Forecasting Temperature Time Series for Irrigation Planning Problems

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Abstract: Climate change is a reality and efficient use of scarce resources is vital. The challenge of this project is to study the behaviour of humidity in the soil by mathematical/statistical modeling in order to find optimal solutions to improve the efficiency of daily water use in irrigation systems. For that, it is necessary to estimate and forecast weather variables, in this particular case daily maximum and minimum air temperature. These time series present strong trend and high-frequency seasonality. This way, we perform a state space modeling framework using exponential smoothing by incorporating Box-Cox transformations, ARMA residuals, Trend and Seasonality.

Keywords: Forecasting; Irrigation; TBATS; Temperature; Time Series Modeling.

1 Introduction

In this work, we address the daily irrigation problem of minimizing water consumption. Our data source are the records of temperatures observed in a farm located in Vila Real County in northern Portugal (Figure 1), registered in the period from January 23rd, 2015 to August 11th, 2018, on a daily basis. The main goal is to forecast the temperature at a location in order to determine, in particular, the evapotranspiration which is directly related to the irrigation planning problem. The location, in this case, is the farm where there are historical observations, but current measurements are not available, including various steps for forecasting.

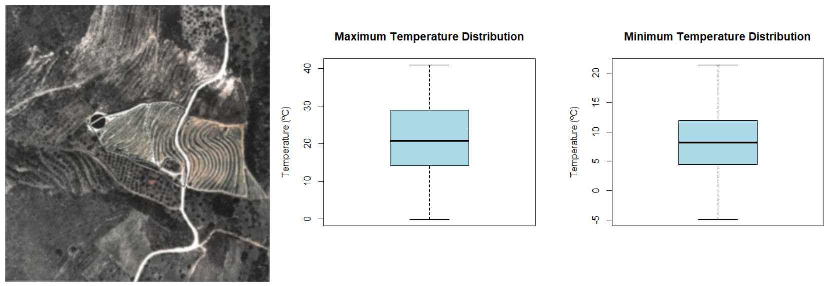

FIGURE 1. Farm in Vila Real County in northern Portugal (left); Maximum and Minimum Temperature daily time series distributions (right).

2 Methodology

In this study were used Trigonometric Seasonal, Box-Cox Transformation, ARMA errors, Trend and Seasonal Components method given by designation $TBATS(\omega, \phi, p, q, \{m_1, k_1\}, \{m_2, k_2\}, ..., \{m_T, k_T\})$, where ω is the parameter of the Box-Cox transformation, ϕ is the damping parameter, the errors are modeled as $ARMA(p, q)$ process, $m_1, ..., m_T$ are the seasonal periods and $k_2, ..., k_T$ are the numbers corresponding to the Fourier terms used for each seasonal period. The smoothing parameters are given by α, β and γ_i for $i = 1, ..., T$. This method has the ability to deal with time series with high-frequency seasonality. The collected data were divided into two sets: training data (in-sample data) and testing data (out-of-sample data) in order to testify the accuracy of the suggested forecasting models.

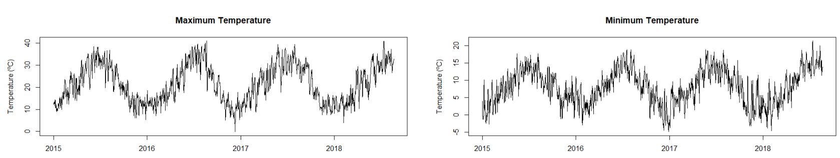

FIGURE 2. Daily time series of Maximum and Minimum Temperature distributions in the farm during the observed period.

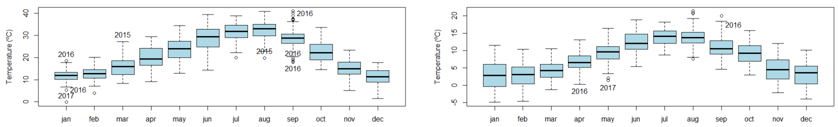

FIGURE 3. Box-plots of the daily Maximum and Minimum Temperature distributions in the farm, by month.

The selected training period was from January 23rd, 2015 to August 11th, 2018 (first 1317 observations), and the test period with the last 10 observations. Figure 2 and Figure 3 show plots of the Temperature series over time and the distributions by month, respectively.

3 Results

The model obtained for Maximum Temperature was $TBATS\,(1, \{3, 0\}\,, 0.92, \{365, 1\})$ and for Minimum Temperature $TBATS(1, \{2, 1\}\,, -, \{365, 8\})$. Figure 4 (left) shows the result for the fit of the TBATS model for Maximum and Minimum Temperature time series, respectively. Figure 4 (right) presents the estimates, and the forecasts (from August 2nd, 2018 to August 11th, 2018). The values of Sigma are 2.882 and 2.253 for Maximum and Minimum Temperature time series modeling, respectively.

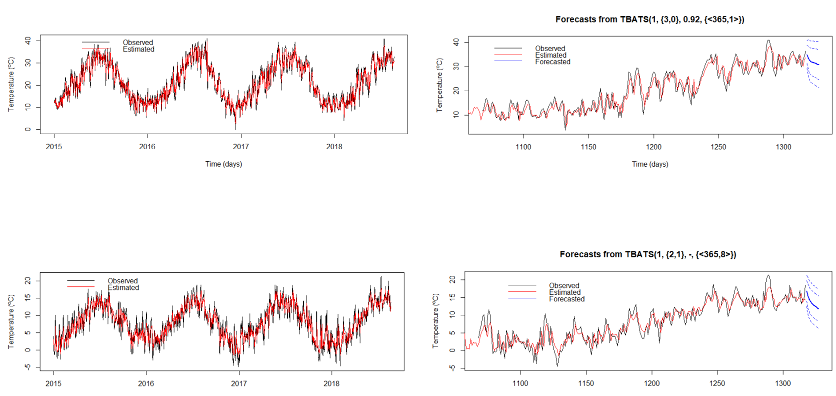

FIGURE 4. Estimates (left) and estimates and forecasts for Maximum and Minimum Air Temperature time series (right-last 250 observations).

The results are satisfactory and allow assuring the capability and optimal performance of the TBATS model, and suggest that the proposed framework is promising for future studies (see Table 1 and Table 2).

TABLE 1. Estimated Parameters using TBATS method.

	ω	ϕ	α	β	γ_1	γ_2	φ_1	φ_2	φ_3	θ_1
Max. Temp.	1	0.91999	0.23332	-0.02287	3.97795e-05	0.00020	0.62759	-0.15828	-0.06488	-
Min. Temp.	1	-	0.00552	-	-0.00267	0.00046	0.83458	-0.18014	-	-0.17154

TABLE 2. Performance metric (different criteria: Mean Error (ME), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Scaled Error (MASE), and Autocorrelation Function for first lag (ACF1)).

	ME	RMSE	MAE	MASE	ACF1
Max. Temp.	0.03972	2.88222	2.30470	0.94509	-0.02451
Min. Temp.	0.06769	2.25386	1.78015	0.88824	-0.00053

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