CLIMATE APPROACH FOR CLASSIFICATION OF THE SUGARCANE PRODUCTION ENVIRONMENTS IN THE STATE OF SÃO PAULO, BRAZIL

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ABSTRACT: Nowadays the sugarcane production environments concept is based only on the soil quality information, disregarding the climate effects on the yield. Therefore the aim of this study was to propose a climate classification for sugarcane production environments based in climate efficiency (CE) and attainable yield (AY) for improving the current classification of those environments. It was selected some traditional and expanding sugarcane regions at State of São Paulo for applying the method and compare the current classification, based only in soil characteristics, and the integrated concept soil-climate classification, considering CE and AY, estimated by FAO yield model. The proposed climate classification had seven levels for both CE and AY. The proposed method for improving the current sugarcane production environments classification allowed to obtain more detailed information about the relationship between the crop and the climate characteristics in each production environment, allowing to have a better characterization of the yield limiting factors in sugarcane at State of São Paulo.
KEY WORDS: production environments, sugarcane, climate efficiency, actual yields.

ABORDAGEM CLIMÁTICA PARA A DEFINIÇÃO DOS AMBIENTES DE PRODUÇÃO DA CANA-DE-AÇÚCAR NO ESTADO DE SÃO PAULO, BRASIL

RESUMO: Atualmente os ambientes de produção da cana-de-açúcar consideram apenas as características intrínsecas à qualidade de solos, desconsiderando os efeitos climáticos na produtividade. Portanto, o objetivo deste trabalho foi propor uma classificação climática desses ambientes de produção baseada na eficiência climática (CE) e na produtividade atingível (AY) para refinar a classificação desses ambientes. Foram selecionadas regiões tradicionais e de expansão da cultura da cana-de-açúcar de modo a comparar a classificação vigente, baseada apenas nas características do solo, com a classificação baseada no conceito de integração das informações de solo e clima, considerando-se a CE e a AY, estimadas por meio do modelo de produtividade da FAO. A classificação proposta é dividida em sete níveis em termos de CE and AY. O método de classificação dos ambientes com base no clima e no solo permitiu obter informações mais detalhadas sobre a relação entre a cultura da cana e o

clima de cada ambiente de produção permitindo se obter uma melhor classificação dos fatores limitantes para a cana-de-açúcar no estado de São Paulo.
PALAVRAS-CHAVE: ambientes de produção, cana-de-açúcar, eficiência climática, produtividade real.

INTRODUCTION

Nowadays the sugarcane production environments concept is based only on soil quality information (water availability, chemical composition, soil natural fertility in the arable soil layer and structure) and average yield from the last five harvesting years, not showing, however, aspects correlated with the climate of the region (PRADO, 2011). The classification of the sugarcane production environments was made considering the mentioned soil characteristics and the average sugarcane yield, ranging from A1 and A2 for the best to E1 and E2 for the worst environments. From this method and considering the average sugarcane yield in the Brazil South-Center region, the classification proposed by Prado (2011) ranges from 100 Mg ha^{-1} in the A1 environment to 68 Mg ha^{-1} to E2 environment. However, this method does not consider the several possible combinations between soil characteristics and climate conditions, which in fact lead to the final sugarcane yield level. It means that an A1 environment can present a sugarcane yield of 70 Mg ha^{-1} if in a restrictive climate.

The best way to insert the climate characteristics in the production environments classification is through the yield estimated by crop simulation models, as the one suggested by Doorenbos and Kassam (1979), which allows to estimate potential (PY) and attainable (AY) yields and the climate efficiency (CE = AY/PY) from the relationship between soil-crop-climate characteristics, which linked to a geographic information system (GIS) will make possible to obtain the spatial distribution of climate environments production.

Therefore, the aim of this study was to propose a climate classification for sugarcane production environments based on CE and AY for improving the current classification of those environments, which are based only in soil characteristics, and support the differences between expected and actual yields in the State of São Paulo, Brazil.

MATERIAL AND METHODS

Some traditional and expanding sugarcane regions in the State of São Paulo were chosen for applying the method propose in this study and compare with expected yield levels proposed by Prado (2011) for sugarcane production environments, based only on soil characteristics. The selected regions are presented in Figure 1.

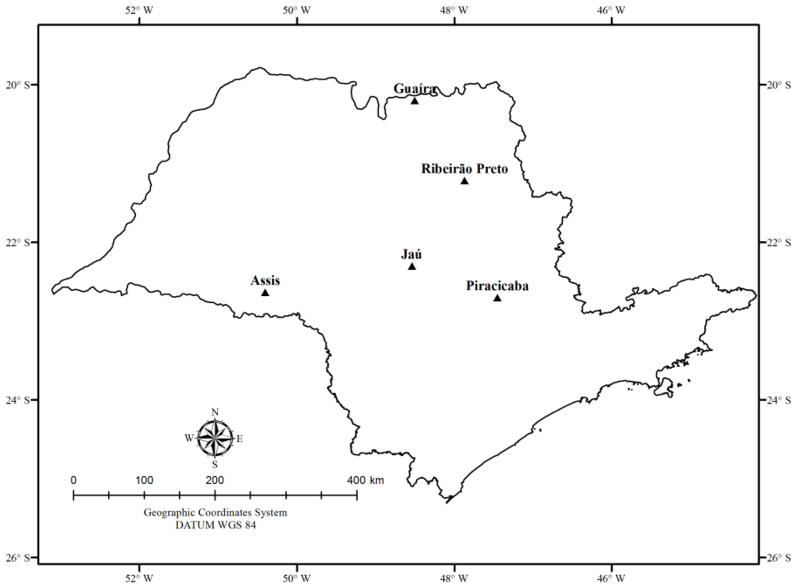

Figure 1 – Spatial distribution of main sugarcane regions in the State of São Paulo, Brazil.

From those regions, were collected information about soil type, observed and expected yields (PRADO, 2011) and annual water deficit (Table 1).

Table 1 – Soil classification according to the Brazilian Soil Classification System (BSCS - EMBRAPA, 2006), sugarcane actual yields and average expected yield levels (Mg ha^{-1}) and annual water deficit (mm $year^{-1}$) according to current production environments classification (PE), based on soil characteristics in some traditional regions at State of São Paulo, Brazil:

Region	Soil Type (in Portuguese)	Reference soil classification	Actual Yield*	Expected Yield and PE (Prado, 2011)	Water Deficit
Ribeirão Preto	Nitossolo	Cuadra et al. (2012)	80	> 100 (A1)	292
Jaú	Argissolo Eutrófico	Gava et al. (2009)	85	98 (A2)	279
Piracicaba	Latossolo Vermelho distrófico	BSCS (2006)	95	< 68 (E2)	290
Assis	Nitossolo	BSCS (2006)	105	> 100 (A1)	186
Guaíra	Latossolo Vermelho acriférrico	Aratani et al. (2009)	65	< 68 (E2)	372

* Average yield of the region according to Brazilian Institute of Geographic and Statistics (IBGE)

Using the FAO model (DOORENBOS; KASSAM, 1979), the potential yield (PY) and the actual yield (AY) were calculated, allowing to estimate the climate efficiency (CE = AY/PY). The first step required by this model was to calculate the potential yield (PY) as a function of extraterrestrial solar radiation (MJ m^{-2} day^{-1}), air temperature (°C), sunshine hours and photoperiod. The next step was to estimate the actual yield (AY), which consider basically the relationship between yield break (1 – PY/AY) and relative water deficit (1 – ETr/ETc), that were weighted by a sensitive water deficit factor (ky) in each crop phenological phase. ETr is the crop evapotranspiration calculated by crop water balance and ETc is the maximum crop evapotranspiration, which was calculated by the product between reference evapotranspiration

(Priestley and Taylor method) and crop coefficient (kc). All data used for these calculations can be found in Monteiro (2012).

Climate efficiency (CE) is a dimensionless index which was calculated by the ratio between AY, considering rainfed conditions, and PY, obtained when considering the best crop management, without any kind of stress. Thus, it was possible evaluate the water deficit impact on the yield of each region through CE (AY/PY), that expresses the maximum percentage of the PY that a production unit could get disregarding reduction factors related to crop management. Another way to evaluate the climate production environments is using AY data, which integrates all the factors that influence sugarcane production.

The AY and CE obtained from the crop yield simulation model were compared with the current production environments, based on soil characteristics, in order to show that the same soil type in different regions can present different expected yield, which is basically controlled by climate conditions. To prove that, case studies were simulated in two ways in order to evaluate the same soil type in different regions and to show that even being an environment with restrictive soil characteristics, the climate conditions can allow satisfactory yield levels, showing a compensatory factor.

RESULTS AND DISCUSSION

According to FAO model, the AY and CE were calculated for locations considered in this study. Table 2 presents the proposed climate classification in terms of AY and CE which were considered as a range of 10 Mg ha^{-1} and 0.5 between levels, respectively. The environment classifications consider that the greater the number of classification in terms of AY and CE, more restrictive is the environment.

Table 2 – Climate classification of production environments according with actual yield (Mg ha^{-1}) and climate efficiency at São Paulo State, Brazil.

Climate Environments			
Environment	Actual Yield	Environment	Climate Efficiency
P1	101 – 110	CE1	0.61 – 0.65
P2	91 – 100	CE2	0.56 – 0.60
P3	81 – 90	CE3	0.51 – 0.55
P4	71 – 80	CE4	0.46 – 0.50
P5	61 – 70	CE5	0.41 – 0.45
P6	51 – 60	CE6	0.35 – 0.40
P7	< 50	CE7	< 0.35

According to Table 2, the climate classification in Ribeirão Preto is P3-CE5, in Jaú is P3-CE4, in Piracicaba is P2-CE4, in Assis is P1-CE1 and in Guaíra is P5-CE7. Using these information, we evaluated both situation, i.e., the first way was considering the same soil type in different locations: although at regions of Ribeirão Preto and Assis have the same soil type (Nitossolo), there is a yield gap between these regions once the climate characteristics become a limiting factor in Ribeirão Preto to obtain high AY. In Assis, the soil and climate characteristics allow to obtain high sugarcane yields. By this approach, the production environment classification proposed by Prado (2011) will require climate information to explain the yield difference between locations because the soil classification does not consider

effectively the climate effect on yield. The water deficit in Ribeirão Preto is 100 mm $year^{-1}$ higher than the one observed in Assis, which is the main reason for the differences observed.
The other approach is considering the compensatory effect of climate characteristics on production environments classification. Although Piracicaba represents a reasonable climate classification, that allows obtaining a satisfactory yield levels (P2-CE4), the representative soil is classified as Latossolo Vermelho distrófico, resulting in a low expected yield, according to the current production environments classification (68 Mg ha^{-1}, E2). On the other hand, even the region of Jaú presenting a great soil classification (Argissolo eutrófico) in which are expected sugarcane yield levels around 98 Mg ha^{-1} according to Prado (2011), the climate classification (P3-CE4) in that region are more limited when compared to Piracicaba. Thus, although the soil characteristics in Piracicaba are not so appropriated for obtaining high yields such as in Jaú, the climate characteristics allowed to achieve similar sugarcane yield levels, proportioning a compensatory effect.
Comparing Guaíra (P5-CE7) and Piracicaba (P2-CE4), it is important to consider the climate characteristics because these regions represent similar soil type. On the other hand, in Guaíra the average water deficit is higher than Piracicaba about 100 mm $year^{-1}$, reflecting in low yield levels in Guaíra, not being possible compare these environments only in terms of soil characteristics, disregarding the climate conditions.

CONCLUSIONS

The proposed method for improving the current sugarcane production environments classification allowed to obtain more detailed information about the relationship between the crop and the climate characteristics in each production environment, allowing to have a better characterization of the yield limiting factors in sugarcane at State of São Paulo.

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