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Computational modeling for forecasting of operational holdings and area in India

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Abstract
Various computational modeling techniques such as ARIMA (Box-Jenkins), State-Space, Structural and other time series depending upon the properties of the given time series from agriculture are now being effectively utilized. Modelling and related forecasting for the time series data of Agriculture Census (2015-16) of the country were performed using Auto-Regressive Integrated Moving Average (ARIMA) model. ARIMA (0, 1, 0) and ARIMA (0, 2, 0) were found suitable for different size groups of operational holdings and their operational area based on the least value of Akaike Information Criterion (AIC). The total number of operational holdings in the country are predicted to be increased from 146 million in 2015-16 to 154 million in 2020-21 and 161 million by 2015-26. Besides, there would be decrease in the operational area from 157.14 million ha in 2015-16 to 155.91 million ha and 154.74 million ha by 2020-21 and 2025-26, respectively. As such, the average size of operational holding is expected to decline to the level of 1.01 ha in 2020-21 and further to 0.96 ha by 2025-26 in comparision to 1.08 ha of 2015-16. The small and marginal farmers holding less than 2 hectares are expected to be 87.34% and 88.35 % with a share of 50.59% and 53.89% in operational area by 2020-21 and 2025-26, respectively. These information's would thus, play a crucial role in development planning, socio-economic policy formulation and the establishment of national priorities.

Keywords: operational holdings, area, ARIMA

Introduction
Agriculture is the primary source of livelihood for about 60 per cent of India's population. That why, the Govt. of India has targeted the food grain production of 285.20 million tonnes during 2018-19 to meet their requirement. Further, it has given the targets to increase the average income of a farmer household at current prices to Rs. 219,724 by 2022-23 from Rs. 96,703 in 2015-16. It could only be possible if the country has comprehensive information about the number and area of operational holdings. These have been witnessed as an important tool across the world for not only increasing food production but also improving the efficiency of agricultural practices. For instance, the United States and Japan, two of the world's most industrially advanced and also agriculturally prosperous nations, carry out the quinquennial or five yearly details by complete enumeration of all agricultural holdings. The US, in fact, started with a decennial such information as early as 1840, and switched over to quinquennial from 1920 as, with increasing application of science and technology to agriculture, growing mechanization and increasing production the demand for more frequent agricultural data became pressing. With realization the importance of these information's bestowed in Agriculture Census, India took initiatives in 1970 only and thereafter conducted every five years. Since 1970, the Agriculture Census has helped to collate important information on basic characteristics of operational holding which has played a crucial role in development planning, socio-economic policy formulation and the establishment of national priorities (Agriculture Census 2015-16, Phase-I, 2018) [1].
Various computational modelling techniques have been developed and are being utilized for analyzing and forecasting the series, depending upon the characteristics of the time series (Box *et al*., 1994; Zang, 2003) [2, 7]. If the time series is linear, the Auto-Regressive Integrated Moving Average (ARIMA) can be employed most of the times. ARIMA models have been utilized for crop yield or any other agricultural production. Further, Sarika *et al*. (2011) [5] and Suresh *et al*. (2011) [6] applied ARIMA model for modelling and forecasting India's pigeon pea production, and area, production and productivity of sugarcane of Tamil Nadu state of India, respectively. Subsequently, for nonlinear time series, ARIMA-ARNN (hybrid) or

Autoregressive Neural Network (ARNN) models can be used. Dheer *et al.*, 2018 [4] applied hybrid model for estimating the production and yield of pulses. Dheer, 2019 [3] applied ARNN model for forecasting the food grain production and productivity of India. Thus, it is an important aspect that's need to be in tune with changing times.

Objectives

Auto-Regressive Integrated Moving Average model was used for estimating the operational holdings and operated area for the year 2020-21 and 2025-26 which could lead the basis for advance planning for referenced years related to agriculture development in totality.

Materials and Methods

The time series data of operational holdings and operated area for the period of 1970-71 to 2015-16 with a gap of 5 year, were analyzed (Agriculture Census 2015-16, Phase-I, 2018). Out of the 10 years data, for training the model - first 8 years data were used and for model validation - the last 2 years data are used for model selection.

Box-jenkins ARIMA model: The most common time series model used in order to predict future outcomes based on a linear function of past data points and past errors terms is the Auto-Regressive Integrated Moving Average (ARIMA) also known as Box–Jenkins model. In theory and practice, ARIMA model is commonly utilized for forecasting a time series, either to predict future points or to get a better insight about the data. To satisfy the ARIMA assumptions, a sequence of steps is performed on the raw data in order to maintain a statistical stationarity property such as mean, variance and autocorrelation which do not change over time. The stationarity condition of a time series can be confirmed by using unit root test such as Augmented Dickey-Fuller test (ADF) or stationarity test such as Kwiatkowski–Phillips–Schmidt–Shin test (KPSS). If a series found to be a non-stationary based on these tests, differencing is performed until the data are finally made stationary. In general, an ARIMA model represented as ARIMA(*p*,*d*,*q*), consists of three parameters: (I) *p*, the order of Auto-Regression (AR), (II) *d*, the order of integration (differencing) to achieve stationarity, and (III) *q*, the order of Moving Average (MA).

$$X_{(t)} = \beta_o + \beta_1 X_{(t-1)} + \cdots + \beta_p X_{(t-p)} + \varepsilon_{(t)}$$

$$+\theta_1 \varepsilon_{(t-1)} + \cdots + \theta_q \varepsilon_{(t-q)} \quad (1)$$

Where $X_{(t)}$ and $\varepsilon_{(t)}$ represent the actual value and random error at time period *t* respectively, $\beta_i (i=1, 2, ..., p)$ and $\theta_j (j=1, 2, ..., q)$ are model parameters, and p and *q* are lagged values. Random errors $\varepsilon_{(t)}$, are assumed to be independently and identically distributed with a mean zero and a constant variance, σ^2.

After satisfying the stationarity condition of the time series, the Box-Jenkins approach follows four steps:

- **Model identification:** Examine the data by ACF (MA (*q*) term) and PACF (AR (*p*) term) to identify the potential models.
- **Parameter estimation:** Estimate the parameters using least square for potential models and select the best model using Akaike Information Criterion (AIC) or Schwarz- Bayesian Criterion (SBC).
- **Diagnostic checking:** Check the ACF/PACF and Ljung Box Test of residuals. Do the residuals follows random distribution? If yes go to (iv), otherwise go to (i) and repeat the same.
- **Final model:** Generate the required forecasts by using the selected model.

Results and Discussion

The first 8-year data from operational holdings and operated area dataset were used as a training set to analyze the time series for their stationarity property and model building with an objective to forecast. The Figure 1 shows the time series of all 10 data points for both the datasets. In order to apply the ARIMA model on training set, it is necessary to check the stationarity of time series by investigating the ACF and p-value of ADF test. It was observed that the dataset is non-stationary and confirmed by ADF test with p-value > 0.05 supporting the null hypothesis that the series is non-stationary. The time series was differentiated and again performed the ADF test which showed no significant autocorrelation. ADF test p-value <= 0.05 confirms the alternative hypothesis about the time series is stationary. After satisfying the stationarity property for ARIMA, the potential model is selected based on the AIC or SBC criterion. After running the experiments, it was found that AR (*p*), I (*d*) and MA (*q*) order identified by least AIC criterion are 0, 1 and 0, respectively. It is confirmed by diagnostic check, that ARIMA (0, 1, 0) and (0, 2, 0) the best suited model. Ljung box test was conducted on fitted residuals of ARIMA (0, 1, 0) and (0, 2, 0) for both the operational holdings and operated area with p-value > 0.05 supporting the null hypothesis that the residuals follow the white noise. The Table1 and Table 2 show the forecasting of all the size groups in operational holdings and operational area for the year 2020-21 and 2025-26 in the Indian context.

The total number of operational holdings in the country was predicted to be increased from 146 million in 2015-16 to 154 million in 2020-21 and 161 million by 2015-26. Besides, the estimation revealed that there would be decrease in the operational area from 157.14 million ha in 2015-16 to 155.91 million ha and 154.74 million ha in the year to come 2020-21 and 2025-26, respectively. As such, the average size of operational holding is expected to be declined to the level of 1.01 ha in 2020-21 and further to 0.96 ha in 2025-26 in comparision to 1.08 ha of 2015-16.

The small and marginal holdings taken together (0.00-2.00 ha) will constitute 87.34% in 2020-21 and 88.35% in 2025-26 against 86.21% in 2015-16 while their share in operational area would be 50.59% and 53.89%, respectively as compared to 47.34% of 2015-16. The semi-medium and medium operational holdings (2.00-10.00 ha) in 2020-21 and 2025-26 are estimated to be 12.21% and 11.31% with 42.02% and 40.41% of operational area, respectively against corresponding 13.22% with 43.61% operated area in 2015-16. The large operational holdings (10.00 ha & above) were predicted to be about 0.45% and 0.34% of total number of holdings in 2020-21 and 2025-26 which would be to share of 7.39% and 5.70%, respectively in the operational area as against 0.57% and 9.04%, respectively for 2015-16. Thus, it is speculated that the number of total operational holdings would be increasing dominating with small and marginal groups and meagre with large holding. Besides, the operational area would be in decreasing trend having comparatively higher with marginal and small groups and considerably followed dy semi-medium and medium groups in Indian agriculture.

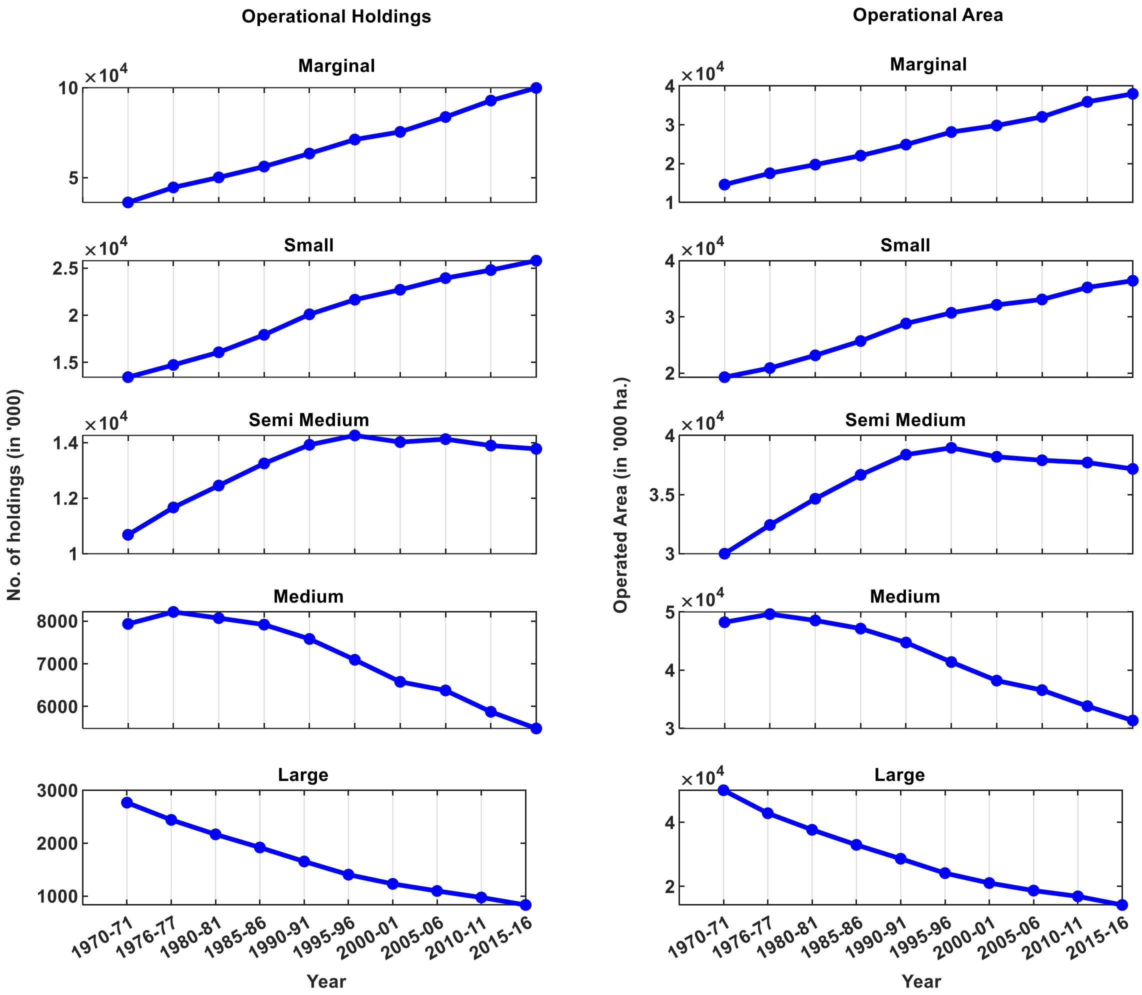

Fig 1: Number of operational holdings and area over agriculture census in India

Table 1: Estimated number of operational holdings of different groups through computational ARIMA model

Size Group/ Year	Marginal	Small	Semi-Medium	Medium	Large
ARIMA	(0,1,0)	(0,1,0)	(0,2,0)	(0,2,0)	(0,2,0)
2020-21	106931 (+-1548.2)	27149 (+-424.05)	13656 (+-305.17)	5095 (+-233.58)	689 (+-38.26)
2025-26	114004 (+-2189.5)	28520 (+-599.69)	13536 (+-682.40)	4705 (+-522.31)	547 (+-85.55)

Table 2: Estimated operational area of different groups using computational ARIMA model

Size Group/ Year	Marginal	Small	Semi-Medium	Medium	Large
ARIMA	(0,1,0)	(0,1,0)	(0,2,0)	(0,2,0)	(0,2,0)
2020-21	40556 (+-679.6)	38341 (+-687.2)	36631 (+-670.4)	28906 (+-1220.9)	11517 (+-1005.1)
2025-26	43151 (+-961.1)	40247 (+-971.8)	36094 (+-1499.23)	26445 (+-2730.1)	8822 (+-2247.6)

In fact, the Agriculture census in India is conducted at five-year interval to collect data on structural aspects of farm holdings. The Agriculture Census programme is carried out in three phases at five yearly intervals with cooperation of States/ Union Territories. The Govt. of India provides a financial and administrative support as well as technical guidance to States/UTs required for Census operations. In each State/UT a nucleus staff of the State Govt., designed as State Agriculture Census Unit is responsible for coordinating the activities of Agriculture Census programme at State/UT level. Thus, it requires a very massive programme in country and led over years to complete the mission. For instance, in spite of all concerted efforts, the 10th Agriculture Census 2015-16 was able to release by the Ministry of Agriculture and Farmers Welfare on October 1, 2018 only. Under such circumstances, if any commonly and suitable computational modelling technique like Auto-Regressive Integrated Moving Average (ARIMA) also known as Box–Jenkins model could be a suitable option for exploring to predict and/ forecast the future points or to get a better insight about the data for the country as a whole.

Conclusion

Computational Auto-Regressive Integrated Moving Average (ARIMA) model could successfully be utilized for the estimation and/ forecasting of number and area of operational holdings which would effectively be utilized by the policy makers to address the pressing problem of food security by evolving specific measures that aim to increase food production by implementing practical measures that designed and backed by advance computational research.

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