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Trends and forecasting of major chemical fertilizer consumption in Telangana: State and district-level analysis

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Abstract

Fertilizer use plays a crucial role in enhancing agricultural productivity, necessitating an assessment of its growth, instability, and future demand. This study analyses the consumption of major chemical fertilizers (N, P, and K) in Telangana using district-level data (2015–16 to 2024–25) and four decades of state-level data. Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), Cuddy–Della Valle Instability Index (CDVI), and ARIMA models were employed for growth, instability, and forecasting analyses. State-level NPK consumption increased from 1,316.25 to 1,879.03 thousand tonnes, while district-level trends varied considerably. Nizamabad recorded the highest growth (5.26%), whereas most districts showed declining fertilizer use. Potash exhibited the highest instability, and the N:P:K ratio remained imbalanced in most districts. ARIMA forecasts indicate that total fertilizer consumption in Telangana will increase by about 11 per cent, from 19.06 lakh tonnes in 2025 to 20.93 lakh tonnes by 2029.

Keywords: Fertilizer consumption, compound annual growth rate, Cuddy–Della Valle instability index, ARIMA forecasting, Telangana, Nutrient imbalance

1. Introduction

Agriculture continues to be the backbone of the Indian economy, contributing nearly 16 per cent to the country's Gross Value Added (GVA) while providing livelihood to about 42 per cent of the workforce, predominantly in rural areas (Economic Survey, 2024–25; Ministry of Finance, Government of India) [3]. India, the world's most populous nation, is projected to have a population exceeding 1.5 billion by 2030 (World Economic Forum), intensifying the demand for food and agricultural commodities. With limited scope for expanding the cultivated area, achieving food security depends primarily on increasing crop productivity rather than bringing additional land under cultivation. In this context, chemical fertilizers have emerged as one of the most critical purchased inputs for enhancing agricultural productivity. They have played a pivotal role in the success of the Green Revolution and continue to remain an essential component of modern crop production technologies, supporting higher yields and ensuring national food security.

Fertilizer consumption in India has increased significantly since the Green Revolution, making the country the second-largest consumer and third-largest producer of fertilizers globally, after China. Total fertilizer consumption reached 64.8 million tonnes during 2023–24 (Fertiliser Association of India, Annual Report 2023–24) [4]. Recognizing the critical role of fertilizers in sustaining agricultural productivity, the

Government of India allocated over ₹1.9 lakh crore towards fertilizer subsidies in 2024–25 to ensure their affordability and timely availability to farmers (Press Information Bureau, Government of India, 2025) [6]. Numerous studies have established a strong positive relationship between fertilizer application and crop productivity, making fertilizer consumption an important indicator for agricultural planning and policy formulation. However, fertilizer use varies considerably across regions due to differences in irrigation infrastructure, cropping patterns, farmers' financial capacity, input accessibility, and the expected profitability and risk associated with different crops (Kaushik and Paharia, 2014) [5]. These factors contribute to significant spatial and temporal variations in fertilizer consumption across states and districts. Since nitrogen (N), phosphorus (P), and potassium (K) perform distinct physiological functions and are not perfect substitutes, balanced fertilizer application is determined by the recommended N:P:K nutrient ratio rather than the quantity of any individual nutrient. Therefore, assessing fertilizer consumption in terms of individual nutrients and their relative proportions is essential for evaluating nutrient-use efficiency and soil health. In India, fertilizer use has consistently deviated from the recommended nutrient balance, with a disproportionate increase in nitrogen consumption relative to phosphorus and potash, resulting in widespread nutrient imbalance. Using an exponential growth

model, Sharma *et al.* (2023) ^[7] reported that potash exhibited the highest growth and instability among the three major nutrients, while nitrogen consumption remained relatively stable, indicating a persistent and widening nutrient imbalance. Similarly, Chandra *et al.* (2022) ^[1], in a study of fertilizer consumption in Chhattisgarh during 2005–06 to 2019–20, employed the Compound Annual Growth Rate and Cuddy–Della Valle Instability Index and observed an increasing trend in fertilizer use, with a positive annual growth rate of 3.40 per cent and relatively low instability (9.91%), reflecting a steady rise in fertilizer consumption over the study period.

Telangana holds a significant position in Indian agriculture owing to its diverse cropping systems dominated by rice, cotton, and maize, coupled with substantial inter-district variations in irrigation coverage, soil characteristics, rainfall patterns, and cropping intensity. These factors strongly influence the demand and consumption of chemical fertilizers across the state. Consequently, state-level averages often mask considerable district-level disparities in fertilizer use. While some districts experience rapid growth and high variability in nutrient consumption, others exhibit stagnation or declining trends, necessitating different policy and management interventions. Therefore, district-level assessment of fertilizer consumption, its growth, instability, and future demand is essential for informed input planning, efficient fertilizer distribution, balanced nutrient management, and evidence-based policymaking aimed at enhancing agricultural productivity and sustainability in Telangana.

1.1 Objectives of the Study

In line with the above rationale, the specific objectives of the study are:

1. To analyse the growth and instability of major chemical fertilizers in the selected districts of Telangana
2. To forecast the major chemical fertilizers consumption in Telangana

2. Materials and Methods

2.1 Study Area and Data Source

The present study was conducted in Telangana using secondary data collected at both the district and state levels. District-wise data on the consumption of the three major plant nutrients— nitrogen (N), phosphorus (P), and potassium (K)—were compiled for a ten-year period from 2015–16 to 2024–25 for the nine erstwhile districts of Telangana: Nizamabad, Medak, Mahabubnagar, Nalgonda, Warangal, Khammam, Karimnagar, Adilabad, and Ranga Reddy. In addition, state-level fertilizer consumption data covering four decades were used to analyse long- term trends and forecast future consumption. The data were obtained from authentic secondary sources, including the Directorate of Economics and Statistics (DES), Government of Telangana, the Commissionerate and Directorate of Agriculture, Government of Telangana, and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad.

To analyse the growth and instability in fertilizer consumption, the Compound Annual Growth Rate (CAGR), Coefficient of Variation (CV), and Cuddy–Della Valle Instability Index (CDVI) were employed. For forecasting

future fertilizer consumption in Telangana, annual state-level data spanning 40 years (1985–86 to 2024–25) were used. The Autoregressive Integrated Moving Average (ARIMA) model was applied to project fertilizer consumption for the subsequent years based on historical trends. A brief description of the analytical techniques used in the study is presented below.

2.2 Compound Annual Growth Rate (CAGR) Analysis

To analyse the growth in consumption of the major chemical fertilizers, compound growth rate analysis was carried out for the ten-year period across the nine districts of Telangana. The compound annual growth function is specified as:

$$Y = A B^t$$

where Y is fertilizer consumption, A is the intercept, B is the regression coefficient, and t is the year. The compound annual growth rate is then obtained as:

$$\text{CAGR (\%)} = (\text{Antilog } b - 1) \times 100$$

2.3 Instability Analysis

2.3.1 Coefficient of Variation (CV)

The Coefficient of Variation was computed to study the variability in the consumption of the major fertilizers over the ten-year period across the nine districts of Telangana, using the formula:

$$\text{CV (\%)} = (\text{Standard Deviation} / \text{Mean}) \times 100$$

2.3.2 Cuddy–Della Valle Instability Index (CDVI)

The Cuddy–Della Valle Instability Index helps to measure instability in linear or exponentially trended time series data. Its principal advantage is that it is derived from the coefficient of determination and can therefore be applied to any time series, including one that exhibits a significant trend. CDVI is calculated as:

$$\text{CDVI} = \text{CV} \times \sqrt{(1 - \bar{R}^2)}$$

where CV is the coefficient of variation and $\bar{R}^2$ is the coefficient of determination from the trend regression.

2.4 Autoregressive Integrated Moving Average (ARIMA) Model

The Autoregressive Integrated Moving Average (ARIMA) model, developed by Box and Jenkins, is a widely used method for analysing and forecasting time series data. It is represented as ARIMA (p, d, q), where p denotes the autoregressive order, d the degree of differencing required to achieve stationarity, and q the moving-average order. When d = 0, the model reduces to an ARMA (p, q) model. The ARIMA model can be expressed as:

$$(1 - \sum \phi_i L^i) (1 - L)^d X_t = (1 + \sum \theta_i L^i) \varepsilon_t$$

where L is the lag operator, ϕ_i is parameters of the autoregressive part, θ_i is parameters of the moving-average part, and ε_t is the error term. ARIMA requires the time series to be stationary and follows the Box–Jenkins procedure of model identification, parameter estimation, diagnostic

checking, and forecasting. The most appropriate model is selected using the autocorrelation function (ACF), the partial autocorrelation function (PACF), and information criteria such as the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). For example, ARIMA (0,1,0), also known as the random walk model, is represented as $X_t = X_{t-1} + \varepsilon_t$.

3. Results and Discussion

3.1 Trend in State-level Fertilizer Consumption

The state-level series (Table 1) shows that total NPK fertilizer consumption in Telangana rose from 1,316.25 thousand tonnes in 2015 to 1,879.03 thousand tonnes in 2024, an overall rise of about 42.8 per cent over the course of the decade. However the increase was not continuous: total consumption fell in 2018 and again in 2021 before resuming its upward path. Nitrogen remained the dominant nutrient throughout the period, rising from 877.30 to 1,287.07 thousand tonnes, while phosphorus rose from 327.79 to 489.70 thousand tonnes. Potash showed the most erratic

pattern of the three nutrients, peaking at 173.22 thousand tonnes in 2020 before falling sharply to 69.46 thousand tonnes in 2022 and only partially recovered to 102.26 thousand tonnes by 2024. (Table 1, Figure 1)

Table 1: State-level Consumption of N, P, K and Total NPK Fertilizers in Telangana, 2015–2024 ('000 tonnes)

Year	N	P	K	Total NPK
2015	877.30	327.79	111.16	1,316.25
2016	926.20	320.66	125.06	1,371.92
2017	896.73	349.04	145.97	1,391.74
2018	888.27	343.14	114.50	1,345.91
2019	987.10	369.68	122.41	1,479.19
2020	1,169.73	474.59	173.22	1,817.54
2021	1,104.81	423.92	107.69	1,636.42
2022	1,191.57	451.50	69.46	1,712.53
2023	1,215.66	467.39	82.91	1,765.96
2024	1,287.07	489.70	102.26	1,879.03

Source: www.indiastat.com

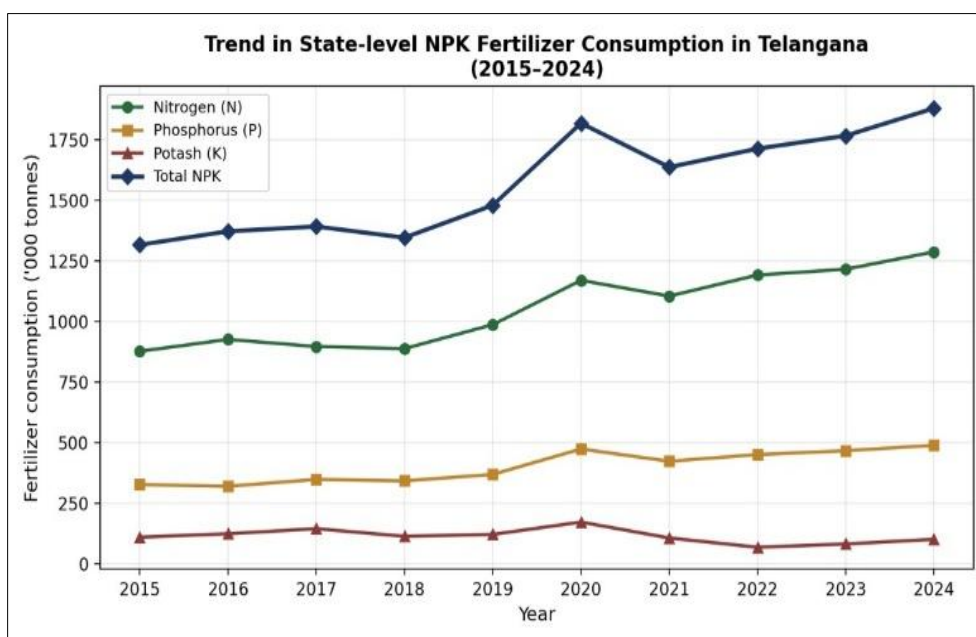


Fig 1: Trend in State-level NPK Fertilizer Consumption in Telangana (2015–2024)

3.2 District-wise Growth Rate of Total NPK Consumption

The district-wise CAGR estimates for total NPK consumption (Table 2) reveal a sharply divided picture that a state-level average alone would conceal. Only Nizamabad, one of the nine districts recorded a positive growth rate (5.26% per annum) significant at 1%, while Nalgonda showed a marginal, statistically non-significant positive growth of 0.22 per cent per annum.

Over the course of the decade, total nutrient consumption decreased in all seven districts, with four of them showing statistically significant declines. Mahbubnagar (–11.66%, significant at 5%), Karimnagar (–8.84%, significant at 1%), Ranga Reddy (–7.56%, significant at 10%), and Adilabad (–7.46%, significant at 10%). This suggests that a single high-growth district (Nizamabad) is disproportionately driving the modest state-level growth reported in Section 4.1, while most districts are seeing a real, statistically detectable

decline in fertiliser nutrient use.

Table 2: District-wise compound annual growth Rate of Total NPK Consumption

District	CAGR (%)	CV (%)	CDVI (%)
Nizamabad	5.26***	20.06	12.65
Nalgonda	0.22NS	15.62	15.61
District	CAGR (%)	CV (%)	CDVI (%)
Khammam	-1.66NS	13.01	11.97
Medak	-2.60NS	39.35	38.59
Warangal Rural	-4.28NS	64.48	62.95
Adilabad	-7.46*	44.79	35.70
Ranga Reddy	-7.56*	51.92	42.62
Karimnagar	-8.84***	42.52	27.44
Mahbubnagar	-11.66**	55.48	38.49

Note: *** significant at 1%, ** significant at 5%, * significant at 10%, ns = not significant

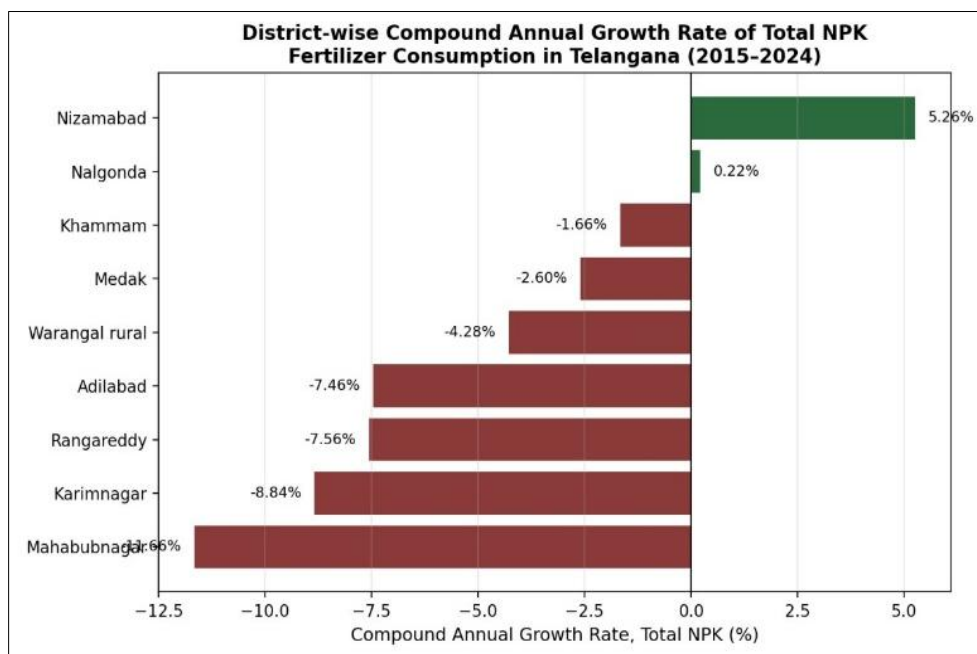


Fig 2: District-wise Compound Annual Growth Rate of Total NPK Fertilizer Consumption in Telangana (2015–2024)

3.3 Nutrient-wise Growth Rates across Districts

Disaggregating growth by nutrient (Table 3) shows that nitrogen was the only nutrient to record a positive and statistically significant CAGR in any district including Nizamabad (8.24%, significant at 1). In contrast phosphorus and potash recorded a negative CAGR in almost every district, frequently significant at the 1 or 5 per cent level. Potash decline was particularly steep and consistent: Ranga

Reddy (–29.88%, significant at 1%), Mahbubnagar (–18.25%, significant at 1%), Warangal Rural (–17.76%, significant at 5%), and Nizamabad itself (–14.14%, significant at 1%), despite rising or stable total or nitrogen consumption. This pattern aligns with Sharma *et al.* (2023)^[7], who identified potash as the most volatile nutrient in Haryana.

Table 3: Nutrient-wise (N, P, K) Compound Annual Growth Rate by District, Telangana, 2015– 2024

District	CAGR (%)		
	N	P	K
Nizamabad	8.24***	-2.00 NS	-14.14***
Medak	-0.60 NS	-15.71 NS	0.09 NS
Mahbubnagar	-9.18**	-17.36***	-18.25***
Nalgonda	3.47 NS	-8.84**	-8.84***
Warangal Rural	-0.60 NS	-15.46**	-17.76**
Khammam	1.42 NS	-7.56**	-11.41***
Karimnagar	-7.31**	-12.97***	-13.05***
Adilabad	-7.05 NS	-7.04*	-15.38***
Ranga Reddy	-2.40 NS	-10.35**	-29.88***

Note: *** significant at 1%, ** significant at 5%, * significant at 10%, NS = not significant

3.4 Instability in Fertilizer Consumption

The Coefficient of Variation and Cuddy–Della Valle Instability Index for total NPK consumption (Table 2, Figure 3) show that instability and growth are not simply mirror images of one another: Warangal Rural combines a modest negative CAGR (–4.28%, non-significant) with the highest instability of all nine districts (CV 64.48%, CDVI 62.95%), while Khammam combines a small negative CAGR (–1.66%) with the lowest instability (CV 13.01%, CDVI 11.97%). The gap between CV and CDVI is informative in

its own right: CDVI adjusts CV for the variation explained by an underlying trend, so a district where CDVI is close to CV (as in Warangal Rural and Nalgonda) is one whose year-to-year fluctuation is largely trend-independent noise, whereas a district where CDVI is significantly lower than CV (as in Karimnagar, CV 42.52% versus CDVI 27.44%, or Mahbubnagar, CV 55.48% versus CDVI 38.49%) is one where a significant portion of the apparent variability is actually explained by a persistent downward trend rather than erratic year-to-year swings.

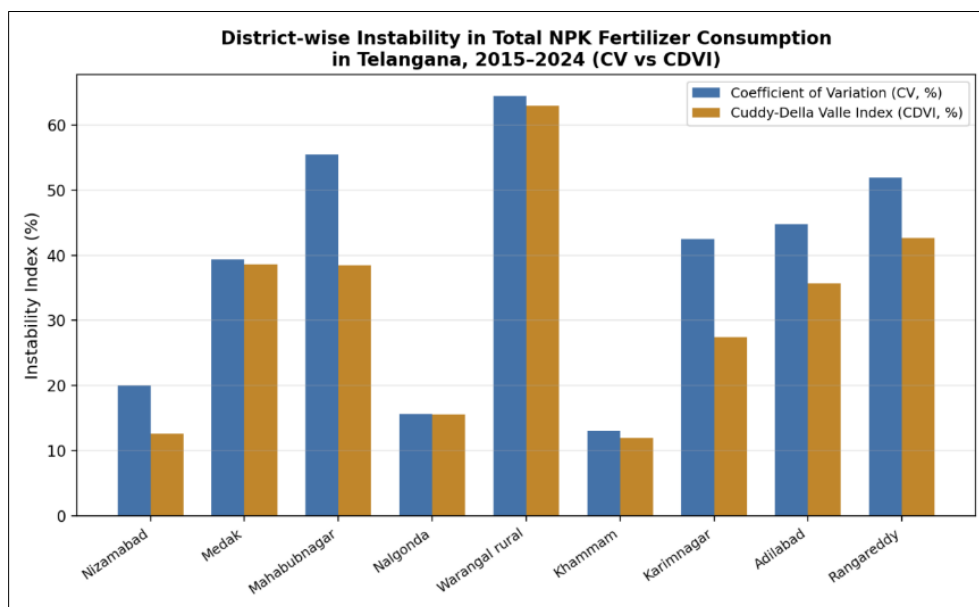


Fig 3: District-wise Instability (CV vs CDVI) in Total NPK Fertilizer Consumption, Telangana, 2015–2024

3.5 ARIMA Forecast of Nutrient-wise Fertilizer Consumption

ARIMA models that were not seasonal were fitted to the series of state level nitrogen, phosphorus, and potash for the period of 40 years (from 1985-86 to 2024-25). Rolling-origin forecast accuracy of one-step ahead over the most recent eight origins was used to determine the best performing ARIMA models as follows: ARIMA (2,1,0) with drift for nitrogen, ARIMA (1,0,0) with drift for phosphorus, ARIMA

(1,0,1) with constant and trend for potash and ARIMA (0,1,1) with drift for total NPK (Table 5). The residual diagnostics indicated the residuals were satisfactory in all the four series since Ljung–Box p-value was above 0.05 for all the four series (from 0.208 for total NPK to 0.765 for potash). This showed there was no significant serial correlation in the residuals for the tested lag. The forecast accuracy using MAPE was good for nitrogen (5.28%), phosphorus (5.84%) and total NPK (4.94%), but weak for potash (26.63%).

Table 5: Selected ARIMA Models and Diagnostic Statistics for Nutrient-wise Fertilizer Consumption

Series	Selected Model		AICc	RMSE	MAE	MAPE (%)	Ljung-Box p
Nitrogen (N)	ARIMA (2,1,0) drift	with	96.79	0.801	0.579	5.28	0.620
Phosphorus (P)	ARIMA (1,0,0) drift	with	44.49	0.369	0.254	5.84	0.434
Potash (K)	ARIMA (1,0,1) constant & trend	with	9.84	0.369	0.276	26.63	0.765
Total NPK	ARIMA (0,1,1) drift	with	133.26	1.293	0.833	4.94	0.208

The corresponding five-year forecast (Table 6, Figure 4) suggests that the total NPK demand in Telangana will increase from 19.06 lakh tonnes in 2025 to 20.93 lakh tonnes in 2029, which implies a rise of about 11.4 per cent during the horizon and an annualised growth of 2.18 per cent relative to the observed value of 18.79 lakh tonnes in 2024. Nitrogen is predicted to grow from 12.93 to 14.13 lakh tonnes, phosphorus from 4.96 to 5.33 lakh tonnes, and potash from 1.17 to 1.47 lakh tonnes over the horizon. The contribution of nitrogen in the total demand will stay the greatest during the

entire forecast horizon, followed by the contributions of phosphorus and potash, respectively, as in the case of the nutrient shares shown in the state-level (Section 4.1) and district-wise (Section 4.5) trends. The prediction interval will expand as the horizon expands because forecast uncertainty increases with an increasing distance from the observed values; thus, the forecasts should be considered as an expected extension of historical trends rather than as a precise requirement figure for the input planning.

Table 6: Five-Year ARIMA Forecast of Nutrient-wise Fertilizer Consumption in Telangana, in (lakh tonnes)

Year	Nitrogen	Phosphorus	Potash	Total NPK	95% Interval (Total)
2025	12.93	4.96	1.17	19.06	17.36 – 20.76
2026	13.24	5.03	1.28	19.55	17.63 – 21.47
2027	13.57	5.12	1.36	20.06	17.96 – 22.15
2028	13.83	5.22	1.42	20.48	18.19 – 22.77
2029	14.13	5.33	1.47	20.93	18.50 – 23.35

Note: Total NPK point forecast is the sum of the nitrogen, phosphorus and potash component forecasts; its 95% interval is an approximate combined interval obtained from the component forecast uncertainties.

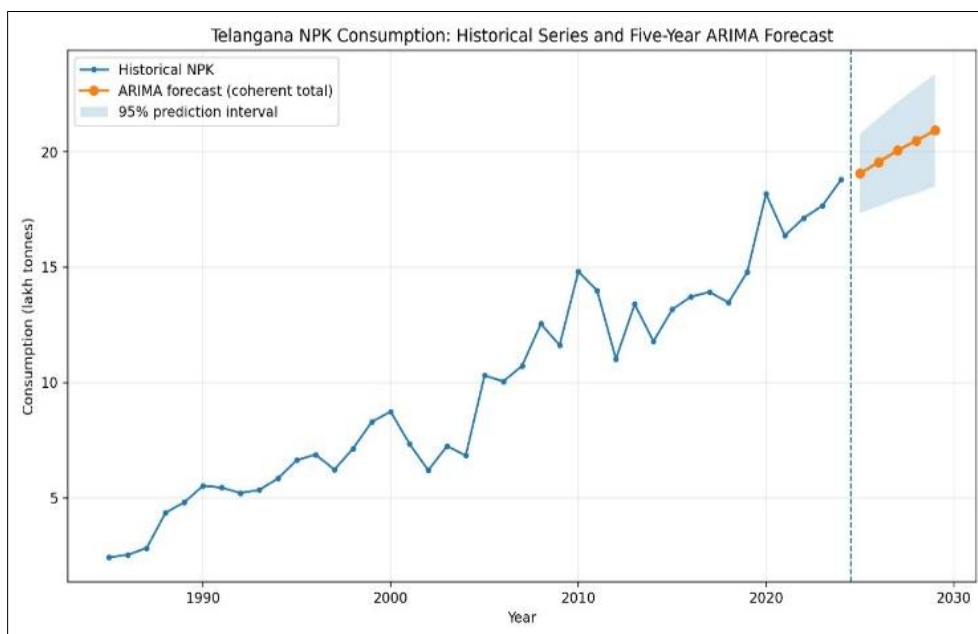


Fig 4: Historical Total NPK Consumption in Telangana and Five-Year ARIMA Forecast with 95% Prediction Interval

5. Conclusion

This study analysed the growth, instability, and future trends of nitrogen (N), phosphorus (P), and potash (K) fertilizer consumption in Telangana using district-level data (2015–16 to 2024–25) and state-level data (1985–2024). The results revealed an overall increase in fertilizer consumption at the state level, although district-wise trends varied considerably. Nizamabad recorded significant growth, whereas most other districts experienced declining fertilizer use. Potash showed the highest instability, and the N:P:K consumption ratio deviated from the recommended balance in most districts, indicating nutrient imbalance. ARIMA forecasts suggest that fertilizer consumption will continue to increase moderately over the coming years. These findings highlight the need for district-specific, soil test-based nutrient management, balanced fertilizer application, and strengthened extension services to improve fertilizer use efficiency and ensure sustainable agricultural production. Future research may employ multivariate forecasting models by incorporating climatic, irrigation, cropping pattern, and policy variables to generate more robust and location-specific forecasts.

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