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Modelling and Forecasting of Wheat Production through Structural Time-Series Models in Chhattisgarh

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ABSTRACT

Purpose of present paper is to discuss STM methodology utilized for modelling time-series data in the present of trend, seasonal and cyclic fluctuations. Structural time series model are formulated in such a way that their components are stochastic, i.e. they are regard as being driven by random disturbances. Structural time series model are formulated in such a way that their components are stochastic, i.e. they are regard as being driven by random disturbances. The study mainly confined to secondary collected data from a period 2009-10 to 2014-15 data of promising varieties of wheat yield. As these techniques, it may be mentioned that models are fitted to the data and coefficient parameter value obtained on the basis of the model are compared with the actual observation for assessing the accuracy of the fitted model. To validate the forecasting ability of the fitted models, for the three years with upper and lower limit. The maximum wheat yield obtained GW-273 variety with forecast for the year 2017-18 obtained 26.92 q/ha and the minimum yield obtained Lok-1(19.00 q/ha), HI-1531 (19.57 q/ha) and HI-1544 (20.48 q/ha).

Key words: *AIC, BIC, Goodness of fit, Forecasting and Structural time series model.*

INTRODUCTION

ARIMA time series methodology is widely used for modelling time series data. Statistical modelling of time-series data in Agriculture is usually carried out by employing ARIMA methodology[5]. This methodology can be applied only when either the series under consideration is stationary or it can be made so by differencing, de-trending, or by any other means. Another disadvantage is that this approach is empirical in nature and does not provide any insight into the fundamental mechanism. An alternative mechanistic approach, which is quite promising, is the "Structural time series modeling[7]". A quite promising, mechanistic approach, which does not suffer from this drawback, is "Structural time-series modelling (STSM)" Harvey).

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The distinguishing feature of this methodology is that observations are regarded as made up of distinct components such as trend and cyclical fluctuations and each of which is modeled separately. The techniques that emerge from this approach are extremely flexible and are capable of handling a much wider range of problems than is possible through ARIMA approach. The Akaike Information Criterion (AIC) is a measure of the relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Hence, AIC provides a means for model selection. BIC is an estimate of a function of the posterior probability of a model being true, under a certain Bayesian setup, so that a lower BIC means that a model is considered to be more likely to be the true model. Once a model is estimated, its suitability can be assessed using goodness fit statistics.

Promising variety is a popular variety and being cultivated widely. It may be a variety, an advance line, strain or land race (recommended or non-recommended). However, variety is a group of plants having distinct, uniform and stable traits which has been recommended for cultivation by a committee. There are many promising varieties of rice, are available but it depends on cultivation practices and geographical areas where some specific varieties are more suitable for its better production[1,2,3].

Rice is an important crop grown in nearly 44 million ha of land in the country with the yield of 2.2 t/ha which is less than the productivity of many countries. Annual population growth rate of the country is nearly 1.8 % and if per capita consumption of rice is expected to be 400 gm of rice per day then the demand for rice in 2025 will be 130 m. tonnes. In Chhattisgarh, rice occupies average of 3.6 million ha. with the yield of the state ranging between 1.2 to 1.6 t/ha depending upon the rainfall[11]. Though the yield of rice in the state is lower-than the national average but high yielding varieties in the state is higher than the state yield as well as national yield which is ranging between 3.9 to 4.9 t/ha.

MATERIALS AND METHODS

The study mainly confined to secondary collected for a period 2009-10 to 2014-15 data of promising varieties of Rice yield. Data collected from various publications, Government of Chhattisgarh were subjected structural time series model. The data are analyzed by using software Statistical Analysis System (SAS). Structural time series model adopted for forecasting purpose is given below.

Structural time Series Model for trend:

A structural time series model is set up in term of its various components, like trend, cyclic fluctuations and seasonal variation, i.e.

$Y_t = T_t + C_t + S_t + \varepsilon_t$ (1)

Where Y_t is the observed time-series at time t, T_t, C_t, S_t, ε_t are the trend, cyclical, seasonal and irregular components.

(i) **Local Level Model** (LLM): In the absence of seasonal and cyclical components, eq. (1) reduce to

$Y_t = \mu_t + \varepsilon_t$, $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$, t = 1, 2... T (2)

Where $\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t$ and $\beta_t = \beta_{t-1} + \varepsilon_t$

(ii) **Goodness of fit:** Goodness of fit statistics is used for assessing over all models fit. Basic measure of goodness of fit in time series model is prediction error variance. Comparison of fit between different models is based on Akaike information criterion (AIC).

AIC = -2 log L + 2n, (3)

Where L is the likelihood function, which is expressed in term of estimated one-step-ahead prediction errors $\hat{u}t = Yt - \hat{Y}t/t-1$. Here n is the number of hyper parameters estimated from the model.

Corrected criterion AIC (CAIC)

It could be argued that a good model selection criterion should work even if the user tries a "bad" (e.g., over-parameterized) model: If the model is bad, the criterion should be able to detect this. In this regard, AIC fails. In order to remove this deficiency, the normal multiple regression model for small samples, we can define the finite sample corrected AIC, namely, originally proposed by Sugiura[14] and later used Hurvich and Tsai[8] introduced a corrected version, CAIC, defined by

$$\mathrm{CAIC} = \mathrm{n}\log(2\pi) + \mathrm{n}\log(\hat{\sigma}^2) + \mathrm{n} + 2\frac{\mathrm{n}(\mathrm{k}+1)}{\mathrm{n}-\mathrm{k}-2},$$

Consistent AIC (AICC)

We recommend the use of the AIC and not the AICC for analysis and inference from capture-recapture data sets. It is proposed by Bozdogan[4] and represented by

$$\mathrm{AICC} = -2\log L + n\,((\log T) + 1)$$

The lower values of these statistics, better is the fitted model.

Schwartz-Bayesian information criterion[12] is also used as a measure of goodness of fit which is given as

$$\mathrm{SBC\ (BIC)} = -2\log L + n\log T,$$

Where, T is the total number of observations.

Hannan–Quinn information criterion (HQIC)

The Hannan–Quinn[6] information criterion (HQIC) is a criterion for model selection. It is an alternative to Akaike information criterion (AIC) and Bayesian information criterion (BIC). It is given as

$$\mathrm{HQIC} = -2\mathrm{L}_{\max} + 2\mathrm{k}\log(\log \mathrm{n})$$

Software for STM Modelling

STM models can be fitted to the data using Structural Time-series Analyser, Modeller and Predictor (STAMP)[9] or by using SsfPack 2.2[10] software package or by SAS (Statistical Analysis System), Version 9.2 software packages. The use of STAMP (Structural Time Series Analyser, Modeler and Predictor) for modeling time series data using state-space methods with un-observed components.

There are two important points to consider in modeling time series, the first is how well the model explains (or fits) the actual data of the production, and the other is how good the model forecasts the yield after a year or two or three.

RESULTS AND DISCUSSION

Modeling yield trends through structural time series (STM) for major crops

Structural time series model was fitted for trend information and yield forecast of rice, wheat and chickpea. To judge the forecasting ability of the fitted model, important measures of the three years forecast were computed.

Structural time series model for wheat crop

AIC, AICC, CAIC, HQIC, and BIC are Likelihood statistics and were calculated for various varieties of wheat crop, based on various goodness of fit, smallest value was found for wheat GW-273 followed by Lok-1 and Sujata (Table 1). According to trend information provided on the basis of small standard error HI-1531 (0.001) is the best variety, but its slope (β) standard error (1.47) is more than other varieties, moreover wheat varieties GW-322 (0.004) and GW-372 (0.470) provided best trend on the basis of standard error (Table 2). Forecasts of wheat yield (q/ha) of different varieties revealed that GW-222, HI-1531, GW-366, HW-2004 (Amar) and GW-273 showed consistent performance for next three years (2015-16 to 2017-18). Whereas, Lok-1 and HI-1544 wheat varieties showed negative yield trends for Chhattisgarh state (Table 3)[13].

Table 1: Likelihood based fit statistics for major varieties of wheat crop

Varieties	AIC	BIC	AICC	HQIC	CAIC
Sujata	24.55	22.71	42.55	20.51	25.71
Lok-1	24.29	22.45	42.29	20.25	25.45
HW-2004 (Amar)	25.90	24.06	43.90	21.86	27.06
DL803-3 (Kanchan)	34.49	32.65	52.49	30.45	35.65
GW-273	18.56	16.71	36.56	14.52	19.71
GW-322	26.60	24.76	44.60	22.56	27.76
GW-366	27.94	25.70	45.54	23.50	28.70
HI-1531	28.48	26.64	46.48	24.44	29.64
HI-1544	32.72	30.87	50.72	28.67	33.78

Smaller is better for AIC, BIC, AICC, HQIC and CAIC.

Table 2: Trend Information (based on the final state) for different varieties of wheat crop

Varieties	Components			
	Level		Slope	
	Estimate	Standard Error	Estimate	Standard Error
Sujata	20.71	0.995	1.531	0.320
Lok-1	22.65	0.963	0.166	0.318
HW-2004 (Amar)	17.87	1.177	0.359	0.389
DL803-3 (Kanchan)	26.22	3.444	1.355	1.133
GW-273	22.93	0.470	1.331	0.155
GW-322	23.25	0.004	-4.171	3.179
GW-366	24.50	1.444	0.651	0.471
HI-1531	20.11	0.001	-0.017	1.470
HI-1544	20.72	2.761	-0.771	0.912

Table 3: Forecast of yield (q/ha) of wheat varieties from 2015-16 to 2017-18 in Chhattisgarh state

	2015-16		2016-17		2017-18	
Varieties	Forecast	Standard Error	Forecast	Standard Error	Forecast	Standard Error
Sujata	21.71	1.87	23.24	2.09	24.77	2.33
Lok-1	22.81	1.81	22.98	2.02	19.00	2.26
HW-2004 (Amar)	18.23	2.22	18.59	2.46	18.95	2.76
DL803-3 (Kanchan)	27.58	6.50	28.93	7.26	30.29	8.10
GW-273	24.26	0.88	25.59	0.99	26.92	1.10
GW-322	11.46	3.11	11.58	7.10	11.86	3.10
GW-366	25.16	2.73	25.81	3.04	26.47	3.40
HI-1531	19.93	3.60	19.75	5.50	19.57	7.20
HI-1544	20.64	5.21	20.56	8.81	20.48	6.49

CONCLUSION

Overall the class of models proposed introduces periodicity without affecting the possibility of extracting signals that are an expression the long run behavior. Therefore, they furnish a reasonable compromise between increasing model complexity in the presence of strong seasonal effects, and preserving the decomposability of the time series. In our study the structural time-series model developed for wheat yield comparison of the state yield showed that the yields of high yielding variety are GW-273for state. This indicates that the promotion of high yielding varieties can be made for improving the overall productivity of the state.

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