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EFFICACY OF THE RICE CROP GROWTH USING DIFFERENT SMOOTHING METHODS

Khadar Babu SK[1], Christophe Chesneau[2,†], Victor Anthonysamy[1], Suganya Ravichandaran[1] and Shakila Chella Vasan[1]

Abstract Rice is one of India's most important food crops. The government of India has a major duty in agriculture: perfect mapping and continual monitoring of paddy rice fields. Rice growth has a major impact on SCATSAT-1 backscatter images, and rice fields have been successfully mapped using a time-series analysis employing satellite data. SCATSAT-1 time-series data was used to detect single-cropped, double-cropped, and triple-cropped rice fields (1 to 3 harvests per year) and identify different phonological stages using a crop phenology-based categorization. The usefulness of rice crop growth utilizing exponential smoothing approaches to estimate and forecast yield growth is demonstrated in this paper. The Holt linear trend, Holt-Winters methods (additive and multiplicative), and Mean Absolute Error (MAE), Sum Squared Error (SSE), Mean Squared Error (MSE), Mean Percentile Error (MPE), and Mean Absolute Percentage Error (MAPE) are used as error factors to choose the best forecasting methods among the exponential smoothing techniques.

Keywords Exponential smoothing, Holt-Winters methods, backscatter values, double-cropped.

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1. Introduction

Agricultural employment is a very important food sector in the Indian economy, employing 54.6% of the population. It provides about 18% of the GDP of India's economy. Production of rice is a major income source for rural people. Farmers usually grow three crops per year. Double cropped (Rice) + winter crop (such as maize, soybean, potato, etc.) Heavy rainfall affects the majority of this crop season [1, 2, 15]. These three major seasons form three types of crops: single-cropped, double-cropped, and double-cropped rice, plus additional crops. These are always based on the location and weather conditions [2]. Time series forecasting methods are most suitable for paddy production in India and give the most accurate forecasting discussed by [3, 7, 12]. Exponential smoothing techniques are the most commonly used methods for forecasting the growth of the rice crop [6]. Forecasting the rice crop's growth is a very important strategy to improve rice yield productiv-

†The corresponding author.
Email: christophe.chesneau@unicaen.fr(C. Chesneau)
[1]Department of Mathematics, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India-632014
[2]Department of Mathematics, LMNO, Universite de caen-Normandie, Campus 2, Science 3,14032 Caen, France

ity. Park [13] classified and mapping of paddy rice by combining Landsat and SAR Time Series data. Nguyen [8] discussed the classification of Sentinel-2 data for field level monitoring of rice crop practice. Subhankar [16] deliberated on Indian Traditional Irrigation Schemes for Supportable Agricultural Practices in India. Mahesh Palakuru [11] studied the identification of different crop stages using SCATSAT-I Scatterometer data, and in that year (i.e., 2020) they developed a procedure for the comparative study of NDVI (MODIs) data on paddy crop growth. The research gap between the Mahesh Palakuru [10] and the present proposed technique for identification of rice growing stages is to be applied as a standard measure, which is the function of all data points and might be very large. The performance of rice crops was studied using quick SCATSAT-I Scatterometer data with a temporal resolution of four days and a spectral resolution of 4.45km. Oza [9] The work focuses on identifying different rice crop growing stages during the monsoon season in 2004 in India. Hoang Phi [14] studied the application of multitemporal Sentinel -1 SAR data for yield estimation of rice crops.

2. Materials and Methods

The satellite backscatter values from the double rice cropped in spring-summer (Kharif season) in 2019 were used in this study. The data are available on the website of MOSDOC.

Many methods of forecasting modeling were developed for time series data, in which simple moving average, exponential smoothing, trend analysis, and the ARIMA models are widely used. For this proposed study, the exponential smoothing methodology is applied. The weighted moving average is the basis of the moving average method. For forecasting by simple moving average, the average of the last n values is taken for the forecast. As a result, giving equal weightage to all observations has a significant impact on lowering future values. But in the exponential smoothing methods, forecasts are made by using more recent data. The term "exponential smoothing" reveals that the weights slow down exponentially as the observed data becomes old [5]. The exponential smoothing is grouped into three strategies dependent on trend and seasonal parts of the time series data, which are portrayed as the single exponential smoothing method, the Holt Linear Trend exponential method, and the Holt-Winters methods. Single exponential smoothing (SES) is a well-known forecasting method for stationary time-series data. But it does not give good results in the non-stationary time-series data.

Agricultural rice crop growth data contains trends and seasonality over time. Hence, SES won't work whenever a trend appears. Therefore, Holt gave a process to deal with such time series data. The process of dealing with trends is called the Holt Linear Trend Method (Double Exponential Smoothing). It deals with two smoothing constants and three smoothing equations. Holt-Winters methods are used with various parameters such as trend, level, and seasonality. It is divided into multiplicative and additive models based on seasonality.

2.1. Holt linear trend methods

Holt [4] linear methods are extended from single exponential smoothing to allow forecasting with trend in the weight calculation, with α and β as smoothing constants, as formulated below:

$$L_p = \alpha X_p + (1-\alpha)(L_{p-1} + T_{p-1}),$$
$$T_p = \beta(L_p + L_{p-1}) + (1-\beta)T_{p-1}$$

and

$$F = L_p + mT_p,$$

where X_p is the actual data, L_p is the level of the series at time p, T_p is the trend of the series at time p, α and β are the smoothing parameters, and F is the m-step ahead forecast.

2.2. Holt-Winters methods

Holt-Winters [17] Methods are divided into two types: additive and multiplicative, based on the seasonal type. A multiplicative method is based on the three equations for trend, level, and seasonality.

The exponential smoothing with multiplicative seasonal models is shown below.

Smoothing Level

$$L_p = \alpha \frac{Y_p}{S_{p-s}} + (1-\alpha)(L_{p-1} + b_{p-1}).$$

Smoothing Trend

$$b_p = \beta(L_p - L_{p-1}) + (1-\beta)b_{p-1}.$$

Smoothing Seasonal

$$S_p = \gamma \frac{Y_p}{L_p} + (1-\gamma)S_{p-s}.$$

Forecast

$$F_{p+m} = (L_p + b_p m)S_{p-s+m}.$$

The additive seasonal smoothing models is shown below.

Smoothing Level

$$L_p = \alpha(Y_p - S_p) + (1-\alpha)(L_{p-1} + b_{p-1}).$$

Smoothing Trend

$$b_p = \beta(L_p - L_{p-1}) + (1-\beta)b_{p-1}.$$

Smoothing Seasonal

$$S_p = \gamma(Y_p - L_p) + (1-\gamma)S_{p-s}.$$

Forecast

$$F_{p+m} = (L_p + b_p m)S_{p-s+m},$$

where s is the length of the seasonality, L_p is the overall estimate value, b_p is the trend component, S_p is the seasonal component, p is time period, F_{p+m} is the estimate for m in the next period, and Y_p represents the observed values.

2.3. Error factors

By comparing actual and predicted values, we can obtain the performance of the forecast methods. To estimate that, we have the following performance metrics to analyze the accuracy of the forecasting values: Mean Absolute Error (MAE), Sum Squared Error (SSE), Mean Squared Error (MSE), Mean Percentile Error (MPE), and Mean Absolute Percentage Error (MAPE), which are defined by

$$\mathrm{MAE} = \frac{1}{n}\sum_{p=1}^{n}|Y_p - \bar{Y}|, \qquad \mathrm{SSE} = \sum_{p=1}^{n}(Y_p - \bar{Y})^2,$$

$$\mathrm{MSE} = \frac{1}{n}\sum_{p=1}^{n}(Y_p - \bar{Y})^2, \qquad \mathrm{MPE} = \frac{100\%}{n}\sum_{p=1}^{n}\frac{Y_p - \bar{Y}}{Y_p}$$

and

$$\mathrm{MAPE} = \frac{100\%}{n}\sum_{p=1}^{n}\left|\frac{Y_p - \bar{Y}}{Y_p}\right|,$$

where Y_p is the observed value at time p, $\bar{Y}$ is the forecasted value at time p and n is the number of data.

3. Data Analysis

We used the Zaitun Time Series 0.1.4 software to plot the time series trend, forecast, and estimate the error factors. Step 1 is plotting the rice double cropped data. (spring and summer crops) with seasonality.

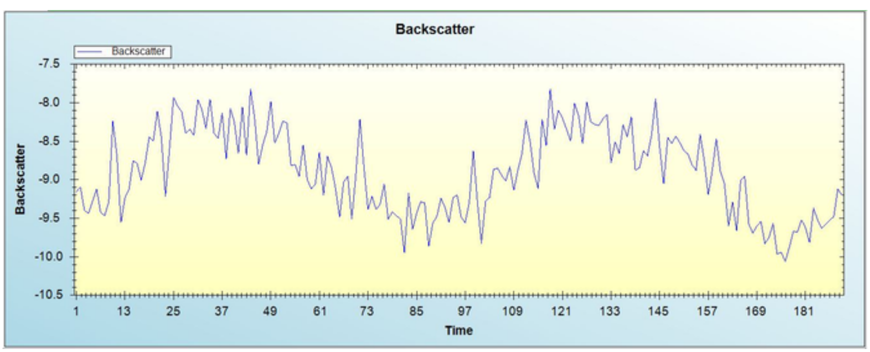

Figure 1. Time plot of rice double cropped data in 2019

To verify the performance of the models, the error factor plays a vital role. All the following: Mean Absolute Error (MAE), Sum Squared Error (SSE), Mean Squared Error (MSE), Mean Percentile Error (MPE), and Mean Absolute Percentage Error (MAPE) are computed. Meanwhile, choosing the smoothing parameters, α, β, and γ were fixed from 0 to 1 to get the least error. The result of the estimation of the forecasting models is in Table 1.

In the Holt linear method, the first step is to identify the smoothing parameters, alpha and beta, to minimize the error. The values are obtained as $\alpha = 0.6$ and $\beta = 0.1$ which are given the MAE = 0.26944, SSE = 22.45984, MSE = 0.11821,

Table 1. Performance metrics for the different forecast methods

Exponential Smoothing	Parameters			Accuracy Measures				
	α	β	γ	MAE	SSE	MSE	MPE	MAPE
Linear	0.6	0.1	-	0.2694	22.4598	0.1182	-0.1181	3.0616
Multiplicative	0.2	0.2	0.1	0.2520	19.5920	0.1031	-0.0583	2.8554
Additive	0.1	0.4	0.2	0.2587	20.4328	0.1075	-0.0663	2.9297

MPE = 0.11814 and MAPE = 3.061624 as error values which are helpful for the study.

Figure 2 compares the actual data and the forecast data of the spring and winter rice crop growth values. Starting from the puddling stage to transplanting, the crop vegetation is gradually increasing. After the heading stage, the vegetation is slowly decreasing and ready to harvest. Soon the land will be prepared for the next cultivation with the same procedures.

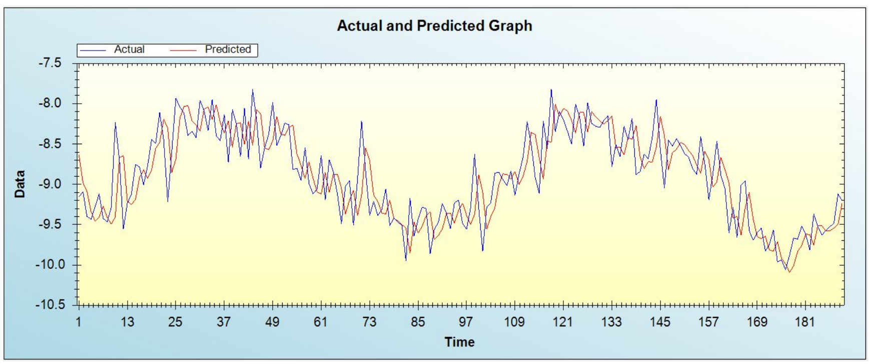

Figure 2. Forecasting time series plot of Holt linear model

In the Holt exponential smoothing for multiplicative methods with smoothing constants are $\alpha = 0.2$, $\beta = 0.2$ and $\gamma = 0.1$, with MAE = 0.25209, SSE = 19.59206, MSE = 0.10311, MPE = 0.0584 and MAPE = 2.85544 as error values.

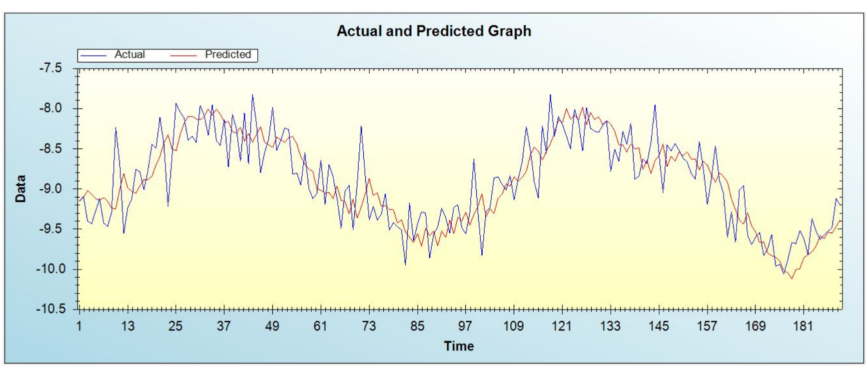

Figure 3. Forecasting time series plot of Holt-Winters multiplicative model

In the Holt exponential smoothing for additive methods with smoothing constants are $\alpha = 0.1$, $\beta = 0.4$ and $\gamma = 0.2$, with MAE = 0.258765, SSE = 20.4328, MSE = 0.107541, MPE = 0.066381 and MAPE = 2.929728 as error values.

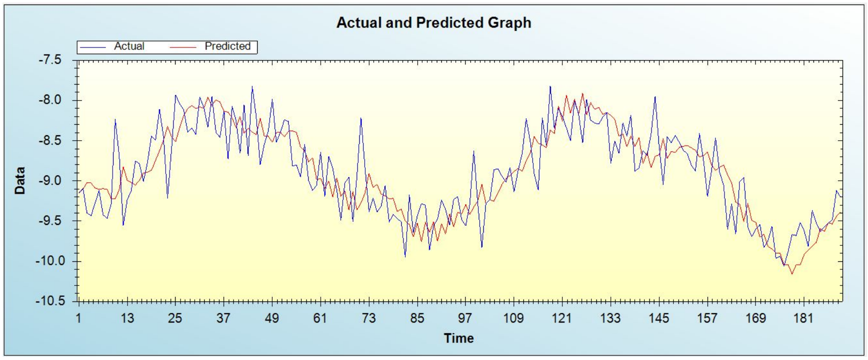

Figure 4. Forecasting time series plot of Holt-Winters additive model

From the above analysis, the effect of forecasting values of Holt linear and Holt-Winters (multiplicative and additive) models was investigated. One year of double cropped vegetation data was taken for the analysis to forecast the growth of the crops.

4. Conclusion

The present article shows that the exponential smoothing methodologies are suitable for rice crop growth using agricultural satellite backscatter values of time series data in 2019. The Holt-Winters multiplicative method was found to have the least error factor compared to the Holt-Winters additive and Holt linear trend methods. As a result, the Holt-Winters multiplicative method is best for predicting and forecasting double-cropped agricultural data growth.

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