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TEMPORAL DYNAMICS OF CLIMATOLOGICAL PARAMETERS AND HYDRIC BALANCE IN THE MANAGEMENT OF AGRICULTURAL CROPS

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KEYWORDS

climate, geostatistical, ordinary kriging, thematic maps.

ABSTRACT

One of the main factors that determine the success of decision-making in the fields is the climatic factor. This way, the geostatistical techniques have been used to represent and understand the spatial or temporal dynamics of meteorological parameters. Therefore, the aim of this research was to represent temporally through thematic maps, the average daily behavior for meteorological variables and the hydric balance for the municipality of Patos de Minas - MG. The climatic data were acquired from the automatic station INMET from the years 1990 to 2015. Later, it was calculated the evapotranspiration and the hydric balance for different capacities of available water in the soil (CAW): 24 mm, 48 mm, 80 mm and 112 mm. The climate variables showed temporal dependence, and through the thematic maps, derived from the ordinary Kriging, it was possible to identify the seasons of the year that are favorable for the production for the different crop groups.

INTRODUCTION

The climatic information, which are dynamic throughout the year, are relevant to the farmers, mainly, in the decision-making in the management of the plantations (Cecílio et al., 2012). The information about the averages of the climatic parameters allows a better understanding of the variability of these over the years, making the agricultural property planning to be executed with higher levels of accuracy, since the climatic variables exert a direct influence in the maximization of agricultural production (Moreno et al., 2016; Silva & Da Silva, 2016).

According to Martins et al. (2015), the climate knowledge is a key element to achieve a correct management of the agricultural crops, because through the knowledge of the climatic variables, it is possible to meet the evapotranspirometric demands. Highlighting the importance of the elements related to the climate and considering their importance in the management of rural properties, it is necessary that this information is available to the farmer in more understandable ways (Pereira et al., 2012). These elements are generally available in tables or graphs, so the interpretation is not direct, requiring a more careful analysis of them, since the temporal or spatial dependence of the data is not clearly represented in these forms.

In order to increase the efficiency of agricultural management and consequently to reduce losses that are directly related to adverse agrometeorological situations, the geostatistical techniques have been used to represent and understand the spatial or temporal dynamics of meteorological parameters (Sartori et al., 2010; Silva et al., 2010; Filgueiras et al., 2015; Emadi et al., 2016; Meyer et al., 2016; Reilly & Melillo, 2016; Gundogdu, 2017). The temporal and spatial behavior of these variables is analyzed by adjusting the experimental variogram to a theoretical variogram, since it is in this verification the dependence is observed over time and/or space (Isaaks & Srivastava, 1989; Heuvelink & Webster, 2001; Yamamoto & Landim, 2013).

Thus, to represent and understand the behavior of climatic variables and hydric balance parameters, which are extremely dynamic over time and space, it is necessary to process these data through interpolators. There are many interpolation techniques, such as the inverse of the weighted distance (IDW), triangulation with linear interpolation, among others (Perin et al., 2015). However, these interpolators do not consider the distribution of the variables, or the spatial autocorrelation of the variables, making the final results simplified (Isaaks & Srivastava, 1989).

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One way to solve this problem, and to make the execution of rural property planning more accurate, is to apply techniques based on geostatistical principles, such as ordinary kriging, known as the best linear unbiased estimator (Yamamoto & Landim, 2013). This can be considered, from geostatistical techniques, the most commonly used, based on the assumptions of the variable to be random and spatially correlated (Heuvelink & Webster, 2001).

Thus, the aim of this study was to represent, temporally, through thematic maps, the average daily behavior of climatological and hydric balance variables for the municipality of Patos de Minas-MG, aiming to make available to the local farmer a product to assist in the decision-making, with regard to irrigation management.

MATERIAL AND METHODS

Study Area

The study was carried out for the municipality of Patos de Minas, Minas Gerais (Figure 1), which is in the Alto Paranaíba mesoregion. It has diversified agriculture, with the production of corn, soybeans, beans, coffee, potatoes, garlic and carrots, besides having an extensive area with livestock farming (IBGE, 2015), being this region of great importance for Minas Gerais agriculture.

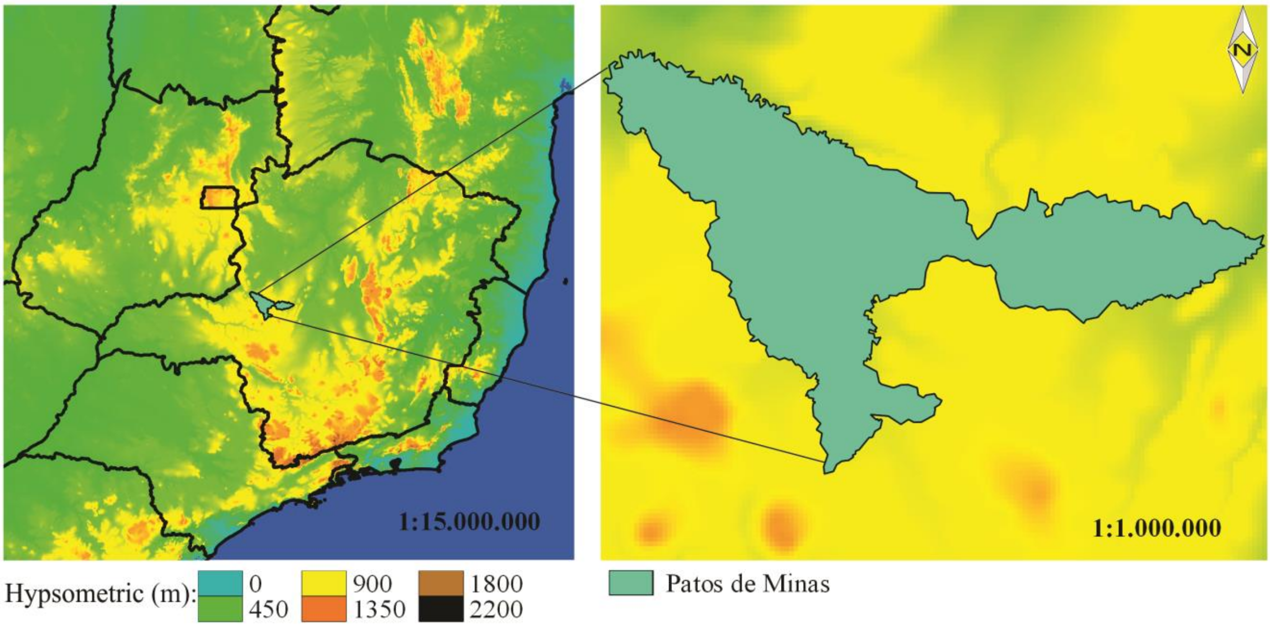

FIGURE 1. Location of the municipality of Patos de Minas in relation to the hypsometric map of the State of Minas Gerais.

The municipality of Patos de Minas-MG is located between the pairs of coordinates 18° 15’ 27” south latitude, 45° 49’ 39.36” west longitude and 19° 00’ 46.44” south latitude, 47° 00’ 18.36” west longitude (SIRGAS 2000 reference system) and average altitude of 832 m. The region has a predominant climate of Cwa type, of semi-humid tropical zone, with a minimum average temperature of 18ºC and an annual average of 22ºC or less. The climatic pattern is characterized by the presence of two well-defined seasons, one cold/dry, covering the months of April to September and the other warm/rainy, which extends from October to March. The average rainfall is 1600 mm year^{-1} (Alvares et al., 2013).

Acquisition of meteorological data

The meteorological information used in the study was taken from the INMET (National Meteorology Institute) historical database. The meteorological station present in the municipality has code 83531 and location in the pair of coordinates 18°30’36” south latitude; 46°25’48” west longitude (SIRGAS 2000 reference system).

The daily data taken from INMET for the station of interest were: rainfall (mm), maximum and minimum air temperature (°C), insolation (h), relative air humidity (%) and wind speed (U_2) in the period from 1990 to 2015.

The period from 1990 to 2015 was selected because it did not contain any inconsistency of data. An analysis to verify if there were missing and discrepant data was carried out prior to their processing, following the methodology described by the World Meteorological Organization (OMM), suggested by Reboita et al. (2015). The discrepant data are values considered outliers for climatological variables in the region of interest, such as maximum monthly temperature of 60 °C (Reboita et al., 2015). In the absence of data occurrence, the average temperature and reference evapotranspiration (ETo) were calculated, the latter being calculated according to the Penman-Monteith equation, as recommended by FAO-56 (Allen et al., 1998).

Hydric Balance

The methodology proposed by Thornthwaite & Mather in 1955 was used to calculate the hydric balance (HB), as described by Vianello & Alves (2012). The daily average values of air temperature (°C) were used for the daily calculation of evapotranspiration. The rainfall data (mm) and evapotranspiration (mm) corresponding to a time series of 26 years were used to calculate the HB.

The HB was calculated considering different capacities of available water in the soil (CAW): 24 mm, 48 mm, 80 mm and 112 mm simulating vegetable crops, annual crops, pasture and fruit growing, respectively. As with the different CAW, different crop evapotranspiration (ETc) were considered. This approach with different CAW and ETc was proposed in order to simulate the water deficit for these different crops, where Kc values were based on Allen et al. (1998).

The ETc was calculated using the methodology (Equation 1) present in Bernardo et al. (2006).

$$\text{ETc}=\text{ETo x Kc x Ks x Kl} \qquad (1)$$

that,

Ks - coefficient of irrigation frequency;

Kc - crop coefficient, and

Kl – coefficient of irrigation location, which is estimated by $0.1\sqrt{P}$, where P is equal to PWA (percentage of wet area) or PSA (Percentage of shaded area), with the highest value always prevailing between the two.

Thus, ETc, water deficit, excess and daily replenishment were calculated for the different agricultural crops, corresponding to an average of 26 years.

Geostatistical Analysis

After the calculation of the HB variables, the analysis of the data was carried out, in order to verify the possibility of the timing of the data through ordinary kriging.

Thus, the descriptive statistics of the data was analyzed, followed by the analysis of the temporal dependence of the data (Zimback, 2001; Sartori et al., 2010; Silva et al., 2010). After this analysis, which took place through the variogram, it was decided to carry out the geostatistical methodologies. The application of geostatistical techniques was used only in the occurrence of variographic amplitude, that is, when a range (t) was observed and then a stabilization of the variance of the data. If the premises of the geostatistics were not met, other interpolation methodologies would be applied, for example, the inverse of the distance square (Tayleur et al., 2016; Winter et al., 2016; Rodríguez-Amigo et al., 2017)

The dependence of the random variables over time was analyzed through [eq. (2)].

$$\text{Y}(t)=\left(\frac{1}{2N(t)}\right)\sum_{i=1}^{N(t)}\left[Z(x_i)-Z(x_i+t)\right]^2 \qquad (2)$$

that,

(t) - semivariogram for a vector t, days;

Z(x) and Z(x+t) - pairs of variables analyzed in the study, separated by a time interval, days,

N(t) - numbers of measured pairs.

The theoretical variograms model were adjusted to the experimental ones. Later, the Temporal Dependency Index (TDI) was calculated through the relation between the structural or temporal variance (C) and the baseline (C+ Co), through the [eq. (3)], proposed by Zimback (2001).

$$\text{TDI}=\frac{C}{C+C_o}\text{x}100 \qquad (3)$$

It is considered a weak temporal dependence for values less than or equal to 25%, between 25 and 75%, moderate temporal dependence and for results greater than 75%, strong temporal dependence (Zimback, 2001). The quality of the model adjustments was verified through cross validation, which consists of comparing the observed values with those estimated by the models. After verifying the temporal dependence of the climatic variables, as well as the variables of the hydric balance, and adjusting the models, the interpolation was performed by the ordinary kriging method, aiming to represent the temporal distribution of the variables under study.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics of the daily averages, corresponding to 26 years of the following climatological variables: precipitation (Pp), maximum temperature (T_{max}), medium temperature (T_{med}), minimum temperature (T_{min}), insolation (Insol), relative air humidity (RH), wind velocity (U_2), reference evapotranspiration (ETo) and the daily averages corresponding to the variables of the hydric balance for the different values of CAW (crop evapotranspiration - ETc, Deficit, Excess and Replenishment).

The descriptive statistics allowed the exploration of the variables characteristics, such as central (averages), dispersion (minimum and maximum values, standard deviations, variance and coefficient of variation), asymmetry measures (kinetic coefficient) and kurtosis (coefficient of kurtosis). From these analyzes, the behaviors of the variables over the years were known.

TABLE 1. Descriptive statistics of the meteorological and hydric balance variables for the different CAW.

Variable	n	Averag	S	S^2	CV(%)	Min.	Max.	C_a	C_k
Pp	366	3.985	3.979	15.832	99,85	0.000	17.450	0.930	0.100
T_{max}	366	28.466	1.314	1.726	4.62	25.680	31.310	-0.170	-0.660
T_{med}	366	21.591	1.562	2.439	7.23	18.360	24.280	-0.680	-0.970
T_{min}	366	16.530	2.160	4.665	13.07	12.330	18.970	-0.580	-1.300
Insol	366	6.823	1.448	2.095	21.22	3.630	9.730	-0.120	-0.990
RH	366	69.166	10.158	103.185	14.69	47.450	84.360	-0.540	-1.010
U	366	1.569	0.352	0.124	22.43	0.950	2.980	1.060	0.970
ETo	366	3.880	0.838	0.702	21.60	2.320	5.630	-0.010	-0.900
CAW 48 mm (Annual)									
ETc	366	1.698	0.973	0.946	57.30	0.000	3.360	-0.570	-1.050
Deficit	366	21.880	21.602	466.636	98.73	0.000	48.000	0.100	-1.850
Excess	366	2.262	3.412	11.641	150.84	0.000	15.680	1.510	1.560
Replenishment	366	1.693	1.343	1.804	79.33	0.000	8.060	0.900	2.220
CAW 112 mm (Fruticulture)									
ETc	366	2.463	1.592	2.534	64.64	0.000	5.140	-0.320	-1.310
Deficit	366	58.440	51.144	2,616.753	87.52	0.000	112.000	-0.120	-1.870
Excess	366	1.502	2.900	8.410	193.08	0.000	14.620	2.100	3.930
Replenishment	366	2.454	2.104	4.427	85.74	0.000	11.350	0.800	0.830
CAW 24 mm (Horticulture)									
ETc	366	1.241	0.643	0.413	51.81	0.000	2.310	-0.710	-0.730
Deficit	366	9.250	10.426	108.710	112.71	0.000	24.000	0.410	-1.680
Excess	366	2.726	3.664	13.427	134.41	0.000	16.270	1.270	0.850
Replenishment	366	1.241	0.941	0.885	75.83	0.000	7.050	1.070	3.970
CAW 80 mm (Pasture)									
ETc	366	1.918	1.108	1.227	57.77	0.000	3.790	-0.560	-1.020
Deficit	366	37.639	36.100	1303.242	95.91	0.000	80.00	0.050	-1.860
Excess	365	2.050	3.291	10.829	160.54	0.000	15.450	1.650	2.070
Replenishment	365	1.917	1.608	2.584	83.88	0.000	9.560	1.130	2.730

Pp: precipitation (mm); T_{max}: maximum temperature (°C); T_{med}: medium temperature (°C); T_{min}: minimum temperature (°C); Insol: insolation (h); RH: relative humidity (%); U_2: wind speed (m s^{-1}); ETo: reference evapotranspiration (mm); ETc: crop evapotranspiration (mm); n: number of observations; s: standard deviation; S^2: variance; CV: coefficient of variation (%); Ca: coefficient of asymmetry; Ck: coefficient of kurtosis.

The characteristics of the variograms models found for the climatological variables analyzed are shown in Table 2. For all the variables, the theoretical models that best represented the experimental variograms were the Gaussian models, followed by the Spherical model. The theoretical models were chosen because they presented a smaller error in the adjustment (Zimback, 2003). Jacomo et al. (2013) and Sartori et al. (2010) adjusted the temporal Pp data to the spherical model, in a study with climatic variables in the state of São Paulo, which is in agreement with this study. Filgueiras et al. (2015) adjusted the spherical model for U and Pp in a study of the timing of climatological normal in the south central region of the state of São Paulo, which was also found in this study.

TABLE 2. The characteristics of the models found for the climatological variables.

Variable	Variogram Model	C_o	C_o+C	A	r²	TDI
Pp	Spherical	0.330	16.650	6.580	0.955	0.980
T_{max}	Gaussian	0.001	1.821	3.204	0.709	0.999
T_{med}	Gaussian	0.001	2.591	3.932	0.705	1.000
T_{min}	Gaussian	0.010	4.939	4.399	0.749	0.998
Insol	Spherical	0.001	2.185	5.750	0.889	1.000
RH	Gaussian	0.100	109.100	4.780	0.898	0.999
U	Spherical	0.006	0.138	5.400	0.894	0.958
ETo	Gaussian	0.016	0.742	4.867	0.915	0.978
CAW 48 mm (Annual)						
ETc	Gaussian	0.001	1.001	3.775	0.737	0.999
Deficit	Gaussian	1.00	497.000	4.832	0.853	0.998
Excess	Spherical	2.190	12.470	8.230	0.968	0.824
Replenishment	Spherical	0.221	1.764	3.960	0.797	0.875
CAW 112 mm (Fruticulture)						
ETc	Gaussian	0.001	2.676	4.156	0.798	1.000
Deficit	Gaussian	1.00	2791.000	5.248	0.901	1.00
Excess	Spherical	2.730	9.183	10.530	0.967	0.703
Replenishment	Spherical	0.280	4.694	4.880	0.869	0.940
CAW 24 mm (Horticulture)						
ETc	Gaussian	0.001	0.437	3.343	0.688	0.998
Deficit	Gaussian	0.100	115.100	4.434	0.792	0.999
Excess	Spherical	1.520	14.250	7.450	0.964	0.893
Replenishment	Spherical	0.130	0.883	2.820	0.545	0.853
CAW 80 mm (Pasture)						
ETc	Gaussian	0.001	1.300	3.845	0.753	0.999
Deficit	Gaussian	1.000	1393.000	5.005	0.873	0.999
Excess	Spherical	2.500	11.670	8.900	0.966	0.786
Replenishment	Spherical	0.285	2.5660	4.180	0.831	0.889

Pp: precipitation (mm); T_{max}: maximum temperature (°C); T_{med}: medium temperature (°C); T_{min}: minimum temperature (°C); Insol: insolation (h); RH: relative humidity (%); U: wind speed (m s^{-1}); ETo: reference evapotranspiration (mm); ETc: crop evapotranspiration (mm); C_o: nugget effect; C_o + C: baseline; A: reach; r²: coefficient of multiple determination: TDI: time dependency index.

The Figures 2, 3, 4, 5 and 6 show the variographic analyzes of the climatological parameters and relative to the average daily hydric balance of 26 years. Table 2 shows that the variables presented temporal dependence. According to Zimback (2001), the only variable related to the hydric balance, which did not present a strong temporal dependence, was the estimated water excess for the CAW of 112 mm. Even so, this variable, according to the same author, showed moderate dependence.

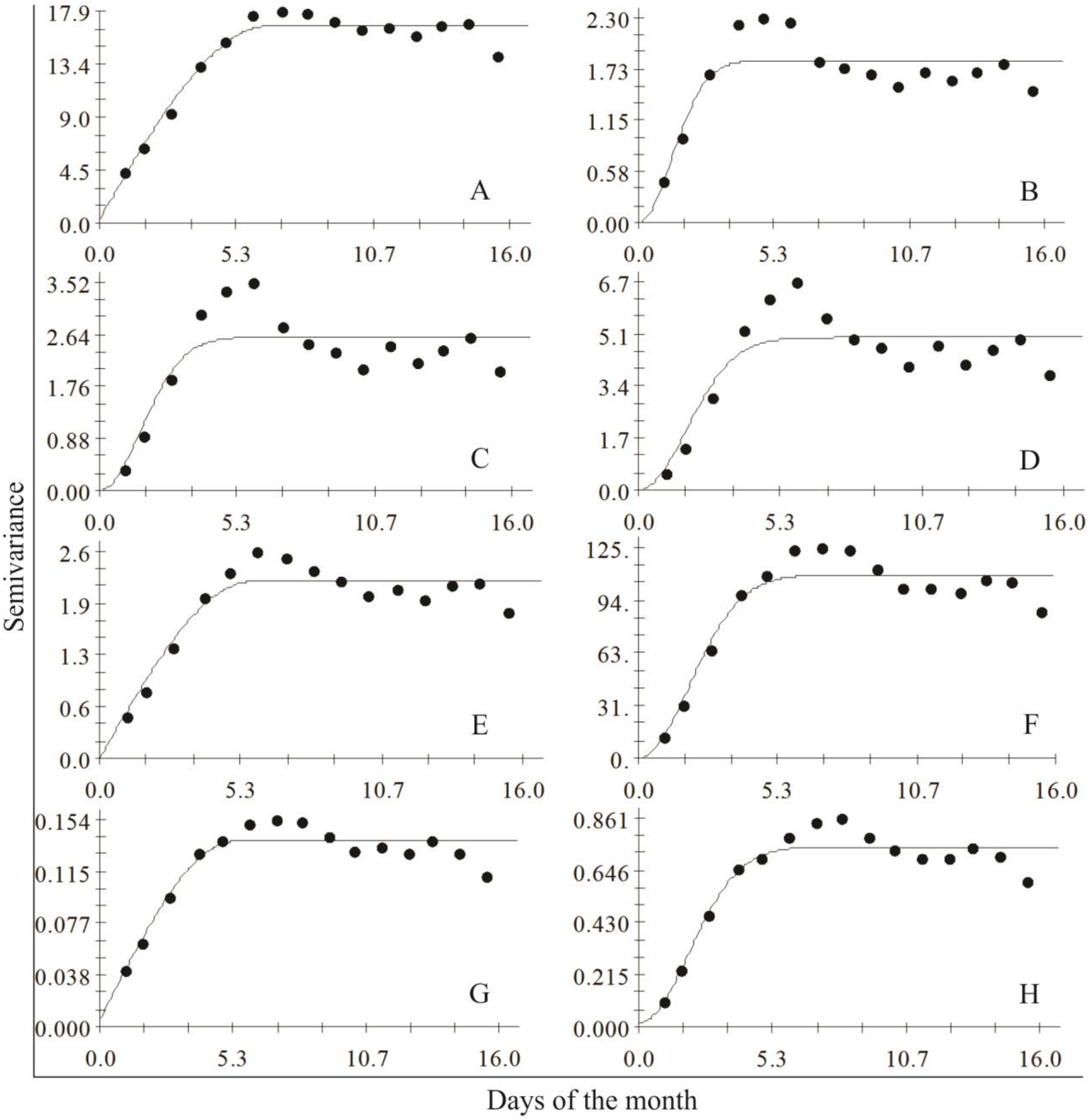

FIGURE 2. Isotropic Variogram of the annual daily average of the meteorological variables, precipitation (A), maximum temperature (B), medium temperature (C), minimum temperature (D), insolation (E), relative humidity wind velocity (G) and reference evapotranspiration (H).

On average, the meteorological variables presented a range (A) of 4.86 days. According to Yamamoto & Landim (2013), the range would be the distance at which the data reach a certain level, called baseline, and which is generally equal to the a priori variance of the data, or also, according to Sturaro (2015), the influence radius of a variable. In this way, becomes liable to statement that the climatological variables were correlated, on average, for approximately 5 days.

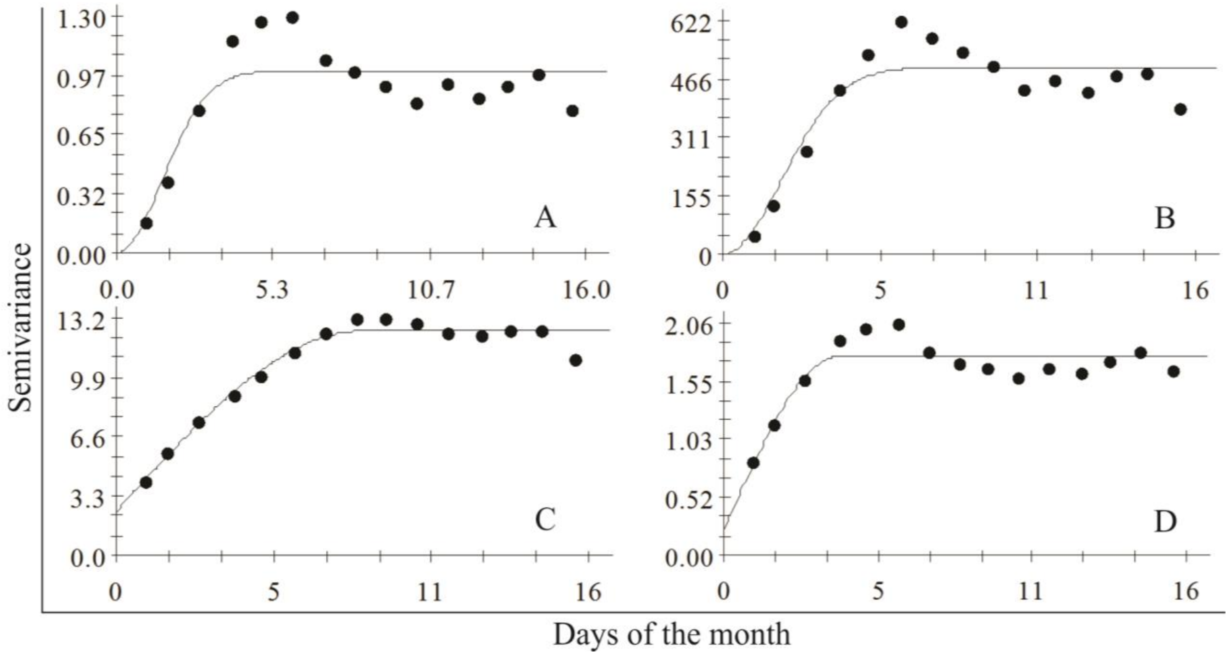

FIGURE 3. Isotropic Variograms of the annual daily average of reference evapotranspiration (A), hydric deficit (B), Excess (C) and Replenishment (D) estimated for the CAW of 48 mm.

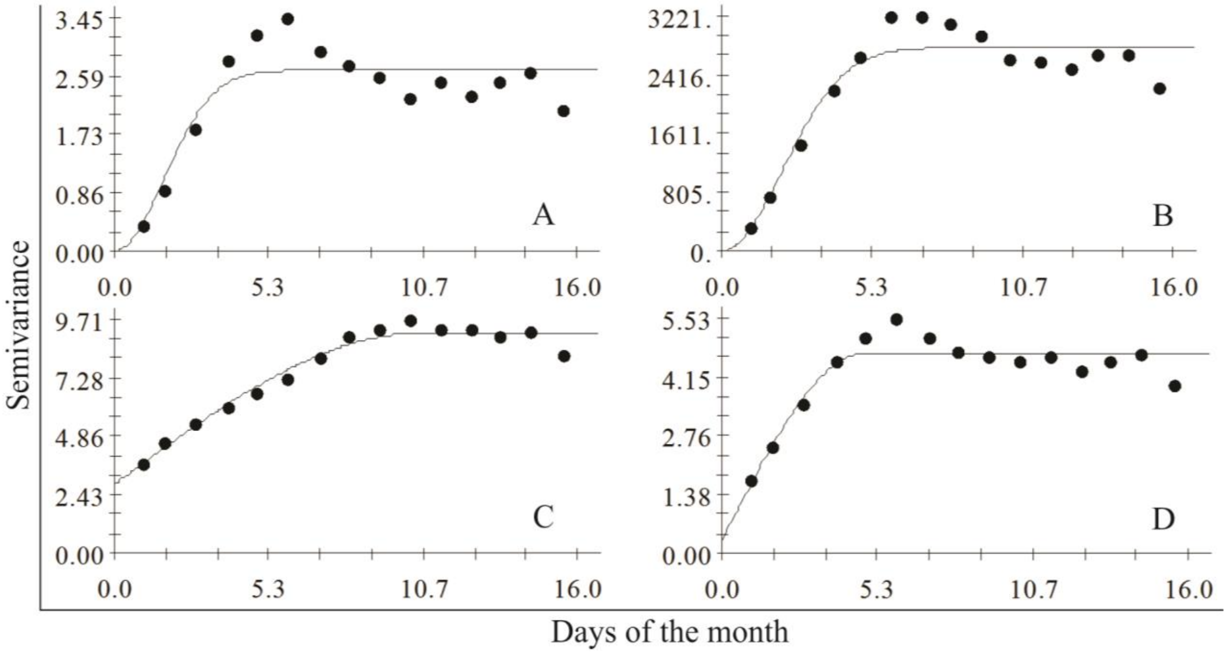

FIGURE 4. Isotropic Variograms of the annual daily average of reference evapotranspiration (A), hydric deficit (B), Excess (C) and Replenishment (D) estimated for the CAW of 112 mm.

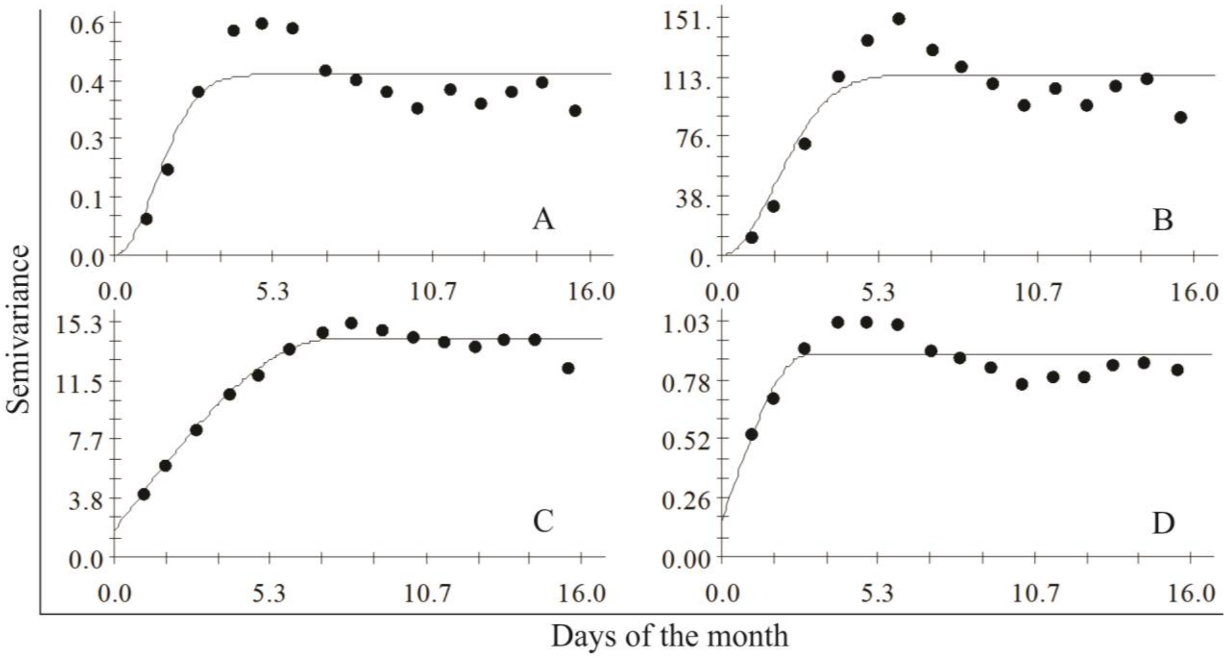

FIGURE 5. Isotropic Variograms of the annual daily average of reference evapotranspiration (A), hydric deficit (B), Excess (C) and Replenishment (D) estimated for the CAW of 24 mm.

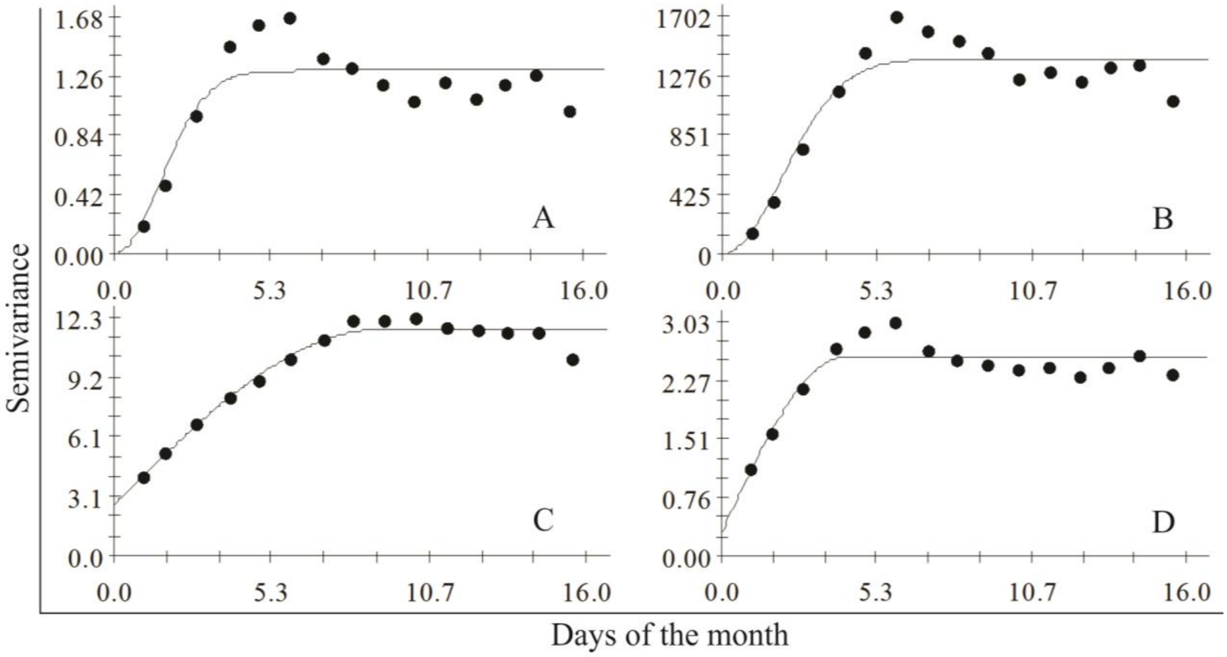

FIGURE 6. Isotropic Variograms of the annual daily average of reference evapotranspiration (A), hydric deficit (B), Excess (C) and Replenishment (D) estimated for the CAW of 80 mm.

The average daily timing of the meteorological variables is shown in Figure 7, and the variability of the climatological parameters throughout the year (average of 26 years) can be observed in thematic maps, and in the abscissa (x) axis, the days of the month and, on the ordinate axis (y), the months of the year. The figure 7A shows that the lowest values of Pp occur in the months from June to August, with a predominance of low precipitation indexes during all the days of these months. However, the highest Pp values are clustered in the months from November to March, which was also observed by Alves & Rosa (2008) in a study on the spatial data of the cerrado region in Minas Gerais and explained by Reboita et al. (2015).

The Figure 7B shows that the trend, in the municipality of Patos de Minas, is the occurrence of higher temperature values during the months of September and October. During these months, a reddish band is perceptible, corroborating with the study carried out by Reboita et al. (2015). These authors carried out a study with the climatic aspects of the state of Minas Gerais, using 40 INMET meteorological stations. One of the stations used in the study of these authors was the INMET station, code

83531, which corresponds to the same station used in this study. Reboita et al. (2015) did not find any discrepancy in the data series of the stations used, for precipitation and minimum and maximum temperature data.

The fact that the highest temperature values occur in the months of September and October does not imply that in other months high temperatures cannot occur, it only highlights the occurrence, more frequently, of the maximum temperatures during these months. The higher frequency of these, in the months of September and October, causes the predominance of the highest average temperatures in the same period, which can be observed by the reddish color throughout Figure 7C.

The predominance of the highest frequencies of minimum temperature (Figure 7D) occurs in the months from May to the beginning of August, verified by the bluish coloration of longitudinal occurrence in the minimum temperature thematic map, a fact also found in the study of Alves & Rosa (2008).The Figures 7E, 7F and 7G shows that the large amounts of hours of insolation associated with high wind speeds and low relative humidity are coupled to the range of maximum ETo values (Figure 7H), not neglecting the fact that high temperatures occur in this period (Figures 7B and 7C).

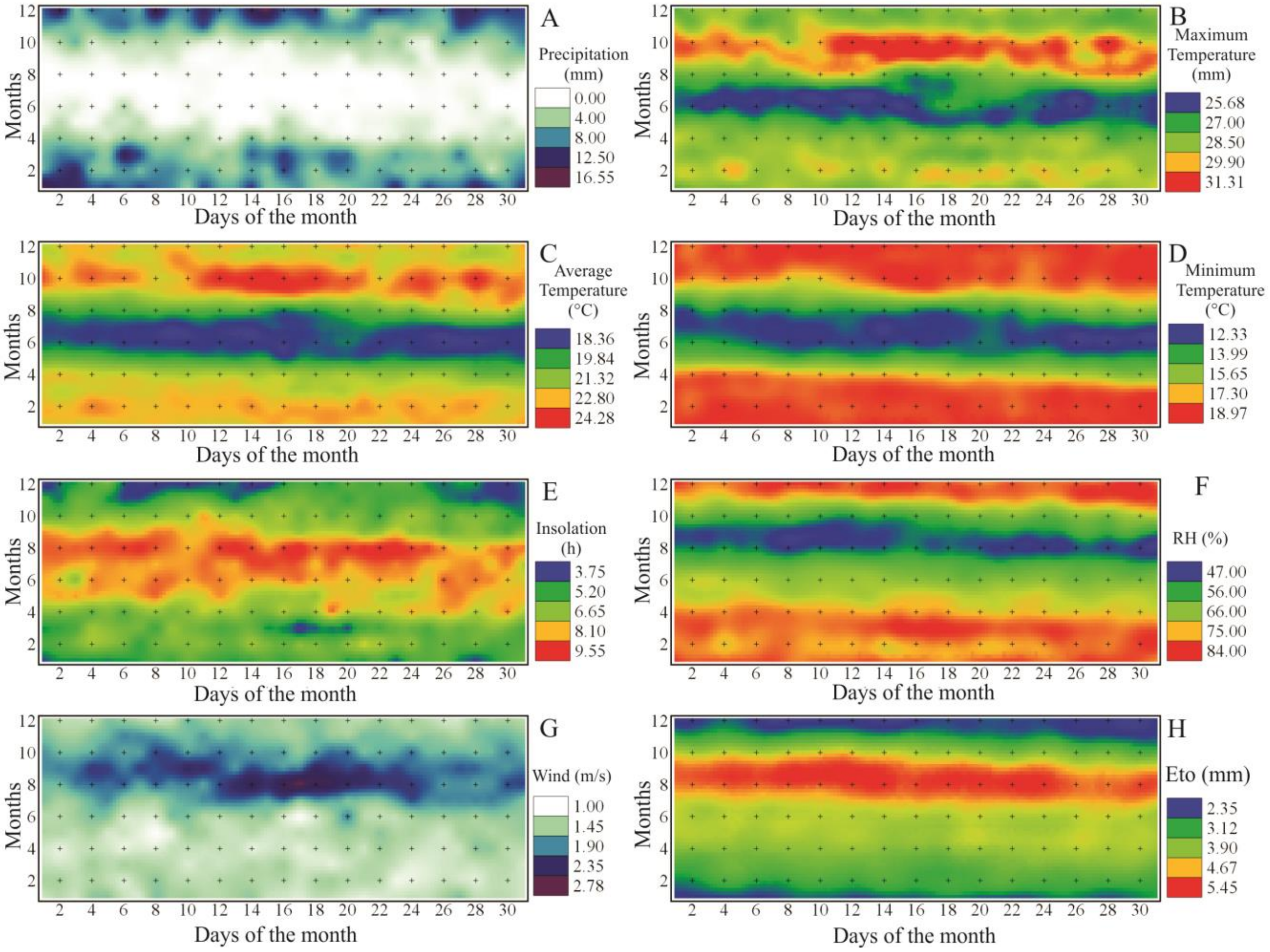

FIGURE 7. Average daily timing of meteorological data during the year.

Observing the timing, it is possible to identify months and days that, based on a long series of data, would be most likely to occur stresses to the cultivation of a certain crop, which can be water stress, temperature, insolation or even wind. In addition, this observation may be beneficial for planning pre-planting activities on the farm, such as soil preparation, acidity correction, pest and weed control. Another factor to be observed is the temperature requirement of some crops, such as pastures and forages, which in general have their metabolism paralyzed at temperatures below 15 ºC (Oliveira et al., 2014). In vegetables, such as garlic crop, require low temperatures, close to 14 ºC, for the bulbification process, and the production is compromised if it does not have this stimulation, caused by the low temperatures.

Figures 8, 9, 10 and 11 show the average daily timing of hydric balance variables for different CAW, in order to simulate the behavior of different crop classes. The analyzed variables were: crop evapotranspiration (A), hydric deficit (B), excess (C) and replenishment (D). This information is of great use to the farmers, since through the analysis of them, it is possible to know the exact moment in which each of these groups of crops needs hydric support. The management of the crop becomes more efficient, with information on how much and when the plant needs water, a fact that becomes easier, when it is precisely known, based on historical data, the production range of each crop group.

According to Figure 8A, the highest ETc for annual crops in the municipality of Patos de Minas occur in the first half of the year, with the highest values being concentrated in the months from February to April. This time, the crops with CAW of 48 mm are favored, as shown in Figures 8B, 8C and 8D. The most critical time for growing annual crops in this region is between May and October, since there is a water deficit during this period, with no water replenishment in the soil. The cultivation of annual crops at this time would only become viable with irrigation.

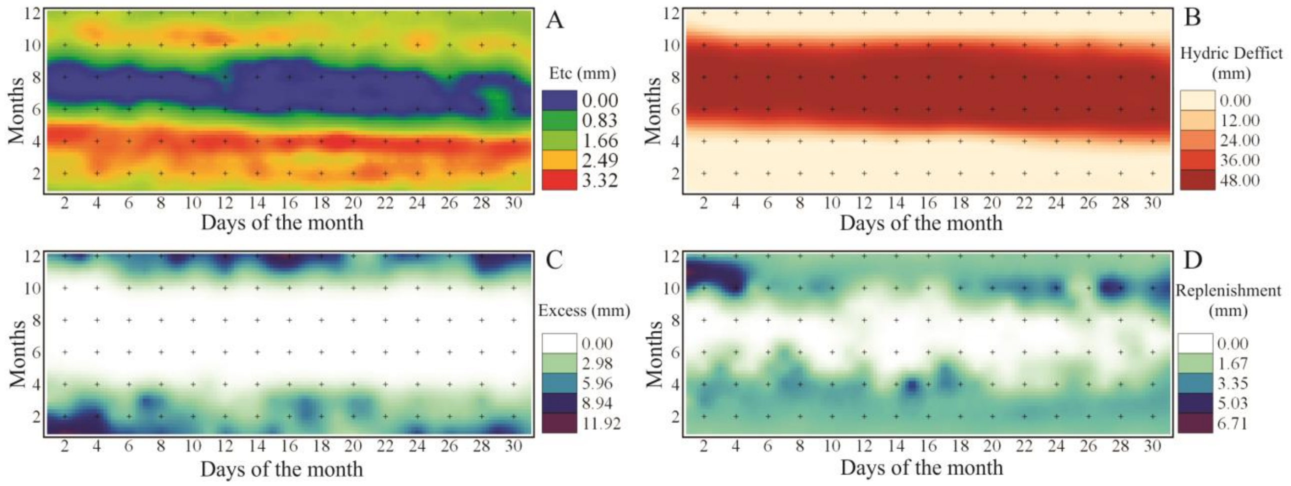

FIGURE 8. Annual daily average timing of hydric balance parameters for CAW of 48 mm, simulated value for annual crops (A - ETC, B - Deficit, C - Excess, D - Replenishment).

The highest evapotranspirometric (ETc) rates for fruit cultivation (Figure 9A), as well as for annual crops, tend to occur between February and May, but the fruit production has higher values than the annual crops. As the fruits are mostly perennial, they go through a long period of water deficit, which varies from May to the end of November, making irrigation support necessary to boost the production in those times.

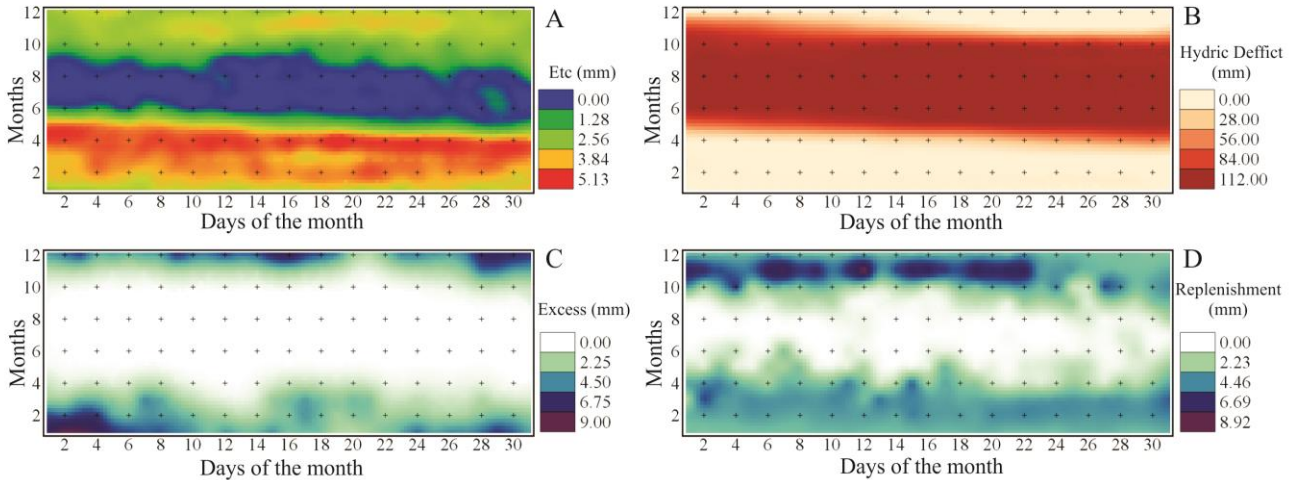

FIGURE 9. Annual daily average timing of hydric balance parameters for CAW of 112 mm, simulated value for fruits (A - ETC, B - Deficit, C - Excess, D - Replenishment).

The higher evapotranspirometric demand (ETc) of vegetables is concentrated in two seasons, in the months of April and October (Figure 10A). The vegetables with a shallower root system have a broader range for production throughout the year, however, it is known that these crops are extremely sensitive to water stresses, which means that they require additional irrigation, even if the soil showed no marked deficit, as observed in the months from January to May and October to December (Figure 10B).

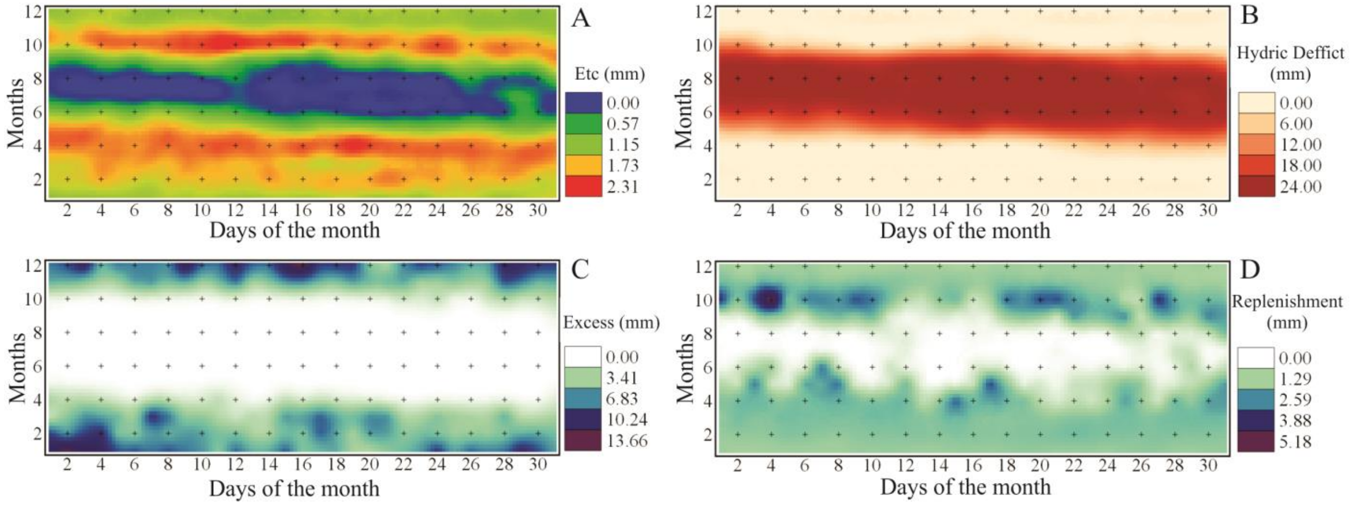

FIGURE 10. Annual daily average timing of the hydric balance parameters for CAW of 24 mm, simulated value for vegetables (A - ETC, B - Deficit, C - Excess, D - Replenishment).

The Pasture, in general, has the highest evapotranspometric demands concentrated in the month of April (Figures 11A). In the months from May to the end of October, the soil for these crops is under water deficit, which makes irrigation essential for biomass production at that time (Figure 11B), since during this period the soil presents small levels of the replenishment, so the available water capacity for these crops is not supplied (Figure 10C, D).

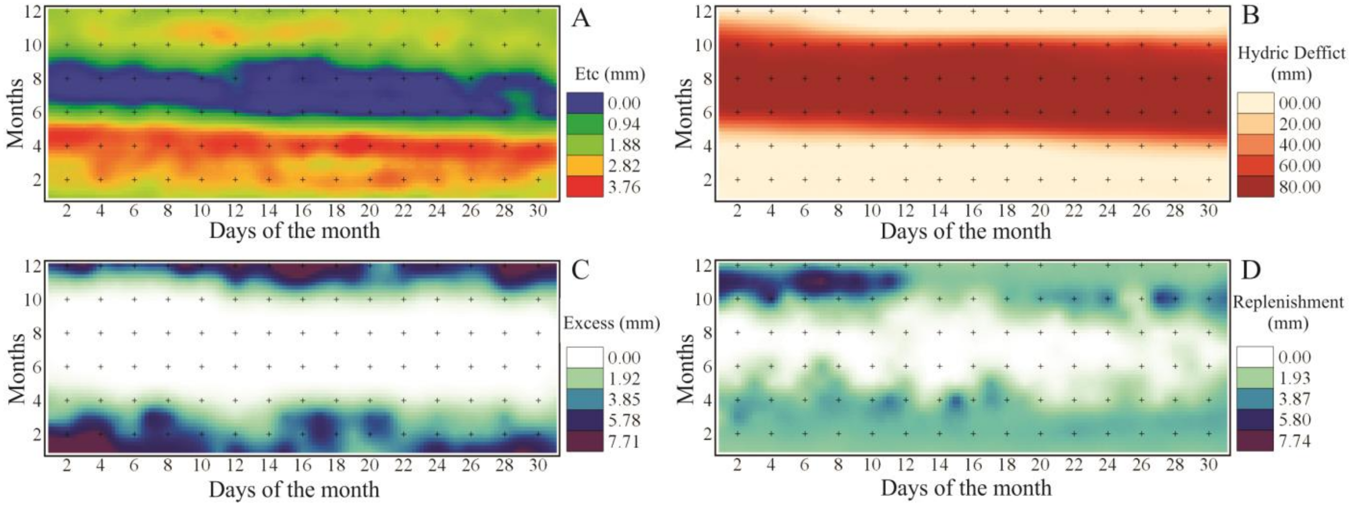

FIGURE 11. Annual daily average timing of the hydric balance parameters for CAW of 80 mm, simulated value for pasture (A - ETC, B - Deficit, C - Excess, D - Replenishment).

Table 3 shows the cross-validation parameters for the study variables. Through the analysis of this information, it is possible to have the knowledge of the adjustment that the studied variables had in relation to the theoretical semivariograms. In this validation, the variables of a day are omitted and their values for this day are estimated with the remaining days, making possible a statistical diagnosis in relation to the predicted data in the interpolation.

TABLE 3. Parameters of the cross-validation of the meteorological variables and the hydric balance.

Variable	B_0	B_1	SE	r^2	Variable	B_0	B_1	SE	r^2
Pp	0.09	0.979	0.03	0.711	Insol	0.05	0.99	0.03	0.77
T_{max}	2.39	0.916	0.02	0.86	UR	0.73	0.99	0.01	0.96
T_{med}	0.44	0.98	0.01	0.96	U	0.02	0.98	0.03	0.69
T_{min}	0.17	0.99	0.01	0.98	ETo	0.06	0.98	0.01	0.92
CAW 48 mm (Annual)					CAW 112 mm (Fruticulture)				
ETc	0.01	0.99	0.01	0.97	ETc	0.01	0.99	0.01	0.97
Deficit	-0.60	1.02	0.00	0.99	Deficit	-1.05	1.01	0.00	0.99
Excess	-0.11	1.04	0.05	0.59	Excess	-0.18	1.13	0.06	0.46
Replenishment	0.00	0.99	0.05	0.55	Replenishment	-0.02	0.99	0.04	0.62
CAW 24 mm (Horticulture)					CAW 80 mm (Pasture)				
ETc	0.01	0.99	0.01	0.96	ETc	0.01	0.99	0.01	0.97
Deficit	-0.21	1.01	0.00	0.99	Deficit	-0.66	1.01	0.00	0.99
Excess	-0.11	1.03	0.03	0.68	Excess	-0.19	1.09	0.05	0.60
Replenishment	0.16	0.86	0.05	0.38	Replenishment	-0.01	0.99	0.04	0,57

B_0 - intercept; B_1 – coefficient of regression; SE - Standard error; r^2 - coefficient of determination.

The analysis of the variables of the cross-validation allows to verify that the theoretical models adjusts well to the experimental ones, since the B_0 and SE approached zero in all the variables and the B_1 and r² approached of the unit in the majority of the parameters studied. The only variables that did not present a high coefficient of determination, of the cross validation, were excess and replenishment, being verified this fact in all variables studied.

CONCLUSIONS

The climatic variables, as well as the variables of the hydric balance, presented temporal dependence, making possible the execution of the geostatistical methodology used in the study. Through the thematic maps, derived from ordinary kriging, it was possible to identify the favorable production seasons for the different crop groups analyzed, as well as to make it possible to plan, with the highest level of accuracy, planting times for this region, as well as the need for irrigation in the critical moments of the crops.

From this methodology, it is easy to interpret the behavior of the climatological variables, as well as the dynamics of the hydric balance throughout the year, for the different crop groups, making the decision-making easier for the farmers of the region.

It is important to emphasize that this methodology can be replicated in other regions, in order to simplify the interpretation of the information, both climatological and relative to the hydric balance for the different crops of interest.

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