Influence of the type of ANN algorithm on prediction of georeferenced sugarcane quality

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Abstract.

Optimizing crop quality and yield is critical to the development of more sustainable agriculture on large scale. Predictive models can provide assessment of those attributes prior to harvesting using techniques of artificial intelligence to support site-specific management. The objective was to investigate the influence of ANN (Artificial Neural Network) algorithms on prediction of sugarcane quality. Brix content of sugarcane, variety CTC 2994 on second ratoon, was measured in laboratory using samples of sugarcane juice from development to maturation crop stages. The samples were obtained from regular grid of 40 m x 40 m from one commercial sugarcane field of 10 ha during the 2025 season in São Paulo state, Brazil. The multispectral imagery from satellite, with spatial resolution of 3.0 m, was selected in the same period of collected samples. Spectral bands and vegetation indexes were pre-selected before using them as inputs on modeling. The most relevant variables considering satellite imagery were GNDVI, blue and near-infrared bands. The weather data was generated by an automatic station around 11 km from the field. It was considered daily variables according to the same period of data collection in the field. Global solar radiation was the most relevant input variable among weather data. The dataset from selected multispectral imagery and weather data was normalized, split into 70:30 for train and test, and submitted in ANN by means of *neuralnet* package (version 1.44.2) in R (version 3.6.0+). The comparison of the algorithms backprop, *rprop+, rprop-, sag, and slr* was investigated according to the error of prediction related to R^2, RMSE (Root Mean Square Error), MAPE (Mean Absolute Percentage Error), and MAE (Mean Absolute Error). The learning rate was set as 0.01 on *backprop* algorithm of ANN. The prediction of Brix content based on *sag* algorithm achieved R^2=0.54 and its RMSE, MAE, MAPE corresponded to 0.15, 0.11, and 0.23%, respectively. So, this algorithm of ANN is the most indicated to predict sugarcane Brix due to the greater accuracy and minor error of prediction for the conditions of the study. The investigated influence of ANN algorithm on performance of sugarcane quality prediction can support further development of artificial intelligence architectures according to the farming conditions. This information, derived from data driven approach, can enhance agricultural practices according to the early mapping of the spatial variability of sugarcane ripeness using non-destructive assessments.

Keywords.

Artificial neural networks, crop modeling, data fusion, multispectral imagery.

Introduction

Industrial processing efficiency of sugarcane is dependent, among other factors, of saccharose accumulation by the plants during the crop cycle. Georeferenced data collection has enabled the spatial and temporal monitoring of patterns associated with characteristics of the plants, allowing growers and suppliers to better understand the variability of sugarcane quality within the fields.

Sugarcane quality is influenced by several factors, such as agronomic and environmental, including soil fertility, weather conditions, and farming practices. Soluble solids content (°Brix), fiber percentage, purity, and recoverable sugar parameters are commonly used to assess crop quality (Barbosa Júnior et al. 2023). However, the conventional methods of sampling those parameters make approaches of prediction modeling challenging. In this context, machine learning techniques, particularly Artificial Neural Networks (ANNs), have emerged as an alternative for modeling nonlinear relationships among crop attributes and handling complex agricultural datasets. The objective was to investigate the influence of ANN algorithms on prediction of sugarcane quality.

Materials and Methods

The methodology involves integrating multispectral and meteorological data with the qualitative attributes of sugarcane as an alternative to increase the robustness of the dataset and crop modeling. Meteorological data of relative air humidity, precipitation, global solar radiation, maximum and minimum temperatures were selected considering the same dates as the field data collection. The Davis Instruments automatic weather station recorded those data daily, which was located approximately 11 km from the field (21°10'41.79"S; 48°17'0.74"W; elevation of 558 m). GDD (development degree-days) variable was calculated from the maximum and minimum air temperatures, considering a baseline temperature of 18 °C.

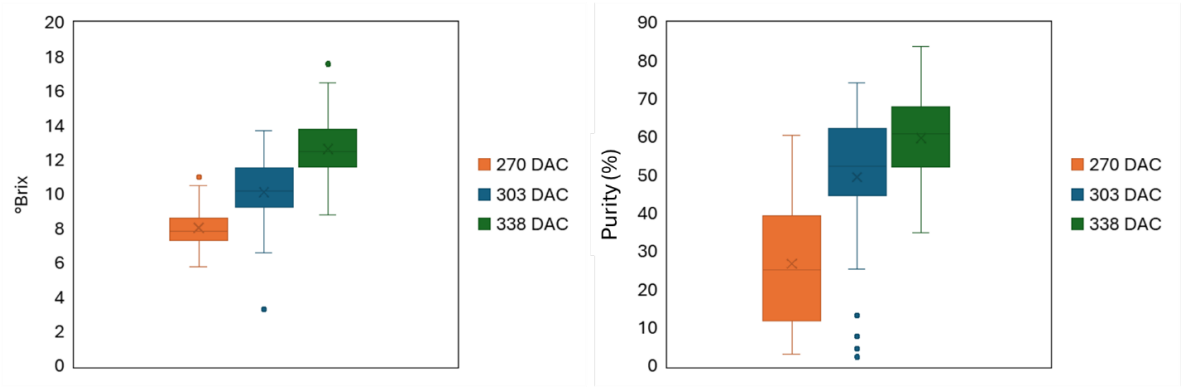
The multispectral imagery was obtained from nanosatellites of PlanetScope considering the same period of data collection, and vegetation index maps (NDVI, GNDVI, WDRVI and CIVE) were generated by normalizing the reflectance values of each spectral band. Geoprocessing of multispectral imagery was performed using Geographic Information System (GIS) - QGIS version 3.34.15 - and RStudio version 2024.12.0+467. All data layers were standardized to the local projection EPSG 32722/UTM 22S. Brix and Purity values were calculated from sampling of sugarcane stalks using regular grid of 40 m x 40 m in the field of, approximately, 10 ha with the crop variety CTC 2994 of second ratoon implemented. Each georeferenced sample was composed of grouping four stalks from central rows and identified according to the grid maps. Brix, Pol, and Purity analyses of sugarcane were performed in laboratory considering a total of 88 georeferenced samples. The sampling points were interpolated using IDW (Inverse Distance Weighted) method with spatial resolution of 1.50 m due to interrow spacing.

The integrated dataset was normalized, split into 70:30 for train and test, and submitted in ANN algorithm by means of *neuralnet* package version 1.44.2 (Fritsch et al. 2019) in R version 3.6.0+. The comparison of the algorithms *backprop*, *rprop*+, *rprop*-, *sag*, and *slr* was investigated according to the error of prediction related to accuracy (R^2), RMSE (Root Mean Square Error), MAPE (Mean Absolute Percentage Error), and MAE (Mean Absolute Error). The learning rate was set as 0.01 on *backprop* algorithm of ANN due to the time required for data processing.

Results and Discussion

The descriptive statistics of the sampling points demonstrated that there was greater dispersion of Purity values at 270 DAC (Figure 1b) compared to the other evaluated periods. It means that there was spatial and temporal variability on qualitative attributes of sugarcane at the field scale. According to the distribution of values, these attributes did not present ideal conditions for harvesting, even though under the period of crop maturation (338 DAC), considering that Brix values were below 18°; and Purity was below 85%. It can cause loss of raw material to the industry of sugarcane. The water stress condition of the plants during the crop development cycle should

be considered to explain the reduced saccharose content due to the precipitation values recorded by the weather station - mean values of precipitation were 0.50 mm at 303 DAC. The best performance for Brix and Purity prediction was achieved by means of *sag* and *prop+* algorithms, respectively, with R^2=0.54 and RMSE=0.15 °Brix; and R^2=0.36 and RMSE=0.23% (Table 1)



(**a**) (**b**)

Fig 1. Values of Brix (**a**) and Purity (**b**) of sugarcane as function of days after cutting (DAC)

Table 1. Performance metrics of predictive modeling by type of algorithm and sugarcane attributes

Type of algorithm	Attributes	RMSE	MAE	MAPE	R^2
Prop-	°Brix	0,15	0,12	0,24	0,50
	Purity (%)	0,29	0,21	0,48	0,12
Prop+	°Brix	0,16	0,13	0,30	0,42
	Purity (%)	**0,23**	0,18	0,36	**0,36**
Backprop	°Brix	0,54	0,50	0,50	0,08
	Purity (%)	0,62	0,55	-	0,14
Sag	°Brix	**0,15**	0,11	0,23	**0,54**
	Purity (%)	0,28	0,21	0,47	0,16
Slr	°Brix	0,15	0,12	0,24	0,51
	Purity (%)	0,23	0,18	0,37	0,33

RMSE: Root Mean Square Error; MAPE: Mean Absolute Percentage Error; MAE: Mean Absolute Error. Bold number represents the best accuracy of predictions

Conclusion

The best performance of prediction of Brix and Purity contents by ANN was based on *sag* and *prop+* algorithms for the conditions of the study. Spatial and temporal variability of qualitative attributes of sugarcane were observed, indicating the potential adoption of precision agriculture for crop mapping and management of crop ripeness under tropical conditions. It demonstrated the influence of ANN algorithm on performance of georeferenced sugarcane quality prediction for further development of artificial intelligence architectures under different field conditions.

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