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Agroclimatic risk zoning for Grape cultivation in the Hydrographic Basin of Paraná River III, Brazil

Zoneamento de risco agroclimático para o cultivo de Uva para a Bacia do Rio Paraná III, Brazil

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ABSTRACT: The capacity to adapt the grape into different climates classification and the improvement of technology in the agriculture were fundamental for the expansion of grape production in partly of the national territory, with a significant socioeconomic relevance. The grape is vulnerable due to its sensitivity to fungal pathology, exhibiting the importance of agricultural management techniques and climate studies to improve its production. The purpose of this study was to perform climate risk agricultural zoning for the grape in the Hydrographic Basin of Paraná River III, Brazil, western region of the state of Paraná. For this, three specific local marketed varieties were selected: Rustic grapes (*Vitis labrusca*), fine table grapes (*Vitis vinifera*) and fine grapes for wine (*Vitis vinifera*). Meteorological data from 43 stations, from 1976 to 2018, were used. The analysis of climatic risk was based on the climatic requirements of the species: Average rainfall, annual water deficiency, average temperature, relative humidity and the risk of frost occurrence. For fine table grapes and rustic grapes for all regions in the basin these two species are recommended for cultivation. However, fine grapes specific for wine were restricted in the eastern portion and in small areas in the southern and western of the basin. Relative humidity and temperature are the key restrictive agrometeorological variable, in the basin.

RESUMO: *A ampla capacidade de adaptação da videira a diferentes climas e o aprimoramento da tecnologia de produção foram fundamentais para a expansão da produção em boa parte do território brasileiro, tornando umas das principais frutas produzidas no país, com notória importância socioeconômica. A espécie apresenta vulnerabilidade decorrente a sua sensibilidade a doenças fúngicas, demonstrando a importância de estudos climáticos para aprimorar suas técnicas de produção e manejo. Dessa forma, o objetivo deste trabalho foi realizar o zoneamento agrícola de risco climático para a videira na Bacia Hidrográfica do Rio Paraná III. Foram selecionadas as três principais variedades comerciais para o Estado, sendo estas: Uvas rústicas (Vitis labrusca), Uvas finas de mesa (Vitis vinifera) e Uvas finas para vinificação (Vitis vinifera). Para isso foram utilizados dados meteorológicos de 43 estações com série temporal de 1976-2018. A análise do risco climático foi pautada nas exigências climáticas da espécie, sendo estas, precipitação, deficiência hídrica anual, temperatura média, umidade relativa e o risco de geada tardia. Para as uvas finas de mesa e uvas rústicas todas as regiões avaliadas se mostraram aptas para o plantio. Por ser mais sensível a propagação de doenças, as uvas finas para a vinificação apresentaram restrição na porção leste e em pequenas áreas do Sul e Oeste da Bacia. As principais variáveis meteorológicas restringentes foram a umidade relativa do ar elevada e a temperatura.*

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1 Introduction

Fruticulture is an activity that makes a key contribution to the national economic development of Brazil. In 2018, grape stands out in this chain, it reached 1.592 million tons produced (IBGE, 2019). The destination of fruit production has three specific routes: being for the fresh trade, the table grape; to produce juices; and, for wine production. In order to maximize productivity and reduce the climatic risks, the applicability of studies on agrometeorological elements has been studied for several authors (Fraga *et al.*, 2018). In the context of climate change and sustainable agriculture, agroclimatic risk zoning has been opening up a field to improve agriculture management, decision making and for agricultural planning (Phogat *et al.*, 2018; Neethling *et al.*, 2019; Silva Padilha *et al.*, 2019; Vianna *et al.*, 2019).

In the 2018, grape occupied an area of 230 hectares, resulting about 3 thousand tons of fruit. The basin of Paraná River III corresponds about 5.2 % of the grape production in the Paraná State, Brazil (Ipardes, 2019). The climate of the basin of Paraná River III is conditioned, basically, by the topography, characterizing the pluviometric regime and considerable average temperature variability, during the year (Caldana *et al.*, 2019).

Grape has a significant dependence of the climate conditions for its development. Air temperature is one of the most important elements for the vine, and its increase can have an impact for grape and cause biological damages for varieties (Chavarria *et al.*, 2007). The climate change can cause damages for the fruticulture. Studies indicates that the grape is one the most vulnerable species for fungal pathology (Ricce *et al.*, 2014; Serpa *et al.*, 2017). Excessive rainfall, combined with higher average temperatures are climate conditions that contribute the fungal action in the plant (Serpa *et al.*, 2017). These fungi can cause rupture and rot of fruits, as a result, harming the maturation and the agronomic quality of the fruit (Back *et al.*, 2012). The meteorological elements that most influence the growth and development of the grape are: Radiation, air temperature, rainfall, relative humidity and wind (Bonfante *et al.*, 2018).

As agroclimatic zoning is the first criterion to be considered when planning the development, studies of this type are fundamental for the expansion of grape production (Ricce *et al.*, 2014). This research instrument and planning tool has great social value for the development of more profitable agriculture and for improving the relation between the environment and cultivated plants (Caldana *et al.*, 2019).

The purpose of this study was to perform climate risk agricultural zoning for the grape in the hydrographic basin of Paraná River III. The three key commercial varieties were selected, being these rustic grapes (*Vitis labrusca*), fine table grapes (*Vitis vinifera*) and fine grapes for winemaking (*Vitis vinifera*).

2 Material and Methods

The municipalities with an area in the Paraná River Basin 3 (figure 01) have a population of 1,073,175 inhabitants distributed in 28 municipalities in the Western Mesoregion of Paraná, with an area of 14,062km². It is noteworthy that the metropolitan regions of Cascavel (512,651 inhabitants) and Toledo (392,278 inhabitants) are concentrated in this area (IBGE, 2019). The area has numerous advantages for the diversification of agriculture. It has land of high fertility, gently undulating relief with an inclination towards West-East, diversified climate, low risk of frost in some areas, in addition to satisfactory infrastructure and logistics, being an important area for studies of this genesis (Medeiros & Zanão Junior, 2015).

For the economy, it is highlighted that the Paraná Basin 3 is mostly occupied by the intensive agriculture class, with a great predominance of grains (soybeans and wheat) occurring in a mixed-use range in the central-southern region of the basin. There are also small areas of forest cover and urban and industrial concentrations, especially in the regions of Foz do Iguaçu and Cascavel (Medeiros & Zanão Junior, 2015).

The hydrographic basin of Paraná River III is in a Cfa climate, which means that it has a humid subtropical climate according to the Köppen climate classification. This is characterized by the absence of drought seasons and by summers with higher average temperatures. This climate is controlled by air masses from tropical regions (the Atlantic Tropical Mass and the Continental Tropical Mass) and the Atlantic Polar Mass. In addition, the Continental Equatorial Mass can influence the Cfa climate zone during the summer season. Due to the temperature and humidity differences in these climatic masses, the area of the basin is a convergence zone for these climatic front systems, particularly in the winter season period (Nitsche *et al.*, 2019).

For the purpose of this study, we selected the hydroclimatic requirements of the studied species and weather data of annual, seasonal, monthly, and daily time series with clipping from 1976 to 2018. In order to analyze climate variability and produce the climate risk zoning, data from meteorological stations distributed around the basin were surveyed. The database comprises data from numerous weather stations, including six IAPAR—Instituto Agronomico do Paraná (Brazil) stations (data from 1976 to 2018), ten SIMEPAR—Sistema Meteorológico do Paraná (Brazil) stations (data from 2000 to 2018 were included to contribute to analyses, even though a short period of time), and 27 Águas Paraná (Brazil) stations (data from 1976 to 2018); see (Figure 2).

For this study, we used data from stations that had long term data series (1976–2018). The spatialization of these data was performed by interpolation, which is an effective method for spatial visualization of climate data. This was done using isohyets and/or by spatially filling the values through adjusted regression statistics, using the

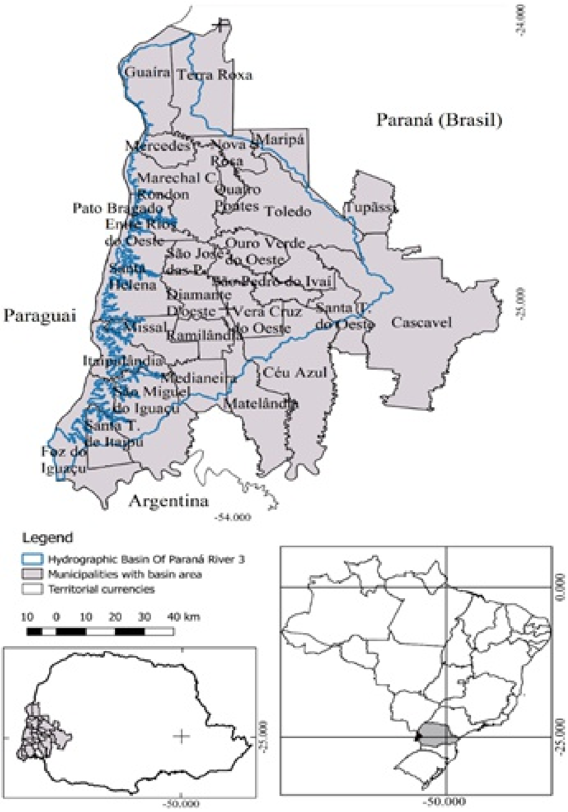

Figure 1. Zinc Location of the Paraná River basin and location of cities. Source: Águas Paraná; IBGE (2019). Organization: the authors (2019.)

Figura 1. Localização da Bacia do Rio Paraná III. Fonte: Águas Paraná; IBGE (2019). Elaboração: Os autores (2019).

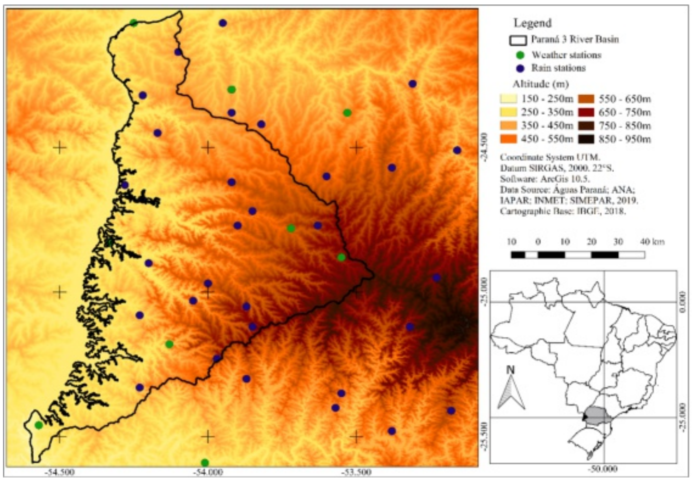

Figure 2. Hypsometry and locations of stations in the hydrographic basin of the Paraná River III. Source: Águas Paraná; INMET; SIMEPAR (2019). Organization: The authors (2019).

Figura 2. Hipsometria e localização das estações na bacia hidrográfica do Rio Paraná III. Fonte: Águas Paraná; INMET; SIMEPAR (2019). Elaboração: Os autores (2019).

inverse distance weighted spatial interpolation algorithm (Caldana *et al.*, 2019). The maps were created using QGIS 3.18.3 'Zürich' software.

The method used for the frost probability was based on the historical series of minimum temperature recorded inside the meteorological shelter. The probabilities of occurring values equal to or less than 1.0°C were determined and later adjusted to the equation:

$$y = a + x.lat + y.long + z.alt. \quad (1)$$

To determine periods with no frost registrations, that estimates the occurrence of the first frost (fall) to the last (spring). The method consists in identifying the frost at the level of the soil surface, when the minimum shelter temperature was below 4, 3, 2, 1 or 0°C. Analyzing the data series of each station, whenever the temperature of a day was lower or equal to one of those temperatures, the value "1" is associated and otherwise, the value "0" was assigned. Then, the probabilities of at least one frost per decade are calculated (Ricce *et al.*, 2014).

In addition, if within a given ten-day period there were one or more frosts, that ten-day period was counted as "1", regardless of the number of times the frost occurred, otherwise, it was counted "0". Based on the "0" and "1" sequences of the entire historical series for each season, the accumulated frequency of frosts throughout the year was calculated for each season. The date on which the 5 % probability accumulated in each of the seasons was assumed to be the first autumn frost, counting from the beginning to the end of the year. The last spring frost was also determined for an accumulated frequency of 5% probability, but calculations were carried out starting from the end to the beginning of the year (Ricce *et al.*, 2014).

Rainfall data (from the monthly totals of each year) and the monthly average temperature (from the monthly averages of the daily values of each year) were extracted of the meteorological stations used for this study. Then, potential evapotranspiration (PET) was calculated according to the Thornthwaite method. First, the standard potential evapotranspiration (PET, mm/month) was calculated using the empirical formula:

$$\text{For: } 0 < Tn < 26.5\,°C \quad (2)$$

$$PET = 16\left(10\frac{Tn}{I}\right)^{a} \quad (3)$$

$$\text{For: } Tn \geq 26.5\,°CTn^{2} \quad (4)$$

$$PET = -415\ 85, + 32\ 24, Tn - 43.0\,Tn^{2} \quad (5)$$

Where Tn is the average temperature of month *n* (*n* = 1 is January, *n* = 2 is February, etc.) in °C, and I is an index that expresses the heat level of the region.

The value of I depends on the annual temperature cycle, integrating the thermal effect of each month, and is calculated using the formula:

$$I = 12(0.2\,Ta)^{1514}. \quad (6)$$

The exponent “a”, being a function of I, is also a regional thermal index, and is calculated using the expression:

$$a = 0.49239 + 1.7912 \times 10^{-2} I - 7.71 \times 10^{-5} I^2 + 6.75 \times 10^{-7} I^3. \quad (7)$$

The PET value represents the total monthly potential evapotranspiration that would occur under the thermal conditions of a standard 30 day month, and with a 12 hour photoperiod (N) each day. Therefore, PET should be corrected (COR) for N and the number of days in the period (NDP), according to the equation:

$$COR = \left(\frac{N}{12}\right)\left(\frac{NDP}{31}\right) \quad (8)$$

Three grape varieties were evaluated in this study. The risk factors selected for agroclimatic zoning of climatic risk were:

a) Rustic grapes (*Vitis labrusca* and their hybrids), intended for the consumption of fresh fruits and for processing (‘Isabel’ and ‘Niágara’). Areas with an average annual relative humidity higher than 85 %, rainfall highr than 2,000 mm and an average annual temperature below 20°C were considered unfit for presenting a high risk of diseases (Ricce *et al.*, 2014).

b) Fine table grapes (*Vitis vinifera*) or for fresh fruit consumption (‘Italy’, ‘Rubi’, ‘Benitaka’ and ‘Brazil’). Areas with an average annual rainfall higher than 1,800 mm, an average annual relative humidity greater than 75 % and an average annual temperature below 20°C were considered unfit for presenting a high risk of diseases (Ricce *et al.*, 2014).

c) Fine grapes for winemaking (*Vitis vinifera*) (‘Cabernet Sauvignon’, ‘Merlot’ and ‘Syrah’). Areas with an average annual relative humidity greater than 85 % or precipitation greater than 1,800 mm and an average annual temperature below 20°C were considered unsuitable because they present a high risk of diseases (Ricce *et al.*, 2014).

d) Annual water deficiency AWD: For the three varieties, annual water deficiency was estimated using Thornthwaite and Matter (1955), with the help of the spreadsheet developed by Rolim *et al.* (1998). The value of 50 mm was used for the available water capacity in the soil, considering that the root system of the vine explores a depth of approximately 50 cm in the soil profile (Chavarria *et al.*, 2009). For the risk of water deficiency, the following were considered: High Risk: AWD> 100 mm, and Low Risk: AWD<100 mm (Ricce *et al.*, 2014).

e) Probability of Occurrence of Frost in the month of September: Also, for the three varieties, in spring, in a generic way, the temperature of 10°C is considered as minimum that there can be vegetative development. Late frosts can harm new vines. (Ricce *et al.*, 2014). A maximum risk of 20 % of late frost per year was validated for the meteorological stations used.

For the creation of thematic maps and the final zoning map, ArcGIS software was used. Firstly, the numerical values from the meteorological stations were transformed into points, according to their geographical coordinates. We then used the edaphoclimatic requirements of the grape species to produce data spatialization, which was used for the delimitation of the representative bands of the grape climate requirements. Thus, the station values were replaced by “1. Apt” or “2. Restricted”, according to the physiological requirements for each meteorological variable analyzed.

The next step was to combine the matrix images. Each pixel was assigned with the values “1” or “2”, as already described. If the combination for a point was filled only with values “1”, the region was classified as fit. If it had a value of “2” it was restricted by a given variable. If two or more “2” values were assigned, the location was classified as unfit.

Then, standardization of the pixels using classifications was performed by dissolving the vector classes. In this way, the agroclimatic zoning classes were grouped, thus defining regions of suitability for the studied species. The final map showing the agroclimatic zoning of each crop will provide an estimate of the representative area of each risk class, ensuring its suitability for the site.

3 Results and Discussion

From the analysis of the spatial distribution of rainfall in the Paraná III River Basin and considering the maximum annual precipitation limits for the three varieties (1800 to 2000 mm), it was observed that a much of the east, southern and a small fragment of the western region exhibited rainfall above the limit values for the proliferation of diseases, as can be seen in the blue areas in Figure 2, The largest registration was 2,125 mm, in the extreme south of the region.

In general, the highest incidence of fungal diseases for the grape is associated with conditions of high relative humidity, excessive rainfall and high temperatures. Excessive rainfall can cause soil to soak and, consequently, affect root development and grape production (Nachtigal & Mazzarolo, 2008). Thus, there is a need, often, to use drainage systems (Ricce *et al.*, 2014). The main diseases linked to excessive rainfall or high humidity are downy mildew and bunch rot, which are harmful to the production and ripening of grapes (Nachtigal & Mazzarolo, 2008). While the lack of rain can impair the development of the plant and, in more serious situations, prevent production if there is no irrigation. In regions where there is a large water deficit for the grapevine, there is a need, normally, recommend for farmers to use irrigation (Zanus & Mandelli, 2004).

The water requirement of the species for the region was also assessed by the water balance (Figure 4). It was identified that the municipality of Cascavel, São Miguel do Iguaçu and Toledo do not exhibit water deficiency, while Assis Chateabreand only 1.2 mm in the month of March. In municipality of Foz Iguaçu and Guaíra, the water deficiency in the month of March exhibit significant values, being 22 mm and 37 mm, respectively. The replacement in Guairá is completed only in the month of May.

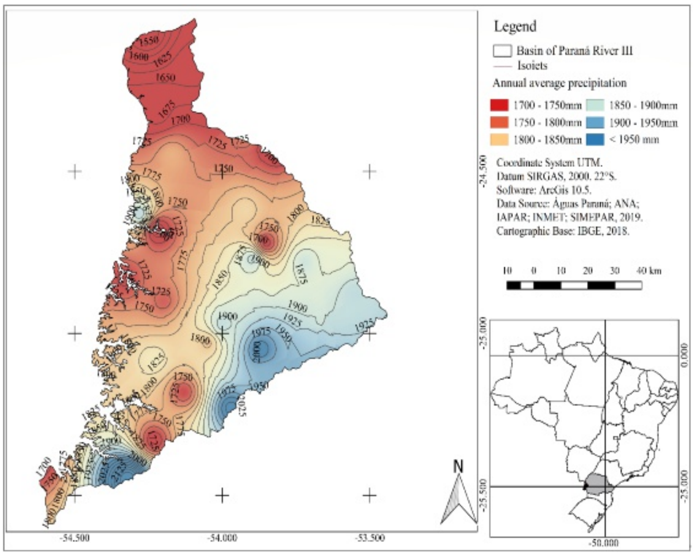

Figure 3. Annual rainfall average in the hydrographic basin of Paraná River III. Source: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Organization: The authors (2019).

Figura 3. Média de precipitação anual na bacia hidrográfica do Rio Paraná III. Fonte: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Elaboração: Os autores (2019).

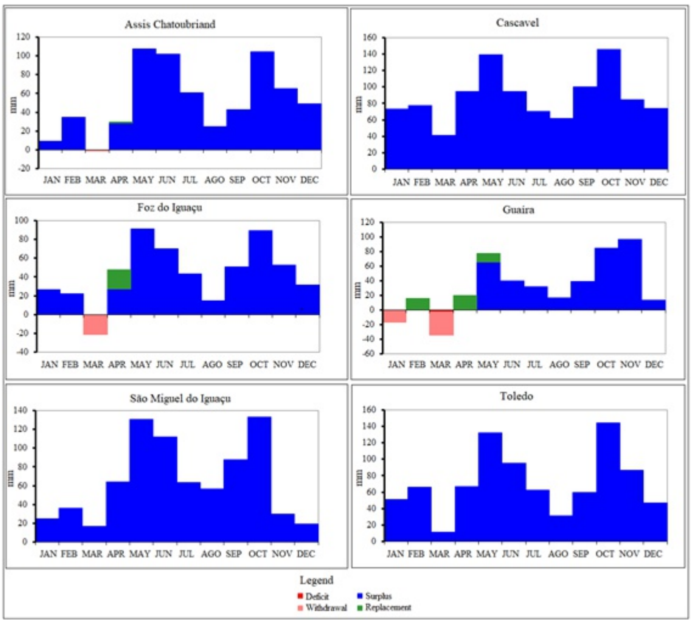

Figure 4. Annual Water balance for grape in the hydrographic basin of Paraná River III. Source: ANA; Instituto das Águas Paraná; INMET; IAPAR (2019). Organization: The authors (2019).

Figura 4. Balanço de água para uva na bacia hidrográfica do Rio Paraná III. Fonte: ANA; Instituto das Águas Paraná; INMET; IAPAR (2019). Elaboração: Os autores (2019).

As the risk assessed was accumulated 100 mm per year for water deficiency for grape, no season exhibits a risk for the grape cultivation. In municipality of Guaíra, that indicates the higher value of water deficiency, the accumulated was 56 mm. As the species has deeper roots, the plant is able to extract water from deeper areas from the soil (Ricce *et al.*, 2014). The extracts less favorable, according to the water balance, is in the months from January to April, thanks to high temperatures and increased evapotranspiration. AWD in these months was not a restrictive factor for the implantation of the grape in the region, however, the farmer must plan the cultivation to avoid droughts periods.

The average temperature for the development of the three grape varieties analyzed was below 20°C. Each phenological vegetative period has a different base temperature, that is: sprouting, 10°C; vegetative development, 12°C; maturation, 14 ° C; and, budding-maturation, 12°C. However, for the entire cycle, the value used is 10°C. In general, grape requires, for its growth and development, increasing temperatures from 10 °C to 30°C.Temperatures below 10°C do not allow growth, and above 38° C, paralyze it (Mandelli *et al.*, 2009).

None of the regions in the basin of Paraná River III exhibited presented average annual temperatures below 20°C (Figure 5). The coldest portion, in the limit area to the east of the basin, exhibits values around 20.5°C, while in the western portion the values are higher than 23°C.

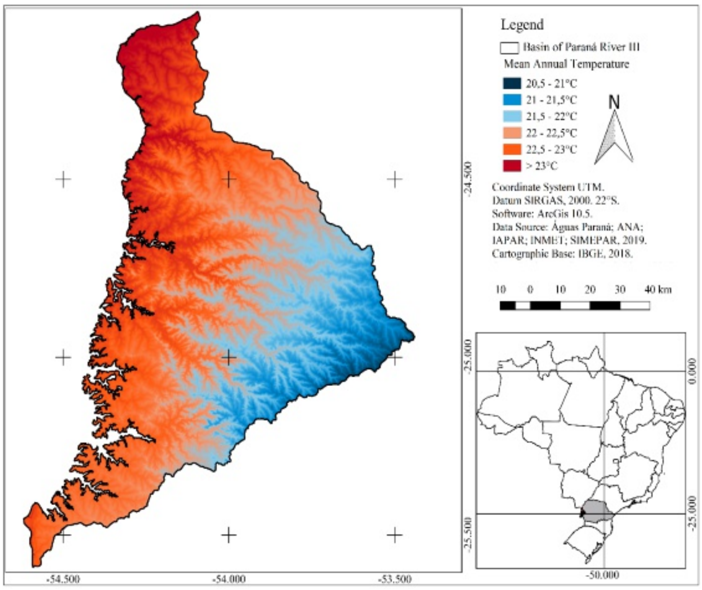

Figure 5. Annual average temperature in the hydrographic basin of Paraná River III. Source: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Organization: The authors (2019).

Figura 5. Temperatura média anual na bacia hidrográfica do Rio Paraná III. Source: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Elaboração: Os autores (2019).

Agricultural practices are indicated to prevent the spread of fungal diseases. Seed with considerable genetic Quality and come from certificated producers must be purchased. Sustainable agronomic practices are also relevant, such as the use of bordeaux mixture to avoid the fungi action; destroy infected cultural remains; perform green pruning, for better aeration of the plant.

Leaf wetness is the factor that most influences the development of fungal diseases. For grape diseases, except for powdery mildew, the longer the leaf wetness, the greater the severity of the diseases. Temperature accelerates or delays the development of epidemics. The average annual relative humidity indicated for the development of the grape varieties analyzed varied from 75 %, for the most sensitive to the spread of diseases, there is 85 % (Nachtigal & Mazzarolo, 2008), The analysis of relative humidity for the region can be seen in Figure 6.

There were no restrictions for rustic grapes and fine grapes for viticulture. The highest humidity values were in the municipality of Foz do Iguaçu with 80 % southern part of the basin (Figure 6). However, this value is already restricted to fine table grapes, and the variety analyzed is more sensitive and may present a high risk for the spread of the disease.

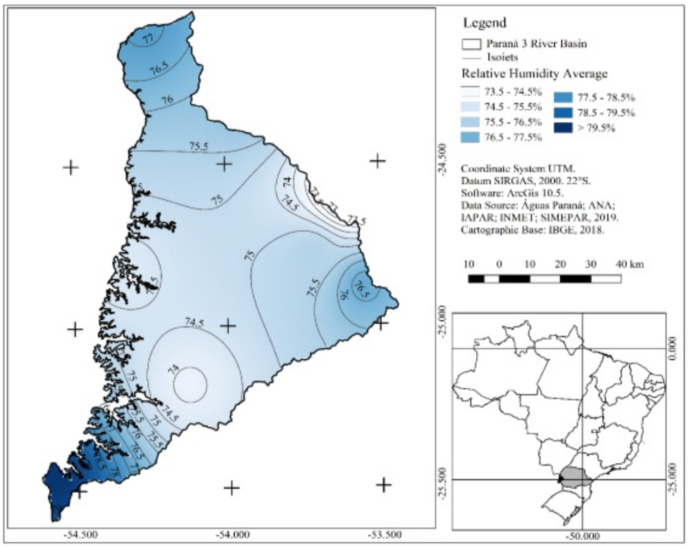

Figure 6. Annual average Relative Humidity in the basin of Paraná River III. Source: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Organization: The authors (2019).

Figura 6. Umidade Relativa média anual na bacia do Rio Paraná III. Source: ANA; Águas Paraná; IAPAR; INMET; SIMEPAR (2019). Elaboração: Os autores (2019).

Frosts (Figure 7) that occur when the grape is dormant are beneficial, because the low temperatures in winter contribute to breaking dormancy of the buds, they improve the sprouting of the grape and the maturation of the branches, also eliminating some parasites (Mandelli *et al.*, 2009). Once the buds are opened, the occurrence of frosts becomes extremely harmful, as it can cause serious damage to plants and serious economic damage to winegrowers. At the beginning of bud swelling, the vine can resist up to -3.5°C (Fachinello *et al.*, 2011; Back *et al.*, 2012).

Frosts can cause serious damage, especially during the period of the development of the grape. Usually, late frosts at the end of winter / early spring are the most damaging, as they “burn” the vegetation, which can compromise the total or partial production of grapes from one season and even affect the next season. Irrigation systems can also be used to protect the crop from frost (Mandelli *et al.*, 2009).

A significant risk of frost (Figure 7) was identified at the municipalities of Toledo and Cascavel, in this first one, the risk of frost in the 2nd and 3rd of July reaches 30 %, the high risk also stands out in the first ten-month period of June. While in Cascavel the only ten-year period with a risk higher than 20 % was July 3rd. In these periods, the occurrence of frost does not pose a risk to the vine culture. The same ten-year period keeps the risk high at the Santa Helena and Foz do Iguaçu stations. In the other seasons, the frost-free period can be seen in Table 01.

As noted, late frost can occur in the basin, with an emphasis on the eastern portion at the end of the winter season, in ten days in Cascavel, and 2 in Toledo. As the risk of occurrence is low, it does not guarantee disability. Sprinkler irrigation systems can be used to protect the crop against frost, in areas at risk, another recommended management practice is late pruning every year, in other areas pruning is recommended during the grapevine resting period (Nachtigal *et al.*, 2009).

In the final map of the agroclimatic risk zoning of the grapevine (Figure 8), it can be seen that the fine grape species for vinification and rustic grapes exhibited suitability in the basin, the only measure to be taken is in the protection against late frost.

For the fine table grapes, three areas were unfit for cultivation, due to the combination of high average rainfall and average annual relative humidity above the recommended, which may favor the proliferation of fungal disease.

Among the three species analyzed, this is the most sensitive (fine table grapes), requiring a maximum relative humidity of 75 %, thus presenting a smaller area suitable for production, as also identified by Ricce *et al.* (2014). The regions delimited as unfit aresimilar, only the western portion, in the municipality of Pato Bragado, was not highlighted as unfit, and the eastern portion showed greater abstraction, due to the zoning in a larger area, that is possible be observed, when analyzed in smaller areas, such as a microbasin or mesoregion.

In temperate regions, planting should be done in winter – July or August - delaying the maximum in places subject to frost. In tropical regions, planting in the months of October to December - rainy months - should be preferred, avoiding the unnecessary use of water for irrigation (Nachtigal *et al.*, 2009).

For the Piauí State, Brazil, Andrade Júnior *et al.* (2009), zoned the grape by connecting the agrometeorological information of the variability of the annual index of Thornthwaite & Mather (1955) and the

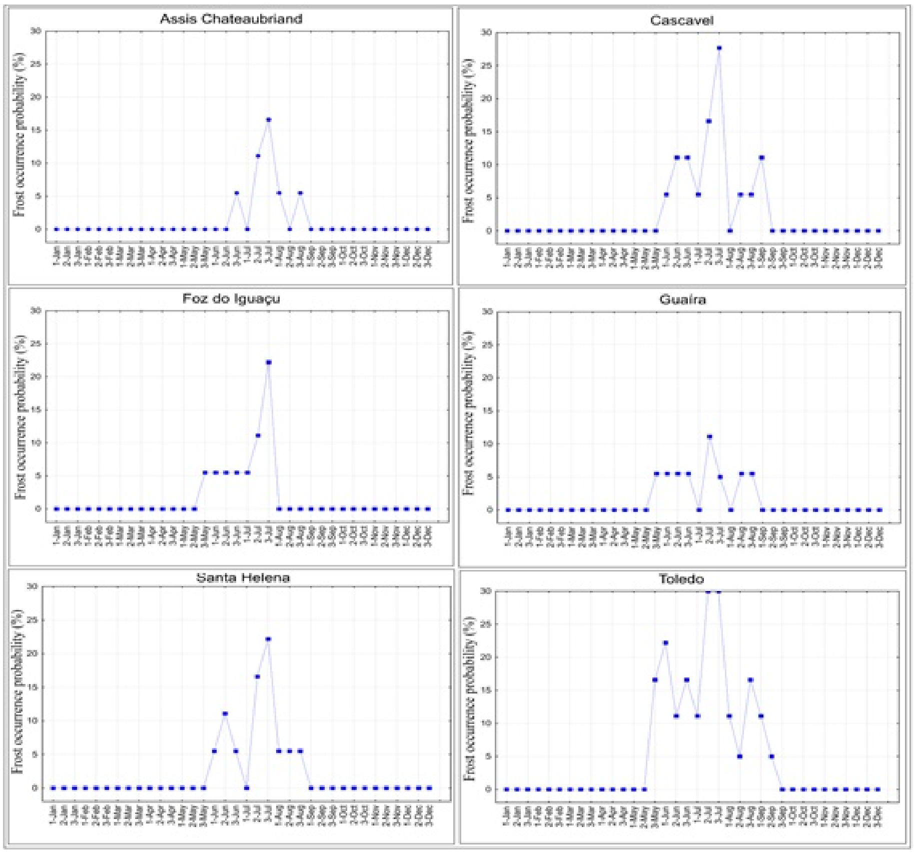

Figure 7. Annual Probabilities of frost occurrences in the basin of Paraná River III.

Figura 7. Probabilidade de ocorrência de geada na bacia hidrográfica do Rio Paraná III.

temperature. Being different from Paraná State, the restriction was due by the water balance.

Medeiros *et al.* (2017) also elaborate the zoning for the grape, however in the Paraíba State. Just like Andrade Júnior *et al.* (2009) used data resources on soil index and temperature to determine zoning. Species are restricted for these areas, especially because the spreading diseases.

Table 01. Periods with no frosts occurrences in the basin of Paraná River III.

Tabela 01. Períodos sem ocorrências de geada na bacia do Rio Paraná III.

Weather Stations Location	Periods without frost registrations
Assis Chateaubriand	First frost: 2-jun Last frost: 3-ago
Cascavel	First frost: 3-mai Last frost: 1-set
Foz do Iguaçu	First frost: 2-mai Last frost: 3-jul
Guaíra	First frost: 2-mai Last frost: 3-ago
Santa Helena	First frost: 3-mai Last frost: 3-ago
Toledo	First frost: 2-mai Last frost: 2-set

It should be noted that zoning does not eliminate the risks, however, only exhibits more favorable climate conditions for the development of the three species of grape commonly found in Brazilian market. As agriculture is a risky activity, all activities are susceptible to extreme events, that could or could not cause harm for the farmer. In the context of climate change and

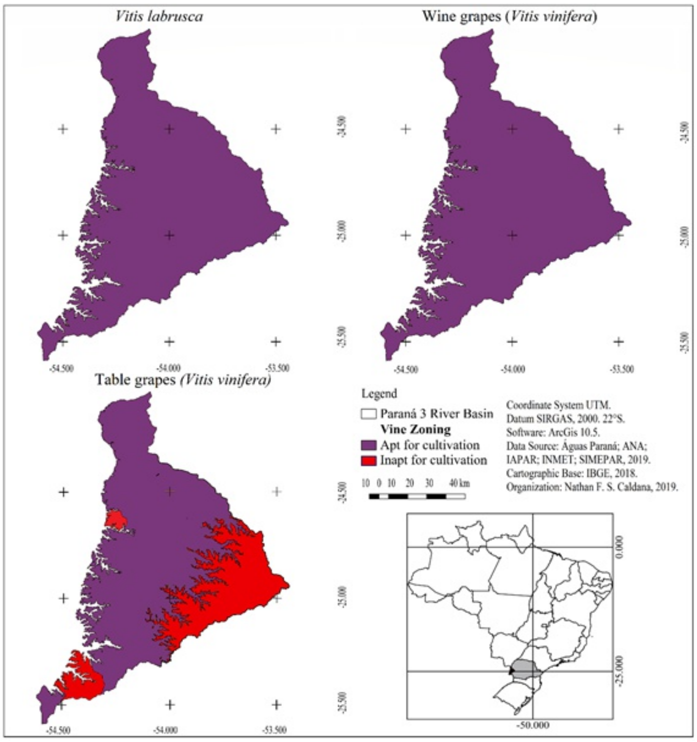

Figure 8. Agroclimatic risk zoning of grape in the hydrographic basin of Paraná River III. Source: ANA; Instituto das Águas Paraná; INMET; IAPAR (2019).

Figura 8. Zoneamento de risco agroclimático para a uva na bacia hidrográfica do Rio Paraná III. Fonte: ANA; Instituto das Águas Paraná; INMET; IAPAR (2009).

conservationist agriculture, agroclimatic zoning provides a significant security in decision-making, agricultural planning.

4 Conclusion

The basin of Paraná River III has regions with low climatic risk for the cultivation of the grapevine, mainly for the varieties of rustic grapes, with the ability to plant throughout the basin.

The water balance exhibited sufficient values in all regions studied. Only in the summer months in some locations was a water deficit, however it does not restrict grape production.

The most limiting factor for production, in part of the basin is the of relative humidity, which may favor to the proliferation of fungal diseases. Restricting production in the eastern portion of the basin, and in the areas of the municipalities of Pato Bragado and São Miguel do Iguaçu. In addition to the influence of temperature for the region.

The risk of later frost, that can cause serious damage to production, proved to be limiting only in the eastern end of the region, however, because the risk was low, it was not inaptitude for this variable. For these areas, agricultural management techniques can also be taken to avoid the risk of frost, such as putting forward planting for the month of July and performing late pruning.

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