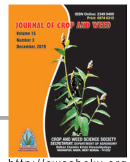
Journal of Crop and Weed, 18(3): 200-205 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315



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Modelling and forecasting of electricity consumption used in agriculture purpose in India

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Received : 12.10.2022 ; Revised : 22.10.2022 ; Accepted : 29.10.2022

DOI : https://doi.org/10.22271/09746315.2022.v18.i3.1636

ABSTRACT:

This study primarily focused on predicting power use for agricultural purposes because it is a highly useful issue in our daily lives.Therefore, it is crucial to examine the nature of overall power consumption as well as its use for agricultural purposes. We attempted to develop a time series forecasting model to anticipate power usage.The ARIMA and State Space models were used to construct the statistical model. Akaike information criterion (AIC), Mean absolute error (MAE), Root mean square error (RMSE), and Mean absolute percentage error were used to evaluate the fitness of the two statistical models (MAPE).On both training and test data series, we were able to establish that state space models are the best model for predicting power usage for agricultural purposes. We anticipated that India's use of electricity for agricultural purposes will increase by 14.36% between 2021 and 2026 to reach 250517.4 (GWh) in 2026.The growth rate for India's total electricity consumption from 2021 to 2026 is predicted to be 16.24%. This paper provides a thorough evaluation of energy use for agricultural purposes in India.

Keywords**:** Time series, agricultural electricity, forecasting, ARIMA

Electricity is one of many sources of energy in nature, but it is the most practical and has had the most impact on human life. Life expectancy, literacy, health, and agricultural output are just few of the areas where electric power has been shown to improve people's lives (Bridge *et al*., 2016). There is a direct correlation between rising income and rising energy usage (Ghosh, 2002). Income rise in tandem with increased power use is particularly obvious in developing nations like India (Ferguson *et al.*, 2000). Households, businesses, farms, SMEs, and MNCs make up India's five largest energy user groups (Bose and Shukla, 1999). Only in the agricultural sector has there been consistent evidence of a long-term correlation between economic expansion and electricity use; elsewhere, the relationship has been more one-sided (Tiwari *et al*., 2021). According to the research of Abbas and Choudhury (2012), there is a two-way relationship between electricity use in agriculture and agricultural GDP in India. While India's domestic energy consumption has climbed by almost 50 per cent since 1971, it is still just around a third of the global average (Chunekar and Sreenivas, 2019). Twenty per cent of India's total electricity consumption in 2019-20 would be used in agriculture, a number that has stayed stable over the past decade, according to the Central electrical authority in New Delhi. Given the importance of energy to India's economic growth and the growing reliance of Indians on it, it's crucial to plan ahead for future electricity use in order to meet rising demand.

There have been numerous attempts to predict a country's overall and individual sectors' energy consumption. With the help of state space modelling, Pao (2009) made predictions on Taiwan's power usage. Short-term predictions using the ECT or the newly proposed ECSTSP were shown to be on par with those using the Seasonal Autoregressive Integrated Moving Average (SARIMA) model, while the ECSTSP model was determined to be the best. Saravanan et al. (2012) used an artificial neural network to anticipate India's electricity usage from 2011 to 2020 based on data spanning the previous 31 years. After comparing the Holt-Winter and ARIMA models for predicting Pakistan's energy consumption, Hussain *et al*. (2016) found that the former provided more accurate results.

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How to cite : Tiwari, R.K., Mishra, P., Kumari, B., Khatib, A.G.M.Al., Yadav, S., Abotaleb, M., Ray, S. and Kumari, M. 2022. Modelling and forecasting of electricity consumption used in agriculture purpose in India. *J. Crop and Weed*, **18** (3): 200-205.

Electricity consumption in India was predicted using the ARIMA model, and the authors concluded that their approach is competitive with other methods. Using black box methods, Rahman *et al*. (2018) estimated India's overall energy usage across the industrial, residential, agricultural, commercial and traction railways sectors. To foretell the demand for power in the Indian state of Uttar Pradesh, Jain *et al*. (2020) used fuzzy time series models. Energy consumption in India and China were predicted using a novel fractional grey polynomial model developed by Liu *et al*. (2020) that included a time power term. The generated model was found to outperform the other models in terms of accuracy of predictions. The ARIMA (1,1,1) model proved to be the most effective predictor when Jamii and Maaroufi (2021) applied it to the problem of estimating future Moroccan power consumption. Industrial, residential, agricultural, commercial, traction, and railroad electricity consumption were predicted using linear, logarithmic, power, and exponential regression models by Rekhade and Sakhare (2021).

It is evident from the literature review that the researchers used varied forecasting tools as per their suitability. The present study has employed ARIMA models to forecast total electricity consumption as well as electricity consumption for agricultural purposes in India.

MATERIALS AND METHODS

The information ontotal electricity consumption and Consumption of Electricity for Agricultural Purposes in India forthe period 1984-2020 were collected and Agriculture Statistics at glance.

Descriptive statistics

It is common practise to differentiate between descriptive and inferential statistics. Descriptive statistics are used to merely describe what exists or what the data demonstrates. With the help of inferential statistics, one might try to draw inferences that go beyond the available raw data. Inferential statistics, for instance, are used to draw conclusions about the entire population based on information obtained from a small representative sample.

Box–Jenkins models: Given a time series of data X_t, the ARMA model is a tool for understanding and, perhaps, predicting future values in this series. There are two components to the model: an AR component and a moving average component. Where p is the order of the autoregressive component and q is the order of the moving average component, this type of model is commonly referred to as an ARMA (p,q) model (as defined below).

Autoregressive model

The notation AR (*p*) refers to the autoregressive model of order *p*. The AR (*p*) model is written

$$X_t = c + \sum_{i=1}^{P} \rho_i X_t + \varepsilon_t$$

where $\rho_1, \rho_2 \ldots. \rho_p$ are the parameters of the model, *c* is a constant and ε_t is white noise. Sometimes the constant term is avoided.

Moving average model

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

$$X_t = \mu + \varepsilon_t + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}$$

Where the è$_1$, ..., è$_q$ are the parameters of the model, ì is the expectation of X_t (often assumed to equal 0), and the $\varepsilon_t, \varepsilon_{t-1} \ldots$

Model formulation

The whole period under consideration (1984-2020) has been divided into two parts.

(a) The model formulation period (1984-2006).
(b) Model validation period (2017-2020).
(c) Forecasting period up to 2020.

Checking for model adequacy

Maximum R2, minimal root mean square error (RMSE), mean absolute error (MAE), minimum or maximum average percentage error, and number of significant digits (NSE) are used to determine the best model from the pool of candidates represented by the Box-Jenkins model (MAPE). Models that meet the majority of the aforementioned criteria are chosen. Measures of goodness-of-fit are defined here for their application in time series modelling.

RESULTS AND DISCUSSION

From 1984 to 2020, the total electricity consumption in India has increased during the period from (1.0234e+005) (GWh) to (1.0523e+006) (GWh). Average total electricity consumption in India was (4.3643e+005) (GWh). Ex. Kurtosis value was (-0.52) indicating small outliers in the data. Followed by a positive value of skewness (0.81) indicating there is an opportunity of rising in thetotal electricity consumption in India. The consumption of electricity for agricultural purposes in India has increased during the period from (18234) GWh to (2.1341e+005) GWh. Average consumption of electricity for agricultural purposes in India was (98747) GWh. Ex. Kurtosis value was (-0.42) indicating the distribution of the data is a mesokurtic.

Table 1: Summary statistics, using the observations 1984 - 2020

Maximum	Minimum	Median	Mean	Variable
1.0523e+006	1.0234e+005	3.2246e+005	4.3643e+005	Total Electricity Consumption
2.1341e+005	18234	88555	98747	Consumption of Electricity for Agricultural Purposes
Ex. kurtosis	Skewness	C.V.	Std. Dev.	Variable
-0.52903	0.81814	0.64853	2.8304e+005	Total Electricity Consumption
-0.42635	0.57646	0.54639	53954	Consumption of Electricity for Agricultural Purposes

Table 2: ARIMA model fitted for total electricity consumption, consumption of electricity for agricultural purposes for training data set (1984 to 2016)

	MODEL	AIC	MAE	RMSE	MAPE
Total Electricity Consumption	ARIMA(2,2,0)	614.155	7091.806	8798.096	1.829
Consumption of Electricity for Agricultural Purposes	ARIMA(2,1,0)	621.198	3794.395	4932.948	4.442

Table 3: State space models for total electricity consumption, consumption of electricity for agricultural purposes for training data set (1984 to 2016)

	Parameter type	Value	Akaike information Criterion (AIC)	MAE	RMSE	MAPE
Total Electricity Consumption	Level variance	3.3943e+07	660.610	7033.716	8992.892	1.864
	Slope variance	2.7195e+07				
	Irregular variance	0.00				
Consumption of Electricity for Agricultural Purposes	Level variance	7.2600e+06	621.578	3511.274	4618.555	4.035
	Slope variance	3.7156e+06				
	Irregular variance	2.2217e+06				

Table 4: RMSE, MAE and MAPE for testing data set (2017 to 2020)

	Model	RMSE	MAE	MAPE
Total Electricity Consumption	ARIMA	23018.90	15432.03	1.4920
Consumption of Electricity for Agricultural Purposes	ARIMA	8345.93	7269.72	3.5860
Total Electricity Consumption	State Space Model	23705.60	15804.95	1.5222
Consumption of Electricity for Agricultural Purposes	State Space Model	8534.94	7233.31	3.5534

Followed by a positive value of skewness (0.57) indicating the possibility of growth in the consumption of electricity for agricultural purposes in India. (Table 1).

The best ARIMA models are shown in (Table 2), these models were nominated based on the criteria (Akaike, Root mean squared error, Mean absolute error, Mean absolute percentage error, Maximum number of significant coefficient).

Parameters type of State Space Models, and the best-fitted models on training data set (1984 to 2016), (based on, lowest values of AIC, RMSE, MAE and MAPE) were shown in (Table 3). State Space Models give better results than the ARIMA Models for forecasting (Consumption of Electricity for Agricultural Purposes). the forecasting accuracy by the State Space Model*s* is very high and outperform the forecasting accuracy of the ARIMA Models, because most values of the

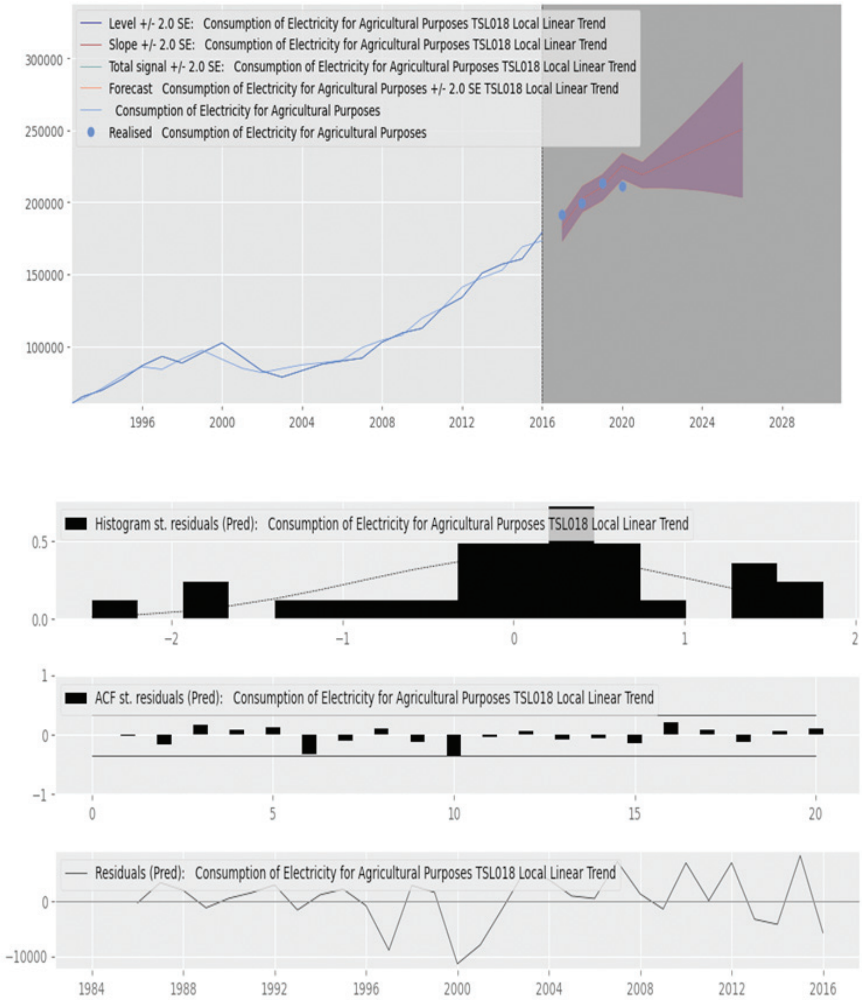

Fig. 1: Actual and forecast values for consumption of electricity for agricultural purposes in India with (Level - -Slope –Total Signal- Trend-Residuals) using State Space Models during the period (1984-2026).

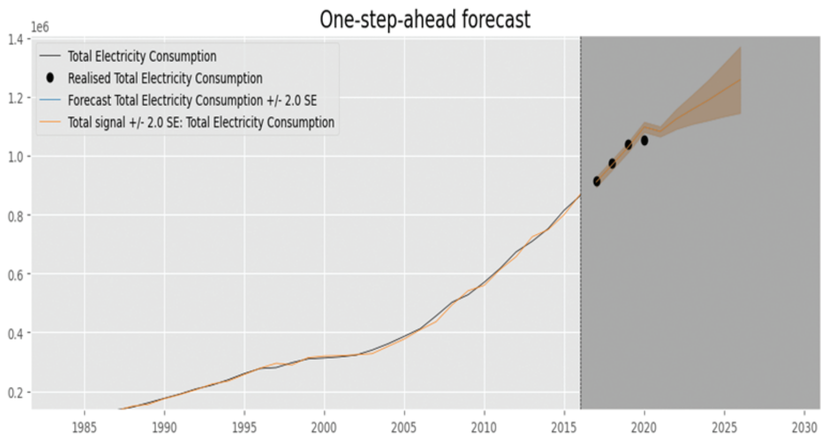

Fig. 2: Actual and forecast values for total electricity consumption in India with (Residuals) using ARIMA (2,2,0) during the period (1984-2026).

accuracy criteria (AIC, RMSE, MAE and MAPE) were lower than the values of the accuracy criteria of ARIMA Models. But for forecasting (Total Electricity Consumption), ARIMA model was the best model.

(Table 4) shows that State Space Models give better results than the ARIMA Models for Forecasting (Consumption of Electricity for Agricultural Purposes) on testing data set (2017 to 2020), based on, lowest values of RMSE, MAE and MAPE. State Space Models are the best models for forecasting (Consumption of Electricity for Agricultural Purposes) on both data sets (training dataset and testing dataset). State Space Model*s* are flexible to capture different specifications of complexnon-linearitynature of the data series,structuralbreaks, shifts, time-varying parameters, missing data and stationarity is not required in these models, State Space Models are also suited to dynamic time series Models that include unobserved components.The performance of ARIMA Model was better than State Space Models for forecasting (Total Electricity Consumption), on training dataset and testing dataset.

Table 5: Forecasting from 2021 to 2026 for consumption of electricity for agricultural purposes, total electricity consumption in India using best models

Year	Consumption of electricity for agricultural purposes	Total electricity consumption
2021	219041.4	1081746
2022	225336.6	1123862
2023	231631.8	1156590
2024	237927	1187933
2025	244222.2	1223061
2026	250517.4	1257423

The Table 5 shows that the Consumption of Electricity for Agricultural Purposes in India is expected to reach 250517.4(GWh) in 2026, with a growth rate of 14.36% during the period 2021-2026. The Total Electricity Consumption in India is expected to reach to 1257423(GWh) in 2026 with a growth rate of 16.24% during the period 2021-2026.

Forecasting

After the top models have been developed, projections are made for both the total amount of electricity used in agriculture in India and the amount of electricity used for all purposes. Time series residuals from the chosen models were found to be stationary white noise. Fig. 1 displays the best-estimated values for the years 2021-2026. (Fig. 2). Predicted values were displayed in the figures; all predicted lines in the figures are rather near to the actual values, demonstrating the usefulness of the proposed models. Agricultural electricity use, as well as total electricity consumption, is expected to rise in the coming years, as shown by the projections.

CONCLUSION

In this study the total electricity consumption along with the power uses in agricultural purpose are modelled by using ARIMA and state space model. Basic statistics were utilised to show the nature of the data series prior to model development. After developing the model we compared the both model based on minimum value of AIC, MAE, RMSE and MAPE. Based on this, state space model performed as a best model over ARIMA model for both training and testing data series of electricity uses for agricultural purpose. It confirmed that State Space Models are suitable for dynamic timeseries models that contain unobserved components because they are flexible enough to capture various specifications of the complex non-linear nature of the data series, structural breaks, shifts, time-varying parameters, missing data, and stationarity is not necessary in these models.On both the training dataset and the testing dataset, the ARIMA Model outperformed State Space Models in terms of forecasting for total electricity consumption data series. We expected that consumption of electricity for agricultural purpose will increase with a growth rate of 14.36% from 2021 to 2026 and total power consumption will increase 16.24% during the period. We firmly think that this research has added to the broad and quickly expanding literature of power consumption forecasting models to aid researchers and policy makers.

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