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Research Article

Time series analysis and forecasting for major wheat producing states in India using ARIMA and Holt's linear trend method

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ABSTRACT

The wheat crop dominates Indian agriculture, making it vital for policymakers and food security planners to anticipate wheat production. In order to forecast wheat production statistics for India and five of its major wheat-producing states from 1950–51 to 2019–20, the research empirically compares the two most popular forecasting techniques Holt's linear trend approach and Box Jenkin's Auto Regressive Integrated Moving Average model. Data was used for model construction from 1950–51 to 2014–15 and for testing from 2015–16 to 2019–20. Although each model could independently produce accurate projections, comparative measurements showed that Holt's technique performed better than ARIMA for both area and yield forecasting of wheat crop in this research. Whereas, ARIMA and Holt's method performed equally well for wheat production in almost all the states. On the basis of the developed models, projections from 2019–20 through 2029–2030 have been made. The effectiveness of statistical tools to forecast wheat production may be further enhanced by the inclusion of production factor input.

Keywords: ACF, ARIMA, forecast, Holt's linear trend method, PACF and RMSE

India's primary and most important harvest is wheat. In the nation, there are around 29.8 million hectares of cropland (www.farmer.gov.in). India is the world's second-largest producer of wheat and third-largest consumer of the grain (FAOSTAT database).The majority of the northern states cultivate wheat, with Uttar Pradesh being the largest producer. With a total production of 25.22 million tonnes, Uttar Pradesh is the biggest producer of wheat in India, followed by Punjab (15.78 MT), Madhya Pradesh (14.18 MT), Haryana, and Rajasthan. Wheat is primarily cultivated in the northern regions of India (www.apeda.gov.in).

It becomes very important for the government and policy makers to know about the future prospects of the wheat crop in India. Consequently, it became necessary to choose an appropriate forecasting technique given by Box and Jenkins (1976), Pankratz (1983), Makridakis *et al.* (1998) and Brockwell *et al*. (2009), to predict area, production and yield of wheat crop in major wheat growing states in India.

The two most popular techniques for predicting time series are Holt's linear trend method and Auto Regressive Integrated Moving Average Model (ARIMA) models, both of which provide complementary approaches to the subject. ARIMA models attempt to discover the autocorrelations in the data, whereas Holt's linear trend models are based on a description of the trend and smoothing constants as mentioned by Hyndman and Athanasopoulos (2018).

By expanding the simple exponential smoothing to include data with a trend for forecasting purposes, Holt (1957) created a methodology for forecasting time series data with trend. By developing appropriate exponential smoothing models for forecasting purposes using Holt's linear trend method, Michel and Makowski (2013), Prity *et al.* (2014), Oni and Akanle (2018) and Celik (2019) emphasize the significance of this approach.

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Using the ARIMA forecasting technique, numerous studies have been conducted to predict the area, production, and productivity of cereals, commercial crops, and animal products.

For example, Suresh and Krishna (2011) predicted the area, production, and productivity of sugarcane in Tamil Nadu, while Debnath *et al.* (2013) focused on cotton production in India. Vishwajith *et al.* (2019) made projections onmung, area, production and productivity in Rajasthan, Dash *et al.* (2020) forecasted cotton area, production and yield in India and Mishra *et al.* (2020) investigated milk Production in major states of India using ARIMA modelling.

MATERIALS AND METHODS

In this paper the secondary data for area, production and yield of wheat crop were collected for a period from 1950-51 to 2019-20 for forecasting purpose. The yearly data of top five wheat producing states of India (www.apeda.gov.in) have been sourced from various issues of Statistical abstract of India which further divided in two sets i.e., data from 1950-51 to 2014-15 was used for model building named as 'training set' and the last five-year data (2015-16 to 2019-20) was used to access the forecasting ability of the model(s) called as 'test set'. The main objective of this study was to find the most appropriate model that provide forecasts in advance by comparing the forecasting performances of the techniques ARIMA and Holt's linear trend method.

Holt's linear trend method

The Holt's method is a popular and effective approach to make short term forecasts. Holt (1957) extended single exponential smoothing to linear exponential smoothing to allow forecasting of data with trends. The forecast for Holt's linear trend method uses two smoothing constants, α and β (with values between 0 and 1), and three equations:

$$L_t = \alpha y_t + (1-\alpha)(L_{t-1} + b_{t-1}) \quad (3.1)$$

$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1} \quad (3.2)$$

$$F_{t+m} = L_t + b_t m \quad (3.3)$$

Here L_t denotes an estimate of the level of the series at time t and b_t denotes an estimate of the slope of the series at time t. Equation (3.1) adjusts L_t by adding the trend of the previous period, b_{t-1}, to the last smoothed value, L_{t-1}, directly and brings L_t to the approximate level of the current data value. Equation (3.2) updates the trend by using smoothing constant β, and if there is a trend in the data, new values will be higher or lower than the previous ones. In equation (3.3) F_{t+m}, the forecast for m period ahead, obtained by multiplying the trend, b_t, by the number of periods to be forecasted(m) and added to the base value, L_t (Makridakis *et al.*,1997).

Autoregressive integrated moving average model

The existing study applies Box-Jenkins ARIMA modeling technique, which is an extrapolation method for forecasting.An ARIMA model is characterized by the notation ARIMA (p,d,q); where p, d and q denote the orders of auto-regression, differencing and moving average respectively. The data have to be made stationary in order to choose an appropriate ARIMA model for forecasting. One of the simplest transformations called 'differencing' can be applied when the mean of a series changes over time and log transformation is used when the variance of a series changes through time. The main stages in setting up a Box-Jenkins forecasting model are: Identification, Estimating the parameters, Diagnostic checking and Forecasting. The foremost step in the process of identification of ARIMA modelling is to check for stationarity of the series as the estimation procedures are available only for stationary series.The stationarity of the data series can be tested either through graphics i.e., Autocorrelation Function (Acf) and Partial Autocorrelation Function (Pacf) orusing other statisticaltests like Augmented Dickey-Fuller test (ADF) of unit root and Kwiatkowski– Phillips–Schmidt–Shin (KPSS) unit root test. The general functional form of ARIMA model i.e., ARIMA (p, d, q) used for the present study is expressed as:

$$\phi_p(B)\,\Delta^d Y_t = c + \theta_q(B)\, e_t$$

where Y= variable under forecasting

B= lag operator

e= error term

t= time subscript

ϕ_p = non-seasonal AR, the autoregressive component represented as a polynomial in the back shift operator

$(1-B)^d$= non-seasonal difference

$\theta_q(B)$ = non-seasonal MA, the moving-average operator, represented as a polynomial in the back shift operator

ϕ's and θ's are the parameters to be estimated and c is a constant term related to the mean of the process(Pankratz(1991)).

Further, at the estimation stage, an attempt was made to obtain the most precise estimates of a small number of parameters of the model. Linear least-squares can be used to estimate only pure auto regressive models and non-linear least squares (NLS) method for all other models. After the tentative model has been fitted to the data, it is important to perform diagnostic checks to test the adequacy of the model and if needed, to suggest potential improvements.The residual acfs along with the associated ‘t’ tests and Chi-squared test are the most commonly used devices for diagnostic checking. Approximate ‘t’ values are calculated for residual acfs using Bartlett’s approximation for the standard error of the estimated autocorrelations.

Comparison and validation of the developed models

The accuracy of post-sample forecasts was tested using the following tests such as relative deviation in percentage (RD%), root mean square error (RMSE) and mean absolute percent error (MAPE).

Relative deviation (RD%)

This measures the deviation (in percentage) of predicted yield from the observed yield. The formula for calculating the percent deviation of forecast is given below:
Reletive Deviation (%) = {(observed yield – predicted yield)/observed yield}*100.

Root mean square error (RMSE)

It is used as a measure of comparing two models and the formula of RMSE is given as

$$RMSE = \left[\left\{\frac{1}{n}\sum_{i=1}^{n}\left(O_i - E_i\right)^2\right\}\right]^{\frac{1}{2}}$$

Mean absolute percent error (MAPE)

MAPE is also used to compare the accuracy of prediction capability and is defined as

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}\left|\frac{O_i - E_i}{O_i}\right|$$

Where, O_i and Ei are the observed and predicted values and n is the number of years for which prediction has been done.

RESULTS AND DISCUSSION

All the time series under consideration are neither cyclic nor seasonal, hence only trend, and random components will be responsible for any fluctuation in the time series(s).Holt’s linear trend method depends on the selection of smoothing constants for model building. To obtain the appropriate model having minimum sum of squared error, the smoothing constants were optimized, that consequently minimize the RMSE and MAPE of the model(s). The estimates of the optimized constants with the lowest RMSE and MAPE have been given in table1. It can be clearly observed that the estimated values of α is relatively high (very close to 1) for all wheat area states except for Rajasthan which indicates the dependence of forecast on the most recent past observations instead of the distant past observations. The value ofβ is relatively low (very close to 0.00), indicating that the estimate of the slope (b) of the trend component is almost equal to its initial value and not updated over the time series. Therefore, it can be concluded that the level of the wheat area time series(s) changes slowly over the time, but the slope of the trend component remains roughly the same. But for wheat production and wheat yield the estimated values of α are comparatively low and shows the involvement of the past observation to forecast the future values. Ljung-Box test statistic for residual autocorrelation provides the diagnostic checking and favours for the appropriate selection of the model(s).R-studio version (4.0.0) have been used to forecast area, production and yield for all the states.

The first stage of ARIMA modelling identifies the stationarity conditions of the time series under consideration. On the basis of the ADF test for the usual 5% level of significance confirmed the non-rejection of null hypothesis of non-stationarity for area, production and yield for all the time series (Table 1). The ADF value obtained after first differencing in table 2 suggests that all the time series became stationary after first differencing. After obtaining the stationary series the appropriate selection of best ARIMA model(s) were based on the most adequate values of AR parameter (p) and MA parameter (q).

Estimates of the parameters for the selected ARIMA model(s) were obtained by using the nonlinear least square method given by Marquardt (1963). Table3 explains the parameter estimates for the selected model(s) along with the error criteria used to select the model with lowest RMSE and MAPE among the different alternate model(s). It could be observed that all the states and India follows a random walk model i.e., ARIMA (0,1,0) with drift except Rajasthan that follows ARIMA (1,1,0) model to forecast area. Again, to forecast wheat production Uttar Pradesh and Madhya Pradesh, Rajasthan and India follow ARIMA (1,1,0) whereas Haryana and Punjab follow ARIMA (0,1,1) model(s). For wheat yield forecasting all the states and India follows ARIMA (0,1,1) model. From the above selected model(s) for different states it can be concluded that all states and India except Rajasthan does not depend on its previous trend and simply the forecast depends on the current year observations only. Ljung-Box statistic (table3) shows the non-significance of residual autocorrelation at a reasonable level for all the states and India.

The wheat area, production and yield prediction of the post–sample years 2015-16 to 2019-20 were obtained on the basis of fitted Holt’s linear trend method and ARIMA models. Comparison of the alternative models for area, production and yield in terms of percent relative deviations have been presented in tables4, 5 and 6.Holt's approach for area forecasting throughout all the states exhibits lower deviations than ARIMA except for Haryana both the techniques perform equally good. For wheat production and yield the percent relative deviations obtained from both the models shows random results. It's difficult to conclude for any one method for performing better than the other.

A comparative view of errors measurements for the testing data sets obtained from the different forecasting techniques to select the best alternate model on the basis of training set for the prediction purpose (Table 7).

Table 1: Smoothing parameters and error criteria of Holt's modelling

States	α (Average)	β (Trend)	RMSE	MAPE	Ljung-Box Q statistic(P-value)
Area					
Uttar Pradesh	0.94	0.09	208.27	2.39	0.48
Punjab	1.00	0.08	125.34	3.43	0.41
Madhya Pradesh	1.00	0.03	301.29	3.97	0.35
Haryana	1.00	0.01	63.11	3.51	0.33
Rajasthan	0.79	0.07	230.26	11.59	0.65
India	0.91	0.08	927.69	4.13	0.92
Production					
Uttar Pradesh	0.63	0.11	1143.56	8.85	0.48
Punjab	0.77	0.01	639.80	9.77	0.75
Madhya Pradesh	0.71	0.09	1034.61	19.43	0.36
Haryana	0.64	0.06	450.20	7.51	0.26
Rajasthan	0.58	0.06	607.96	14.37	0.63
India	0.64	0.10	3173.89	8.21	0.51
Yield					
Uttar Pradesh	0.56	0.13	133.38	7.51	0.55
Punjab	0.69	0.05	198.92	6.88	0.26
Madhya Pradesh	0.50	0.38	153.41	12.09	0.98
Haryana	0.59	0.06	190.12	5.87	0.20
Rajasthan	0.39	0.04	192.34	9.75	0.79
India	0.58	0.11	102.23	5.93	0.69

Table 2: Stationarity identification using ADF test before and after differencing

States	ADF Value	P-Value	Conclusion	ADF Value after first differencing	P-Value	Conclusion
Area						
Uttar Pradesh	-1.09	0.92	Non-Stationary	-3.72	0.03	Stationary
Punjab	-1.36	0.83	Non-Stationary	-3.28	0.05	Stationary
Madhya Pradesh	-2.22	0.49	Non-Stationary	-3.33	0.04	Stationary
Haryana	-1.91	0.61	Non-Stationary	-5.01	0.01	Stationary
Rajasthan	-3.39	0.67	Non-Stationary	-3.87	0.02	Stationary
India	-1.96	0.59	Non-Stationary	-4.88	0.01	Stationary
Production						
Uttar Pradesh	-2.84	0.24	Non-Stationary	-4.30	0.01	Stationary
Punjab	-2.77	0.26	Non-Stationary	-4.43	0.01	Stationary
Madhya Pradesh	-1.99	0.57	Non-Stationary	-3.86	0.02	Stationary
Haryana	-2.37	0.42	Non-Stationary	-4.63	0.01	Stationary
Rajasthan	-1.74	0.68	Non-Stationary	-3.94	0.02	Stationary
India	-2.56	0.35	Non-Stationary	-4.20	0.01	Stationary
Yield						
Uttar Pradesh	-2.90	0.21	Non-Stationary	-5.07	0.01	Stationary
Punjab	-2.73	0.28	Non-Stationary	-3.72	0.03	Stationary
Madhya Pradesh	-1.54	0.76	Non-Stationary	-3.51	0.04	Stationary
Haryana	-2.59	0.34	Non-Stationary	-4.76	0.01	Stationary
Rajasthan	-2.47	0.38	Non-Stationary	-5.99	0.01	Stationary
India	-2.86	0.23	Non-Stationary	-3.92	0.02	Stationary

Table 3: Parameter estimates of selected ARIMA models with error criteria for area, production and yield of wheat in all the selected states

States	Selected Models	Type	Estimate	Standard-Error	RMSE	MAPE	Ljung-Box Q statistic (P-value)
Area							
Uttar Pradesh	ARIMA(0,1,0)	Constant	103.52	25.81	201.60	2.38	0.43
Punjab	ARIMA(0,1,0)	Constant	31.63	14.89	116.28	3.41	0.38
Madhya Pradesh	ARIMA(0,1,0)	Constant	-0.48	-3.78	393.19	5.36	0.26
Haryana	ARIMA(2,1,2)	Constant	36.14	8.62	175.31	6.86	0.99
Rajasthan	ARIMA(1,1,0)	AR(1)	-0.28	0.12	212.13	10.33	0.48
		Constant	40.77	21.30			
India	ARIMA(0,1,0)	Constant	326.73	110.55	863.50	3.66	0.68
Production							
Uttar Pradesh	ARIMA(1,1,0)	AR(1)	-0.44	0.11	1069.45	9.59	0.95
		Constant	449.94	95.76			
Punjab	ARIMA(0,1,1)	MA(1)	-0.25	0.13	621.10	8.76	0.76
		Constant	248.78	59.83			
MadhyaPradesh	ARIMA(1,1,0)	AR(1)	-0.30	0.12	985.37	17.65	0.19
		Constant	191.22	97.21			
Haryana	ARIMA(0,1,1)	MA(1)	-0.30	0.13	438.53	12.35	0.46
		Constant	181.13	39.38			
Rajasthan	ARIMA(1,1,0)	AR(1)	-0.48	0.11	572.49	15.33	0.96
		Constant	146.26	49.92			
India	ARIMA(1,1,0)	AR(1)	-0.40	0.11	3002.07	8.72	0.76
		Constant	1410.70	276.01			
Yield							
Uttar Pradesh	ARIMA(0,1,1)	MA(1)	-0.45	0.12	123.89	6.73	0.56
		Constant	37.66	8.77			
Punjab	ARIMA(0,1,1)	MA(1)	-0.38	0.12	186.09	5.99	0.28
		Constant	62.66	15.01			
Madhya Pradesh	ARIMA(0,1,1)	MA(1)	-0.48	0.12	139.85	10.44	0.89
		Constant	30.04	9.55			
Haryana	ARIMA(0,1,1)	MA(1)	-0.46	0.12	179.87	5.93	0.18
		Constant	58.33	12.61			
Rajasthan	ARIMA(0,1,1)	MA(1)	-0.69	0.09	180.80	8.32	0.78
		Constant	38.78	7.39			
India	ARIMA(0,1,1)	MA(1)	-0.42	0.11	96.87	5.51	0.68
		Constant	39.97	7.31			

Table 4: Comparison of forecasting performance of Holt's linear trend method and ARIMA model for wheat area in testing data set

Methods		Holt's method		ARIMA	
Year	**Observed**	**Predicted**	**RD (%)**	**Predicted**	**RD (%)**
Uttar Pradesh					
2015	9645	9908.23	-2.73	9948.03	-3.06
2016	9885	9967.21	-0.83	10050.06	-1.66
2017	9917	10026.20	-1.10	10152.09	-2.34
2018	9540	10085.19	-5.71	10254.13	-7.08
2019	9853	10144.18	-2.96	10356.16	-4.96
Punjab					
2015	3508	3511.14	-0.09	3534.11	-0.74
2016	3500	3517.22	-0.49	3563.22	-1.80
2017	3480	3523.29	-1.24	3592.33	-3.19
2018	3520	3529.36	-0.27	3621.44	-2.87
2019	3521	3535.43	-0.41	3650.56	-3.66

Cont..

Table 4 cont..

Madhya Pradesh					
2015	5911	6007.98	-1.64	6002.00	-1.51
2016	6422	6013.96	6.35	6002.00	6.98
2017	6309	6019.95	4.58	6002.00	5.10
2018	6520	6025.93	7.58	6002.00	8.60
2019	6551	6031.91	7.92	6002.00	9.10
Haryana					
2015	2576	4772.76	-53.04	4778.52	-52.59
2016	2558	4833.43	-57.11	4841.04	-56.21
2017	2526	4894.09	-67.84	4903.56	-66.42
2018	2553	4954.76	-63.41	4966.08	-61.60
2019	2534	5015.42	-67.71	5028.60	-65.44
Rajasthan					
2015	3109	1441.58	53.63	2278.26	57.63
2016	3349	1347.33	59.77	1121.48	165.34
2017	3495	1253.07	64.15	1857.42	130.68
2018	2880	1158.82	59.76	1389.22	128.65
2019	3118	1064.57	65.86	1687.09	134.41
India					
2015	31470	17033.89	45.87	9471.00	129.15
2016	30420	16662.22	45.23	9471.00	125.73
2017	30600	16290.56	46.76	9471.00	129.70
2018	29319	15918.89	45.70	9471.00	124.68
2019	31357	15547.22	50.42	9471.00	140.77

Table 5: Comparison of forecasting performance of Holt's linear trend method and ARIMA model for wheat production in testing data set

Method		**Holt's method**		**ARIMA**	
Year	**Observed**	**Predicted**	**RD (%)**	**Predicted**	**RD (%)**
Uttar Pradesh					
2015	25425	26979.64	-6.11	27520.70	-7.77
2016	30056	27274.64	9.25	27173.97	10.57
2017	31879	27569.64	13.52	27832.59	14.68
2018	32741	27864.64	14.89	28109.44	16.62
2019	32586	28159.64	13.58	28531.26	14.40
Punjab					
2015	16081	16043.41	0.23	16081.99	-0.01
2016	16441	16194.77	1.50	16308.25	0.82
2017	17830	16346.13	8.32	16534.52	7.93
2018	18262	16497.49	9.66	16760.78	9.10
2019	17616	16648.85	5.49	16987.04	3.78
Madhya Pradesh					
2015	17689	17987.90	-1.69	16127.48	8.68
2016	17939	19971.96	-11.33	17267.48	3.36
2017	15911	21956.02	-37.99	18615.20	-12.32
2018	16521	23940.09	-44.90	17582.82	-4.43
2019	19607	25924.15	-32.22	19231.18	1.45

Table 5 cont..

Haryana					
2015	11352	10907.84	3.91	11008.91	3.15
2016	11547	11060.65	4.21	11022.12	4.75
2017	10765	11213.47	-4.17	11231.34	-4.16
2018	12574	11366.29	9.60	11380.68	10.50
2019	11876	11519.11	3.01	11548.31	2.84
Rajasthan					
2015	9871	9893.89	-0.23	9472.81	4.02
2016	8985	10198.41	-13.50	9858.59	-8.57
2017	9369	10502.92	-12.10	9885.21	-4.91
2018	10083	10807.44	-7.19	10086.89	-0.04
2019	10916	11111.96	-1.80	10203.24	6.41
India					
2015	86869	93084.98	-7.16	93575.77	-7.21
2016	94877	94402.98	0.50	93619.45	1.33
2017	93506	95720.98	-2.37	95490.33	-2.07
2018	95850	97038.98	-1.24	96634.42	-0.81
2019	88938	98356.98	-10.59	98067.60	-9.28

Table 6: Comparison of forecasting performance of Holt's linear trend method and ARIMA model for wheat yield in testing data set

Method		Holt's method		ARIMA	
Year	**Observed**	**Predicted**	**RD (%)**	**Predicted**	**RD (%)**
Uttar Pradesh					
2015	2277	3129.13	-37.42	3134.05	-27.39
2016	2636	3167.29	-20.16	3170.96	-16.89
2017	3113	3205.46	-2.97	3207.87	-2.96
2018	3432	3243.62	5.49	3244.78	5.77
2019	3432	3281.79	4.38	3281.68	4.58
Punjab					
2015	4294	5027.02	-17.07	5105.53	-16.15
2016	4583	5096.16	-11.20	5023.28	-8.64
2017	4704	5165.30	-9.81	5142.63	-8.49
2018	5188	5234.44	-0.90	5286.06	-1.87
2019	5003	5303.58	-6.01	5263.20	-4.91
Madhya Pradesh					
2015	2850	2588.73	9.16	2418.03	16.68
2016	2993	2724.75	8.95	2449.00	19.95
2017	2976	2860.78	3.87	2479.97	17.34
2018	2993	2996.81	-0.13	2510.95	16.09
2019	2993	3132.84	-4.67	2541.92	14.40

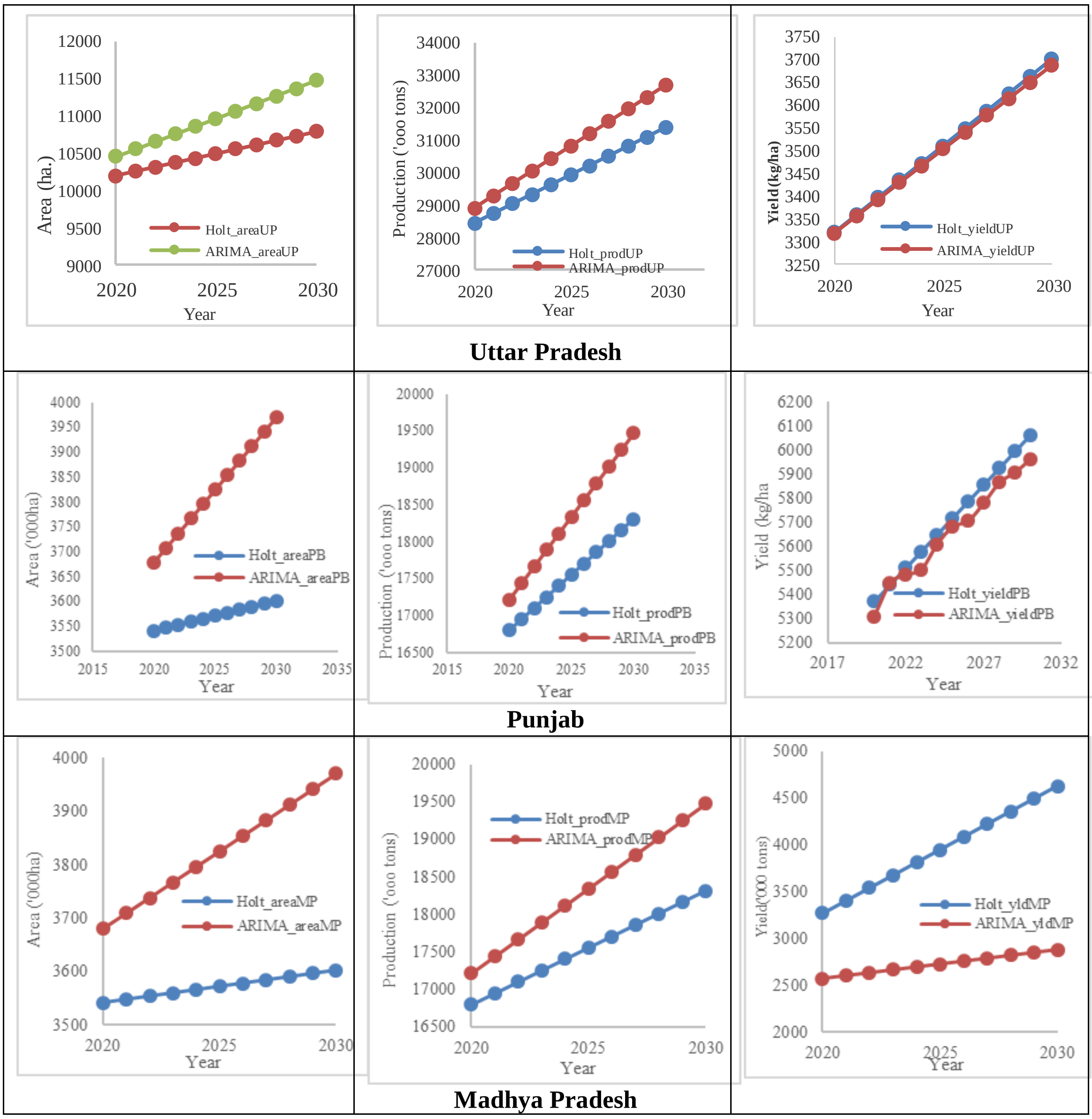
Table 6 cont..

Haryana					
2015	3981	4772.76	-53.04	4778.52	-52.59
2016	4407	4833.43	-57.11	4841.04	-56.21
2017	4514	4894.09	-67.84	4903.56	-66.42
2018	4925	4954.76	-63.41	4966.08	-61.60
2019	4687	5015.42	-67.71	5028.60	-65.44
Rajasthan					
2015	2961	3108.28	-4.99	3157.54	-6.34
2016	3175	3124.42	1.59	3194.55	-0.63
2017	3175	3140.56	1.08	3231.55	-1.80
2018	3501	3156.70	9.83	3268.55	7.36
2019	3501	3172.84	9.37	3305.56	6.16
India					
2015	2750	3205.28	-16.56	3193.29	-13.83
2016	3034	3252.08	-7.19	3232.73	-6.11
2017	3200	3298.88	-3.09	3272.16	-2.19
2018	3533	3345.68	5.30	3311.59	6.62
2019	3440	3392.48	1.38	3351.03	2.62

Table 7: MAPEs and RMSEs of post-sample wheat area, production and yield prediction based on alternative models

Methods		**Holt's method**	**ARIMA**	**Holt's method**	**ARIMA**
States/ Relative error measures		**RMSE**		**MAPE**	
Uttar Pradesh	Area ('000 ha)	306.59	433.01	-2.57	-3.77
	Production ('000 ton)	3797.23	3659.61	10.66	9.64
	Yield (kg ha^{-1})	463.68	466.34	-7.30	-7.36
Punjab	Area ('000 ha)	22.25	94.21	-0.50	-2.40
	Production ('000 ton)	1123.56	932.14	5.47	4.26
	Yield (kg ha^{-1})	470.35	473.79	-8.00	-8.03
Madhya Pradesh	Area ('000 ha)	393.19	411.98	5.36	5.67
	Production ('000 ton)	5209.77	1514.52	-18.95	-1.01
	Yield (kg ha^{-1})	185.82	482.42	3.87	19.40
Haryana	Area ('000 ha)	1568.65	1533.02	-38.12	-37.61
	Production ('000 ton)	666.46	654.53	3.64	3.41
	Yield (kg ha^{-1})	460.96	467.99	-8.07	-8.25
Rajasthan	Area ('000 ha)	1948.99	1587.72	156.91	103.08
	Production ('000 ton)	815.11	628.71	-6.28	-0.59
	Yield (kg ha^{-1})	224.41	164.08	3.84	0.88
India	Area ('000 ha)	14366.28	21176.36	88.20	223.44
	Production ('000 ton)	5174.83	5185.73	-3.60	-3.86
	Yield (kg ha^{-1})	245.75	244.19	-3.38	-2.58

Prediction of wheat growing area in Uttar Pradesh, Punjab, Madhya Pradesh and India Holt's Linear Trend method provide better forecast for the available data as compare to the other technique (Table 7). Fig. 1 reveals the comparison of both the techniques and insights for the future prospects using the available information. Therefore, it can be concluded that for Uttar Pradesh, Punjab and Madhya Pradesh the wheat crop area will increase very slowly in the coming years but for India Holt's method provides a different scenario of a slow decrease in the wheat crop area in near future. On the other hand, selection of ARIMA model on the basis of RMSE and MAPE (table7) predicts 15.25 percent crop area growth from year 2020 to the year 2030.Whereas for Rajasthan wheat crop area, neither positive nor negative growth have been recorded for the selected technique. ARIMA modelling technique is suggested to use for better forecasting of wheat production in all the selected states over the Holt's method and showed a rapid growth in wheat production in the coming years. Here it can be observed that the increase in the wheat production may be due to the technological advancement in the agriculture and some other factors as the steady growth of crop area has been observed in advance. Both the models are performing equally well for the wheat production forecast in India and shows a rapid growth (13.6%) in wheat production from 2020 to 2030. Holt's linear trend method is suggested to be used for wheat yield forecasting for all the states except India and Rajasthan where ARIMA model provides more accurate forecasts as per the error measure criteria RMSE and MAPE.



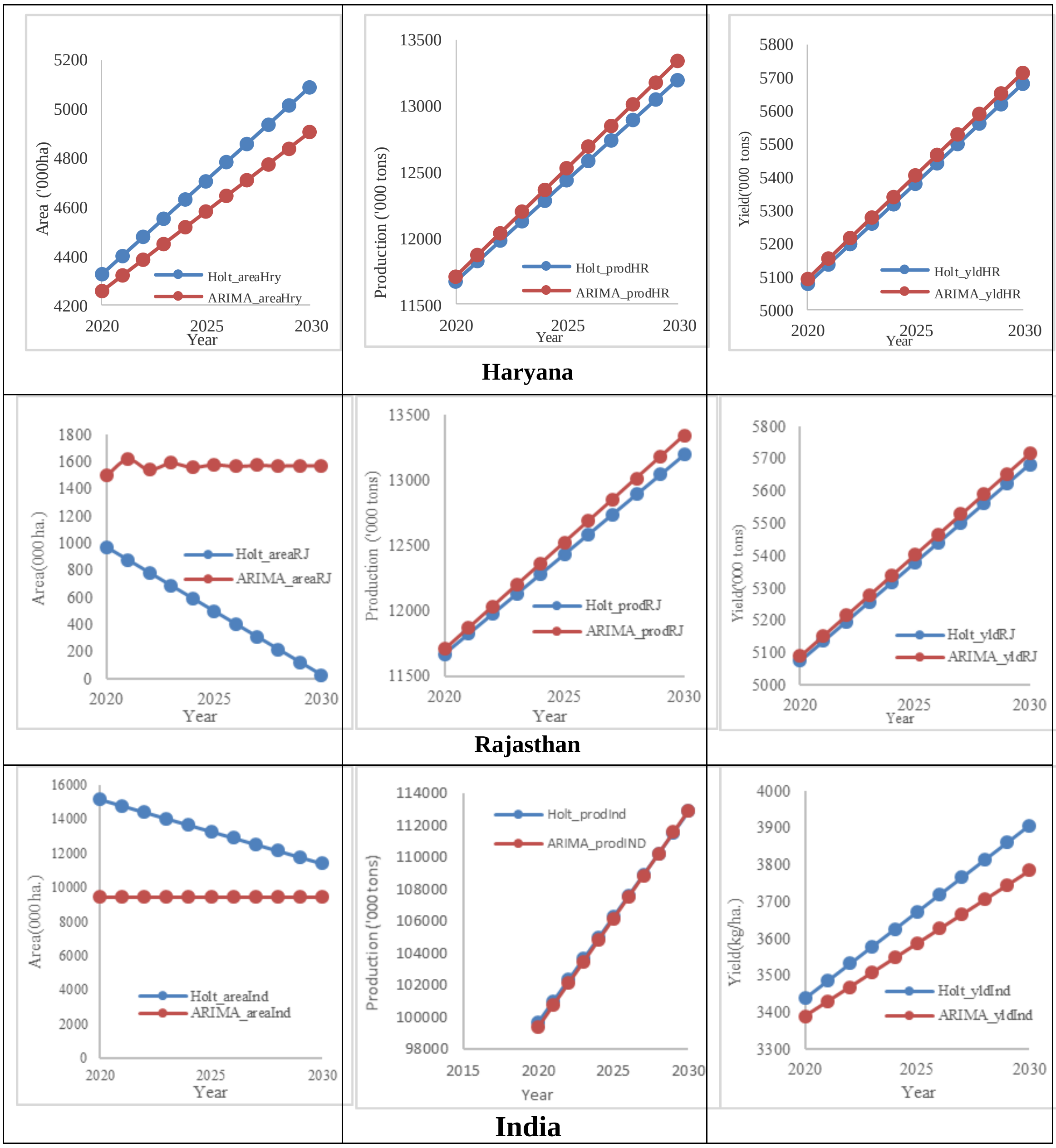


Fig.1: A graphical view of wheat area, production and yield forecast from 2020-2030 using Holt's linear trend method and ARIMA model for all states

CONCLUSION

Hence it may be concluded that not a single forecasting technique should be used to forecast the wheat crop area, production and yield forecast, rather a mixed approach of using more than one technique for the purpose could provide better results.

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