SUGARCANE *(SACCHARUM OFFICINARUM L.)* YIELD FORECASTING USING DECISION SUPPORT SYSTEM FOR AGROTECHNOLOGY TRANSFER (DSSAT)-CANEGRO: A MODEL CALIBRATION AND VALIDATION IN ISABELA, PHILIPPINES

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DOI: https://doi.org/10.54476/ioer-imrj/612693

ABSTRACT

Agricultural simulation models have become increasingly vital in modern agricultural production due to their wide range of applications. To fully harness their potential in predicting crop growth and yield under specific agro-climatic conditions, local calibration and validation are essential. This paper explores the use of the Decision Support System for Agrotechnology Transfer (DSSAT)-CANEGRO model as a tool to enhance and streamline sugarcane yield estimation within the agro-climatic context of the Isabela Mill District. The genetic coefficients of the Phil 99-1793 variety were calibrated using local agronomic, weather, and soil data from the Isabela State University Research and Development Station. Model validation was subsequently conducted across five field sites in Echague, Isabela, for two cropping seasons: newly planted fields (2023-2024) and first ratoon fields (2024-2025). Calibration results showed strong agreement between observed and simulated data, with R^2= 0.92, RMSE= 0.35m, d=0.85 for stalk height, and R^2= 0.81, RMSE= 8.72 TC ha^{-1}, and d=0.89 for fresh cane yield. Validation for newly planted fields produced satisfactory predictive performance (R^2= 0.83, RMSE= 9.8 TC ha^{-1}, d=0.89). These results highlighted that the DSSAT-CANEGRO model is reliable for estimating sugarcane yield for newly planted fields in the district under normal growing conditions. However, its ability to simulate yields affected by extreme weather events remains limited due to the absence of submodules that can capture typhoon-induced damage, leading to significant overestimations during the 2024-2025 cropping year.

Keywords: Genetic Coefficients, Phil 99-1793, Pooled Validation, Model Performance, Yield Simulation

INTRODUCTION

Sugarcane *(Saccharum officinarum L.)* is a prominent crop widely cultivated and considered a major source of sugar and bioethanol in tropical and subtropical regions. In the Philippines, sugar is one of the country's key export commodities, with the United States being its largest importer. The total production of sugar reached $700 million in 2019, making it the 5th largest agricultural crop product by value, following rice, bananas, corn, and coconut (Dina Padilla-Fernandez et al., 2022).

Sugarcane production is complex, as yield level is influenced by multiple interacting factors, such as genotype, environmental conditions, and crop management practices (Dias & Sentelhas, 2017). The sugarcane plant is vulnerable to drought, and it was considered a major threat to sugarcane production (Reyes et al. 2021), especially when it occurs during the stem elongation phase, because at this stage the sugarcane crop demands the maximum Crop Water Requirement (CWR) and Irrigation Water Requirement (IWR) (Qin et al., 2023). In recent years, the Philippines experienced prolonged drought attributed to El Niño, which caused severe and costly damage to the sugarcane industry throughout the country. The Sugar Regulatory Administration (SRA) has reported that the drought has caused P215,700,114 worth of damage to sugar and molasses in Western Visayas and P200,178,856 in Negros Occidental (Adiong, 2024).

Given these challenges attributed to climate change, the use of DSSAT software offers a potential solution, as it contains modules to simulate the impact of climate-related events on sugarcane growth and development, forecast yield under future climate scenarios, and evaluate adaptation controls to mitigate this impact (Alejo et al.,2016; Abayechaw, 2021).

. The CANEGRO model embedded in the DSSAT software is one of the crop simulation models that have been implemented in research and development of sugarcane crop (Singels et al., 2008). This model utilizes daily weather data, specific genetic coefficients corresponding to the variety, soil, and management practices related to crop development and growth, to simulate sugarcane development (Singels et al., 2010; Dias and Sentelhas, 2017; Godinho et al., 2020). Nevertheless, in order to ensure that the model produces credible simulation output, it has to be calibrated under local agro-climatic conditions (Dias and Sentelhas, 2017).

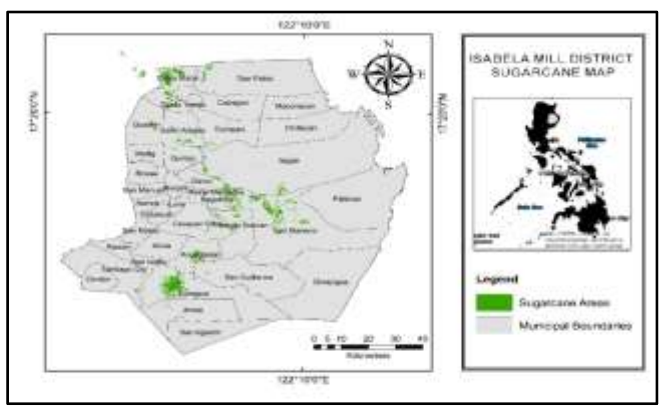
OBJECTIVES OF THE STUDY

This study generally aimed to localize the DSSAT-CANEGRO model and evaluate its performance in forecasting sugarcane yield in the Isabela Mill District. Specifically, it aims to: (1) calibrate the DSSAT-CANEGRO model using agronomic data of Phil 99-1793 sugarcane high yielding variety; (2) evaluate the model's yield forecasting performance for newly planted fields during the 2023-2024 cropping year; (3) for first ratoon fields during the 2024-2025 cropping year; and (4) assess the accuracy and reliability of the model under the agro-climatic conditions of Isabela Mill District.

MATERIALS AND METHODS

The Study Area

The province of Isabela is located at 17˚N; 122˚E, in the northeastern part of Luzon, bounded by the provinces of Cagayan, Kalinga, Ifugao, Nueva Vizcaya, Quirino, and Aurora. Based on the modified Coronas' Climate Classification in the Philippines, the province of Isabela is under Type III climate, with frequent rainfall for the month of May to October, with an average rainfall of 2,000 mm annually (Alejo et al.,2016). Figure 1 illustrates the geographical location of sugarcane production areas in the province of Isabela.



Source: SRA-Isabela Mill District sugarcane map
Figure 1: Sugarcane map of the Study Area

Model calibration and validation framework

The model was calibrated using the agronomic data of the Phil 99-1793 variety from the study conducted by Puyot and Simon (2019) at the Central Experiment Station, Research and Development, Isabela State University - Cabagan, Isabela. The calibrated model was evaluated using observed yields from validation sites planted with Phil 99-1793 variety. Yield data from the 2023-2024 (new plant) and 2024-2025 cropping year (first ratoon) were used to assess the model's predictive performance across both crop cycles.

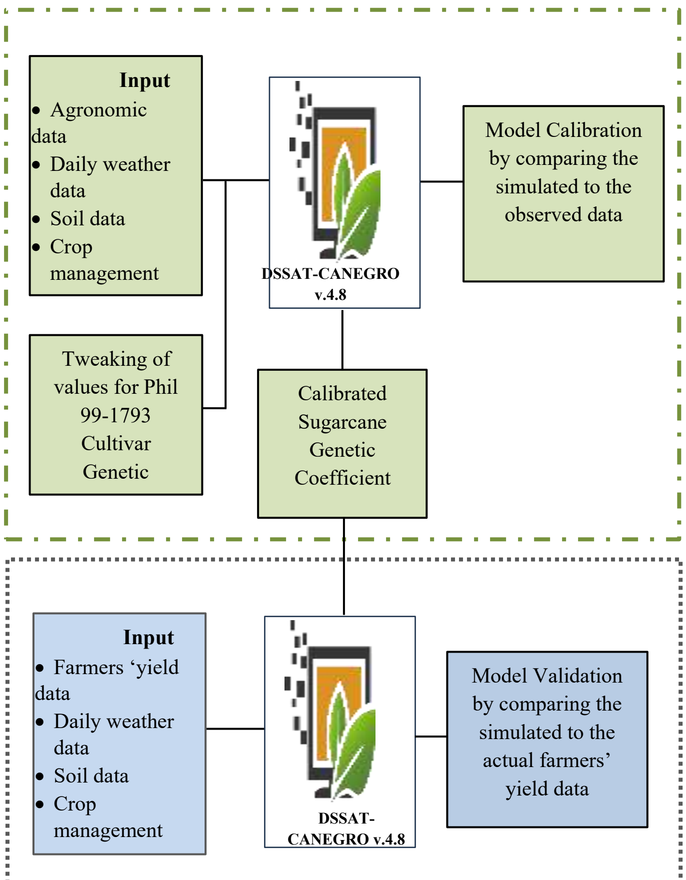


Figure 2: Model Calibration and Validation Framework

Weather data

In model calibration, daily weather data (i.e., solar radiation, max. and min. temperature, and rainfall) from 2017 to 2018 were obtained from PAGASA, Tuguegarao City, Cagayan weather station. For model validation, daily weather data from the year 2023 to July 2025 were obtained from the ISU-PAGASA Agrometeorological Research Station.

Soil data

Soil samples were collected from a depth of 0-25 cm below the soil surface using a soil auger across validation sites located in the Barangays of Busilelao, San Felipe, San Salvador, and Pag-asa, Echague, Isabela. These samples were subsequently transported to the Department of Agriculture- Regional Soil Laboratory, Tuguegarao City, Cagayan, for comprehensive analysis.

Crop management file

The sugarcane crop management practices applied in the study of Puyot and Simon (2019) were utilized for model calibration. For model validation, data on crop management practices for the calendar years 2023-2024 and 2024- 2025 were collected from validation sites through a survey questionnaire.

Calibration of Phil 99-1793 cultivar genetic coefficients

As the genetic coefficients for the parameters associated with cultivar Phil 99-1793 were not available in the DSSAT cultivar file, the default genetic coefficients for Nco376 (Table 2) were utilized as a baseline. This coefficient was subsequently adjusted based on the reference values (refer to Table 1) to optimize the fit between the simulated and experimental data. The refined genetic coefficient was then saved in the DSSAT genotype database and employed for model validation purposes.

Table 1
Parameter Code, Reference Values, and Category of Parameters for Genetic Coefficients Calibration in DSSAT-CANEGRO Model

Parameter	Reference values	Category
MaxPARCE	5-7	Biomass accumulation
APFMX	0.88	Biomass partitioning
STKPFMAX	0.6-0.8	
SUCA	0.5-0.7	
TBFT	25	Sucrose accumulation
LFMAX	10-13	Canopy leaves
MXLFAREA	360-600	
MXLFARNO	15-23	Canopy leaves
LER0	0.2-0.3	
PI1	50-90	
PI2	107-170	Leaf phenology
PSWITCH	12-18	
TDELAY	20-50	
TAR0	0.01-0.045	Tiller phenology
POPTT16	10-13.5	
TTPLNTEM	50-150	
TTRATNEM	30-50	
CHUPIBASE	1000-1500	Phenology
SER0	0.14-0.3	
TT_POPGROWTH	500-700	
LG_AMBASE	220	Lodging

Source: Singels et al., 2008 & Godinho et al., 2020

Model performance

Different statistical indices were used to evaluate the accuracy and reliability of the DSSAT-CANEGRO model in forecasting sugarcane yield for both newly planted and first ratoon fields under the prevailing conditions of Isabela Mill District. These include the coefficient of determination (R^2), Root Mean Square Error (RMSE), and Willmott's index of agreement (d-stat),

RESULTS AND DISCUSSION

1. Calibration of the model

The calibration of cultivar-specific genetic coefficients is essential to ensure that the DSSAT-CANEGRO model can accurately reflect local conditions. In accordance with the guidelines of the DSSAT methodology and in line with the prescriptions of Singels et al. (2008) and De Carvalho et al. (2018), the genetic coefficients of the NCo376 cultivar were taken as the baseline and manually modified to the Phil 99-1793 variety because the current version of the GLUE estimator does not work with the CANEGRO module (Hoogenboom et al., 2019).

Table 2
Genetic Coefficients for NCo376 and Phil 99-1793 Cultivar

Parameter code	NCo376	Phil 99-1793
MaxPARCE	5.7	7.0
APFMX	0.88	0.88
STKPFMAX	0.7	0.78
SUCA	0.58	0.7
TBFT	25	25
LFMAX	12	12
MXLFAREA	360	600
MXLFARNO	15	15
LER0	0.25	0.26
PI1	69	60
PI2	169	107
PSWITCH	18	15
TDELAY	50	40
TAR0	0.02	0.035
POPTT16	13.3	12
TTPLNTEM	80	70
TTRATNEM	30	50
CHUPIBASE	1050	1000
SER0	0.14	0.14
TT_POPGROWTH	600	500
LG_AMBASE	220	220

Measured data for stalk height and fresh cane yield obtained from Puyot and Simon's (2019) study were used to calibrate the genetic coefficients specific to the Phil 99-1793 variety. The calibrated genetic coefficients (Table 2) were saved in the genotype file and used for model validation.

Calibration results revealed high model accuracy in simulating major sugarcane growth parameters. Simulations of the stalk height produced an R^2 of 0.92, RMSE of 0.35 meters, and a d-stat of 0.85, meaning that the observed and simulated stalk height are strongly correlated, as shown in Figure 3. In the same manner, the calibrated coefficients also demonstrated good agreement between observed and simulated fresh cane yields, obtaining an R^2 of 0.81, an RMSE of 8.72 tons of cane (TC) ha^{-1}, and a d-stat of 0.89. Figure 4 shows the goodness of fit between observed and simulated fresh cane yields for the four calibration data points. These findings show that the model can replicate the phenological development and yield performance of Phil 99-1793 under the agronomic and climatic conditions of Isabela Mil District. These results are in line with those of Godinho et al. (2020) and De Carvalho et al. (2018), who also found credible model performance following cultivar calibration using observed experimental data.

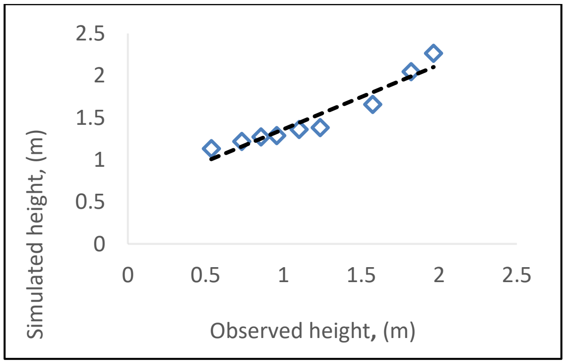


Figure 3: Calibration Results for Stalk Height

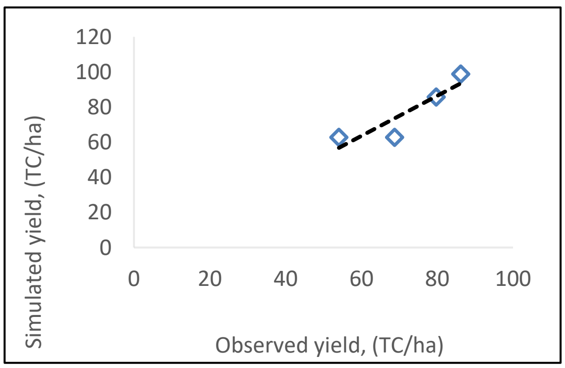


Figure 4: Calibration Results for Fresh Cane Yield

2. Validation of the model using observed yield data from newly planted fields during the 2023-2024 cropping year

The model's performance in simulating sugarcane yield was evaluated across five different newly planted fields with the Phil 99-1793 variety during the 2023–2024 cropping year. A pooled validation methodology was used, combining the actual yield and making a comparison with the simulated yields of each validation site. It was a way of conducting a wider evaluation of the model predictive performance under the different management practices and field conditions across the validation site. The model maintains its acceptable predictive accuracy, achieving an $R^2 = 0.833$, RMSE = 9.8 TC ha^{-1}, and d-stat = 0.89. These values are within an acceptable model performance as defined by Ghimire et al. (2025), Alejo (2020), where an R2 value of more than 0.5 is taken to be acceptable and RMSE of 9.8 TC ha^{-1}, which is equal to 18 percent of the mean measured value is also considered acceptable, as it is within the acceptable range of 10-20 percent (Alejo, 2020; De Carvalho Jose Leonaldo De Souza et al., 2018; Jamieson et al., 1991).

However, validation showed that Field 4 did not agree with the rest, which showed an absolute deviation of 21.3 TC ha^{-1}. This implies that the model inputs might not have been able to capture local anomalies like unequal fertilization, drainage, or the pressure of pests. Nevertheless, the validation proves that the DSSAT-CANEGRO model can be used to estimate sugarcane yield in a newly planted field under the typical growing conditions of the SRA-Isabela Mill District, thereby fulfilling the second research objective.

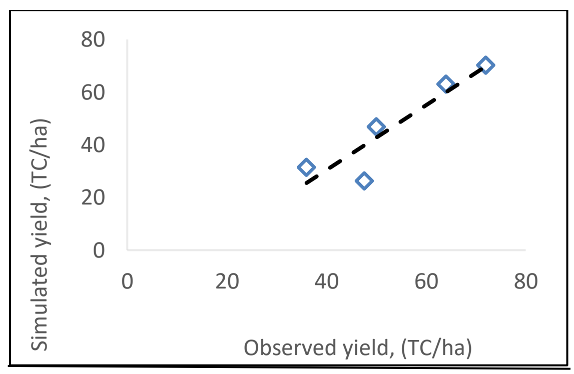


Figure 5: Simulated and Observed Yield of Validation Sites

3. Validation of the model using observed yield data from first ratoon fields during the 2024-2025 cropping year

The DSSAT-CANEGRO model was tested to assess the capability of predicting the first ratoon yield across validation sites for the 2024-2025 cropping year. The model, however, did not provide good agreement between the simulated and observed yields, as presented in Figure 6 with an R^2 of 0.0, a RMSE of 42.08 TC ha^{-1}, and a d-stat of 0. The high deviation between the simulated and actual yields was likely attributed to the model's inability to identify external stressors (Guarin et al., 2024; Valeriano et al., 1993).

These inconsistencies may be explained by the fact that DSSAT is simply not able to model crop damage caused by typhoons or lodging caused by winds, which were common in the area during this validation phase. Super typhoons, Marce, Nika, and Ofel had disastrous impacts on Isabela, resulting in extensive crop lodging and stalk breakage that are not yet captured in DSSAT. In fact, it considers rainfall as a water input. Abayechaw (2021) also made a comparable observation, stating that the central limitation of DSSAT is that it does not include mechanisms to model the influence of cultivation practices, pest infestation, and other factors that may severely impact crop performance. Such a constraint is especially applicable in areas where weather plays a central role in yield performance.

Research studies by Sarol et al. (n.d.) and Singh et al. (2000) support the necessity to consider wind-stress or lodging sub-modules in the modeling process since lodging can result in a 3% - 41% loss of sugarcane yield at 10% and 100% lodging, respectively. As such, the model works well in normal or controlled conditions, but its ability to forecast yields influenced by extreme weather events remains limited due to the absence of sub-modules that simulate typhoon-induced damage.

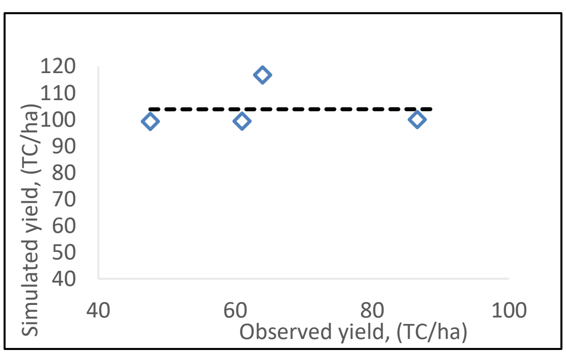


Figure 6: Simulated and Observed Yield of Validation Sites

CONCLUSION

The study successfully calibrated and validated the DSSAT-CANEGRO model for the Phil 99-1793 sugarcane variety under the agronomic conditions of the SRA-Isabela Mill District. The model showed strong performance during calibration, with R^2 values exceeding 0.80 for both stalk height and fresh cane yield, and satisfactory validation metrics for the 2023-2024 cropping year (R^2 = 0.833; RMSE = 9.8 TC ha^{-1}; d = 0.89), confirming its suitability for yield estimation under typical field conditions. However, validation for the 2024-2025 cropping year revealed model limitations in accounting for typhoon-induced lodging and crop damage, leading to significant overestimations (R^2= 0.0; RMSE=42.08 TC ha^{-1}; d-stat= 0.0). This identifies a critical limitation of the DSSAT-CANEGRO model when applied in regions frequently affected by extreme weather events. Thus, while the model is suitable for yield estimation under managed or average conditions, its application in risk-prone environments must be supplemented with auxiliary modeling approaches that account for storm damage, pest infestation, and management anomalies.

RECOMMENDATIONS

Based on the results of the study, the following recommendations are proposed;

1. The calibrated DSSAT-CANEGRO model is recommended for operational yield estimation of Phil 99-1793 in the SRA-Isabela Mill District during normal climatic conditions, as the model does not simulate yield losses caused by extreme events such as typhoons.
2. Integrate the DSSAT-CANEGRO model with external tools or modules capable of simulating typhoon-induced damage (e.g., lodging, stalk breakage) to improve its accuracy in yield forecasting under extreme weather conditions.
3. Calibration and validation should be extended to other prominent sugarcane varieties to improve the model's versatility and support broader district-level application.

4. Further validation of the model for predicting yields of ratoon crops is encouraged to better assess its performance across different crop cycles.

5. Yield forecasting should incorporate probabilistic scenarios (e.g., typhoon risk, drought severity) using ensemble weather forecasts to increase predictive reliability.

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