Pradesh is expected to have 108.12 thousand MT, respectively.

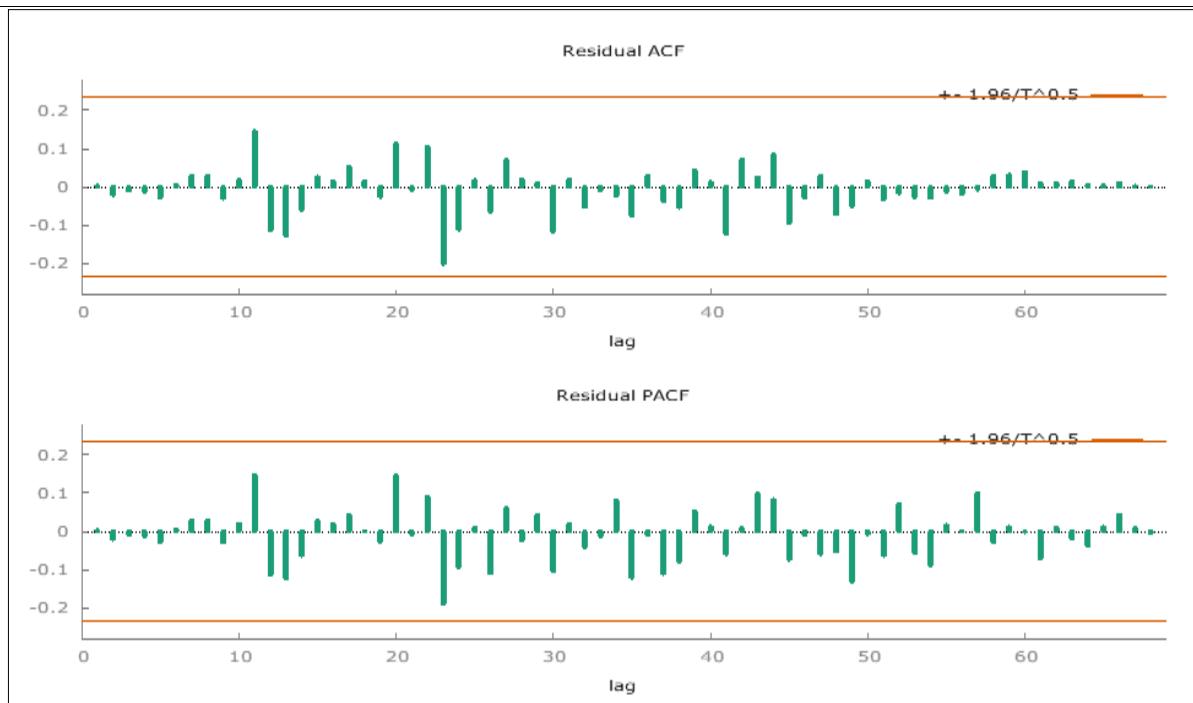
The ACF and PACF plot of first difference, the value of yield under turmeric in Andhra Pradesh was represented in Fig. 8, which suggests that the tentative values of p and q that would be suitable for yield under turmeric are $p=1$ and $q=10$ for Andhra Pradesh. Thus, ARIMA (1, 1, 10) were shown to be the best ARIMA model for yield under turmeric in Andhra Pradesh. As shown in Table 6, the ARIMA (1, 1, 10) yield under turmeric has the lowest RMSE, MAPE and MAE values and the maximum R² Value in Andhra Pradesh. So the best fitting model is ARIMA (1, 1, 10) in Andhra Pradesh. In 2023-2024, the yield of turmeric in Andhra Pradesh was 1700 kg/ha, respectively, compared to 2032.18 kg/ha predicted. As shown in Table 7 for the years 2030-2031 andhra Pradesh will expect to have 118.23 kg/ha.

Table 5. Model validation and forecasting of production (000 MT) under turmeric in Andhra Pradesh

| Year | Observed | Predicted |
|------|----------|-----------|
| 2016 | 79.73 | 136.14 |
| 2017 | 79.73 | 112.86 |
| 2018 | 85.5 | 55.12 |
| 2019 | 71.32 | 24.18 |
| 2020 | 73.24 | 36.88 |
| 2021 | 74.69 | 87.74 |
| 2022 | 73.52 | 83.99 |
| 2023 | 38.03 | 57.67 |
| 2024 | | 101.3 |
| 2025 | | 158.1 |
| 2026 | | 175.72 |
| 2027 | | 139.83 |
| 2028 | | 109.89 |
| 2029 | | 95.9 |
| 2030 | | 108.12 |

Table 6. Different ARIMA models for yield (kg/ha) under turmeric in Andhra Pradesh.

| Yield ARIMA | R ² | RMSE | MAPE | MAE | AIC |
|----------------|----------------|----------|---------|----------|-----------|
| ARIMA (0,1,0) | 0.7470 | 910.3400 | 14.9570 | 578.8200 | 1140.1210 |
| ARIMA (0,1,1) | 0.7459 | 904.3400 | 14.7700 | 573.2800 | 1141.2300 |
| ARIMA (0,1,2) | 0.7560 | 879.4700 | 14.6410 | 555.7800 | 1139.4990 |
| ARIMA (0,1,3) | 0.7619 | 872.2400 | 14.1080 | 540.0200 | 1140.4170 |
| ARIMA (0,1,4) | 0.7621 | 869.8500 | 14.2680 | 537.3300 | 1142.0930 |
| ARIMA (0,1,5) | 0.7620 | 869.5200 | 14.1530 | 533.3500 | 1144.0380 |
| ARIMA (0,1,6) | 0.7660 | 860.7000 | 14.2230 | 531.8000 | 1144.7950 |
| ARIMA (0,1,7) | 0.7670 | 859.5600 | 13.9070 | 527.0900 | 1146.5700 |
| ARIMA (0,1,8) | 0.7702 | 856.0800 | 13.7590 | 528.8700 | 1148.1090 |
| ARIMA (0,1,9) | 0.7737 | 852.1900 | 13.9490 | 530.7500 | 1149.7850 |
| ARIMA (0,1,10) | 0.7755 | 849.4700 | 13.7160 | 521.2200 | 1151.3700 |
| ARIMA (1,1,0) | 0.7464 | 907.1000 | 14.7950 | 574.9500 | 1141.6360 |
| ARIMA (1,1,1) | 0.7469 | 896.2200 | 14.8920 | 571.5200 | 1142.0140 |
| ARIMA (1,1,2) | 0.7628 | 868.6400 | 14.4060 | 541.3600 | 1139.9350 |
| ARIMA (1,1,3) | 0.7626 | 868.2300 | 14.4920 | 543.6300 | 1141.8780 |
| ARIMA (1,1,4) | 0.7637 | 867.4700 | 14.3300 | 541.4100 | 1143.7540 |
| ARIMA (1,1,5) | 0.7636 | 867.4500 | 14.3340 | 541.0300 | 1145.7510 |
| ARIMA (1,1,6) | 0.7664 | 860.1400 | 14.0710 | 528.8100 | 1146.6840 |
| ARIMA (1,1,7) | 0.7719 | 854.8000 | 13.7150 | 525.5300 | 1147.9530 |
| ARIMA (1,1,8) | 0.7745 | 851.4000 | 13.8000 | 526.5000 | 1149.6090 |
| ARIMA (1,1,9) | 0.7752 | 850.4600 | 13.8230 | 525.4500 | 1151.5260 |
| ARIMA (1,1,10) | 0.7761 | 848.7400 | 13.6380 | 518.3800 | 1153.2210 |

**Fig. 8.** ACF and PACF graphs of residuals for the best-fitted models of yield under turmeric in Andhra Pradesh.**Table 7.** Model validation and forecasting of production under turmeric in Andhra Pradesh

| Year | Observed | Predicted |
|------|----------|-----------|
| 2016 | 4160 | 7259.64 |
| 2017 | 4063 | 4727.69 |
| 2018 | 4200 | 4732.06 |
| 2019 | 2400 | 3447.71 |
| 2020 | 2400 | 2578.71 |
| 2021 | 2920 | 2728.7 |
| 2022 | 2200 | 3120.15 |
| 2023 | 1700 | 2032.18 |
| 2024 | | 1577.03 |
| 2025 | | 1147.4 |
| 2026 | | 482.26 |
| 2027 | | 244.02 |
| 2028 | | 259.02 |
| 2029 | | 293.4 |
| 2030 | | 118.23 |

Conclusion

This study demonstrates substantial shifts in turmeric farming trends in Andhra Pradesh over time. While there was significant expansion from 1984 to 1993, the recent years (2014 -2023) have seen a drop in both area and output, primal due to bifurcation of Andhra Pradesh, which led to regional reorganisation and altered resource distribution. This decreasing trend may continue, with acreage and output likely to decrease even more by 2030-31, as per the records. To address these declining trends, strategic initiatives are required. Efforts such as promoting sustainable farming techniques, improving market access, providing financial assistance and harnessing current agricultural technology can all help to stabilise turmeric production. Addressing these concerns is crucial to protect turmeric farmers' livelihoods and maintain India's dominating position in the global turmeric trade.

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Authors' contributions

MPN were involved in conceptualisation and wrote and prepared the original draft. RRK were involved in conceptualisation and was responsible for the supervision. HM, MG, ST and DS took part in reviewing and editing. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare

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