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Suitable vegetation indices for predicting sugarcane Brix content in the field

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Abstract

The goal of this research was to identify the optimal vegetation indices for predicting the Brix content of sugarcane. The study focused on Khon Kaen 3 sugarcane at ages 10 to 13 months. The models were optimized using linear regression equations to establish the relationship between four vegetation indices (i.e., NDVI, GNDVI, PVR, and RVI) derived from multispectral images and the measured °Brix content from ground sampling. The calibration model was developed using sugarcane samples obtained from the Sugarcane Breeding Institute at Khon Kaen University, while the validation sets included sugarcane samples from Ban Phai District, Khon Kaen Province, and Saraburi Province. The results showed that the overall °Brix content ranged between 16.8 and 24.8 °Brix. The GNDVI vegetation index demonstrated the best performance as a calibration model, providing the linear relationship of $Y = -22.482x + 31.832$, where Y represents the predicted °Brix and x is the GNDVI index. For the validation results, sugarcane in Ban Phai District, Khon Kaen Province, had a Bias value of 0.40 °Brix and a SEP (Standard Error of Prediction) value of 1.64 °Brix. Meanwhile, the sugarcane from Saraburi Province showed a Bias value of 2.80 °Brix and a SEP value of 0.80 °Brix. The results indicated that multispectral imaging using the GNDVI index could be effectively used for real-time monitoring of cane quality in the field.

Keywords: Sugarcane, Brix content, Vegetation Indices

1. Introduction

Sugarcane (Saccharum Officinarum L.) is an important economic crop in Thailand. In addition to being used as the main raw material for the production of sugar It is also used in other industries, such as bagasse, used as fuel, generating electricity. It is used to produce construction materials such as compressed as plywood, fiber Heat sheet Produce pulp and different types of paper The molasses is used to produce alcohol. Sludge or sediment is used as a fertilizer to nourish the soil. Therefore, sugarcane is important to the industry in many ways [1].

During the harvest season, sugarcane must be sweet and weigh in accordance with factory standards. Farmers sell sugarcane to the factory, which then sends an agency to assess whether the harvesting area is ready. Currently, the sweetness of the sugarcane is measured using human labor and tools, specifically a Brix refractometer, which is used to determine the concentration of sugar in the liquid based on the principle of light refraction. The measurement is given in degrees Brix (°Brix). While this method is accurate, it has the disadvantage of being time-consuming, not covering large areas effectively, and potentially damaging samples.

The producer therefore sees the problem, so this problem has been used to improve with agriculture 4.0 that uses technology and innovation in the production of precision agriculture by choosing. Using unmanned aerial vehicles (UAV), the drone can be used to help with 2 accurate agricultures. Used to explore and plan the production of plants, which includes the use to explore the area or monitor the growth of plants. The second approach is used as a tool for use in labor, which will use the first approach by flying to explore the area and shooting sugarcane plots by attaching a multi -packed camera (Multispectral Camera), which has a reflective property during the visible and unable to see. Many researchers applied UAV and multispectral image for sugarcane, such as sugarcane yield estimation by assimilating UAV-derived plant height [2], identification of weeds in sugarcane fields [3], monitoring sugarcane growth response [4] and detection of sugarcane crop lines from UAV images. Chea et al. [6] integrated Vegetation Indices (VI) from multispectral imagery with estimates of crop height, sugarcane age, and weather data (rain events) to predict the Brix content in sugarcane fields. The study, conducted over four consecutive growing seasons (2017–2021), covered multiple fields with varying crop management techniques in a tropical climate. It achieved an R^2 of 0.75, with an RMSEP of 2.81 °Brix and an RPD of 1.8, using a model that combined CIrededge, PPR, GLI, and simple inverted reflectance green, along with estimated sugarcane height and rain event data.

The objectives of this research are to identify the optimal Vegetation Index (VI) for predicting the Brix content of sugarcane in field plots and to test and apply an equation previously used with actual plots in order to reduce the duration of work, making it faster and more effective. The study involves using drones to predict the Brix (°Brix) in agricultural areas within the Faculty of Agriculture, Khon Kaen University. The tests will be conducted at 14:00 h with a drone altitude of no more than 70 meters. The equation will be tested in sugarcane fields at the Saraburi Sugar Plant in Kham Phan Subdistrict, Wang Muang District, Saraburi Province, and in sugarcane plots in Ban Phai District, Khon Kaen Province, using Khon Kaen Sugarcane 3 for educational purposes.

2. Methodology

2.1 Cane plots used in education

Test plots are sugarcane plots in the crop category. Faculty of Agriculture Khon Kaen University There are 6 rai areas (Figure 1) with various sugarcane varieties at the Faculty of Agriculture. Khon Kaen University Conducted research and experiment the sugarcane varieties that are studied are Khon Kaen 3 species because it is the most popular species in Thailand. Age of sugarcane during 10-13 months.

Figure 1 Sugarcane field

2.2 Flying planning

Unmanned aircraft model VESPA Hex 650/HG Robotics is a 6-type Multi Rotor type. The body weights include a 45 kg battery. Multispectral GPS camera model MINI UBLX NEO-M8N. Battery, 10,000 mAh, 22.2 v. The drone will connect the signal on the tablet (Figure 2) and will use the application on the tablet, which is written by HG Robotics Company Limited for flight planning, speed and Guarantee GSD in the experimental plot.

Aviation during the day at 14.00 hrs. At the GSD 5 height, because if the GSD value is less than 5, it will get too much images, which will take a long time to take pictures. The drone has a limitation of batteries that can be used to fly for testing for just 15 minutes, so it's not suitable to use too little GSD. And if the value is more than 5 resolutions of the image will be less error, the GSD 5 is the most suitable value and uses a speed of flight at a speed of 6 km/h.

Figure 2 Flight planning on the application

2.3 Image processing and calculating index

The camera that uses Micasense Rededge - Multispectral Camera from the United States. The camera is responsible for the light waves that hit the sugarcane leaves and reflected to the camera with different wavelengths, 5 bands, Blue, Green, Red, NID, and RedEdge, respectively.

2.3.1 After completing the mission, the image will be received from SD Card (Figure 3), bring the pictures taken as a map in the Pix4D program.

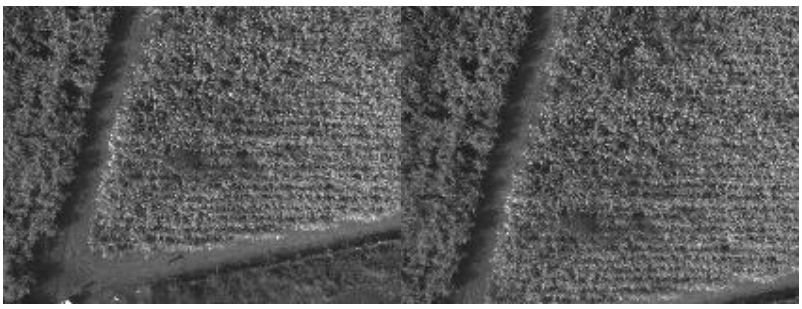

Figure 3 Mosaic images from a drone

2.3.2. When receiving the map image (Figure 4), calculating the Reflectance Map.

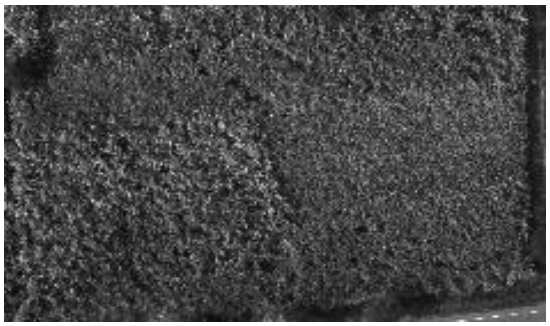

Figure 4 Reflectance Map

2.3.3. Find the average of each plot (Figure 5), which when the crop is sub - The program will calculate the average of each band.

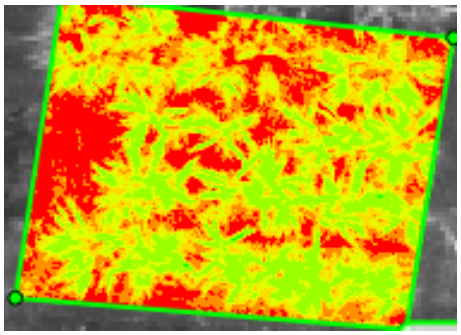

Figure 5 Cropping of the sub-plot images

2.3.4. Take each average of the 4 types of plants (Figure 6)

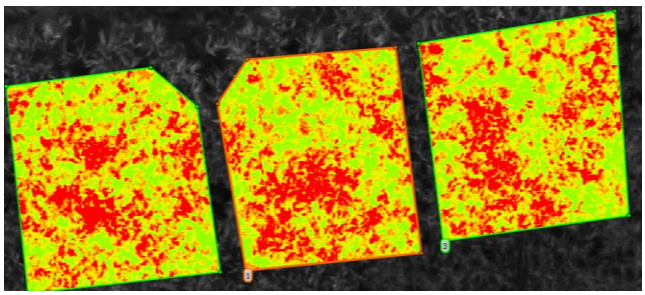

Figure 6 Calculation of the values of all 4 plant indices

2.4 Measurement of the BRIX (° Brix) with standard methods

Random of sugarcane from the crop category of the Faculty of Agriculture Khon Kaen University, with a test area of 6 rai, with a plot of 3 plot, divided into sub-plots, each of the sugar cane has a 6x8 meter area. Test the Khon Kaen 3rd 3. One test will collect all 3 Plot by randomly 1 plot. Per 2 samples, collecting °Brix by collecting rows 1 and 4 rows. The reason for using rows 2 and 3 is not because the Faculty of Agriculture wants to study sugarcane in that area. By choosing sugarcane that has a complete characteristics, which are tall, strong, not falling (Figure 7) showing the random sugarcane tree to measure the value of Khon Kaen 3, which is randomly 1 plot per 2 samples/test/time.

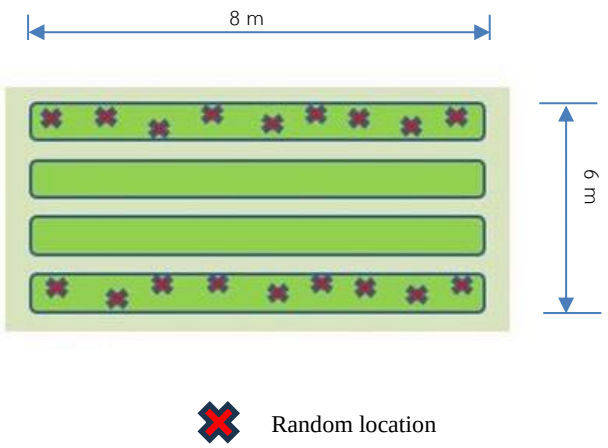

Figure 7 Locations where samples were collected to measure °Brix

2.5 Sweet prediction

Vegetation Index, VI) is a calculated value from the introduction of light waves related to plants. Come to do the proportion of each other. The VI used in this study has 4 values which are

- NDVI (Normalized Difference Vegetation Index)

$$\mathrm{NDVI} = \frac{\mathrm{NIR-RED}}{\mathrm{NIR+RED}} \quad (1)$$

- GNDVI (Green Normalized Difference Vegetation Index)

$$\mathrm{GNDVI} = \frac{\mathrm{NIR-}GREEN}{\mathrm{NIR+GREEN}} \quad (2)$$

- RVI (Ratio Vegetation Index)

$$\mathrm{RVI} = \frac{\mathrm{NIR}}{\mathrm{RED}} \quad (3)$$

- PVR (Photosynthetic Vigor Ratio)

$$\mathrm{PVR} = \frac{\mathrm{GREEN}}{\mathrm{RED}} \quad (4)$$

NIR is the infrared wave range of nearby, Red is the light wave that can be seen. Green is the light wave that can be seen in green. Create a Simple Linear Regression (SLR) equation for the relationship between the NDVI, GNDVI, RVI, PVR and ° Brix values from the test plot. With a form of equation in the equation 5.

$$Y = mx + c \quad (5)$$

Competency of the equation Consider the consideration of the consideration coefficient (R^2) with the equation as in the equation 6.

$$R^2 = 1 - \frac{\sum(Y-Y_{pre})^2}{\sum(Y-\bar{Y})^2} \quad (6)$$

Where Y is the ° BRIX tested in the experimental plot.

Y_{PRE} is the ° BRIX that is tested in the sample plot.

Standard Error of Calibration (SEC) and standard error of Prediction (Sep) with the equation 7.

$$SEC, SEP = \sqrt{\frac{\sum((Y_i-Y_{pre})-(\frac{\sum(Y_i-Y_{pre})}{n}))^2}{n-1}} \quad (7)$$

2.6 Inspection of equations by using in the sample plot

To check the accuracy of the equation, samples were taken from sugarcane plots in Ban Phai District, Khon Kaen Province, and in the promotional area of Saraburi Sugar Factory in Kham Phan Subdistrict, Wang Muang District, Saraburi Province.

A drone was flown over the 70-rai sugarcane plot in Ban Phai using a two-round flight plan due to the high number of drones, which limited the ability to capture the entire area. The flight was conducted at a ground sample distance (GSD) of 5 and at a speed of 6 meters per second, collecting 40 Brix samples.

For the sugarcane plots in the Saraburi Sugar Factory's planting area, six flight plans were executed across three plots, also at a GSD of 5 and a speed of 6 meters per second. Since the factory had already collected sweetness data from these plots, no additional samples were taken.

Images captured from both areas were processed in the Pix4D program, where all four indices were calculated. These indices were then substituted into the equation developed from the tests, and the results were compared to the actual values collected from the sample plots to evaluate accuracy.

3. Results and discussion

3.1 The results of the equation and testing of the equation

Figure 8 shows the relationship between Plant and Brexual Index. From the experiment in the Farm Faculty of Plant Testing Faculty Khon Kaen University Received the equation of plants and R^2 values by showing details as shown in Table 1.

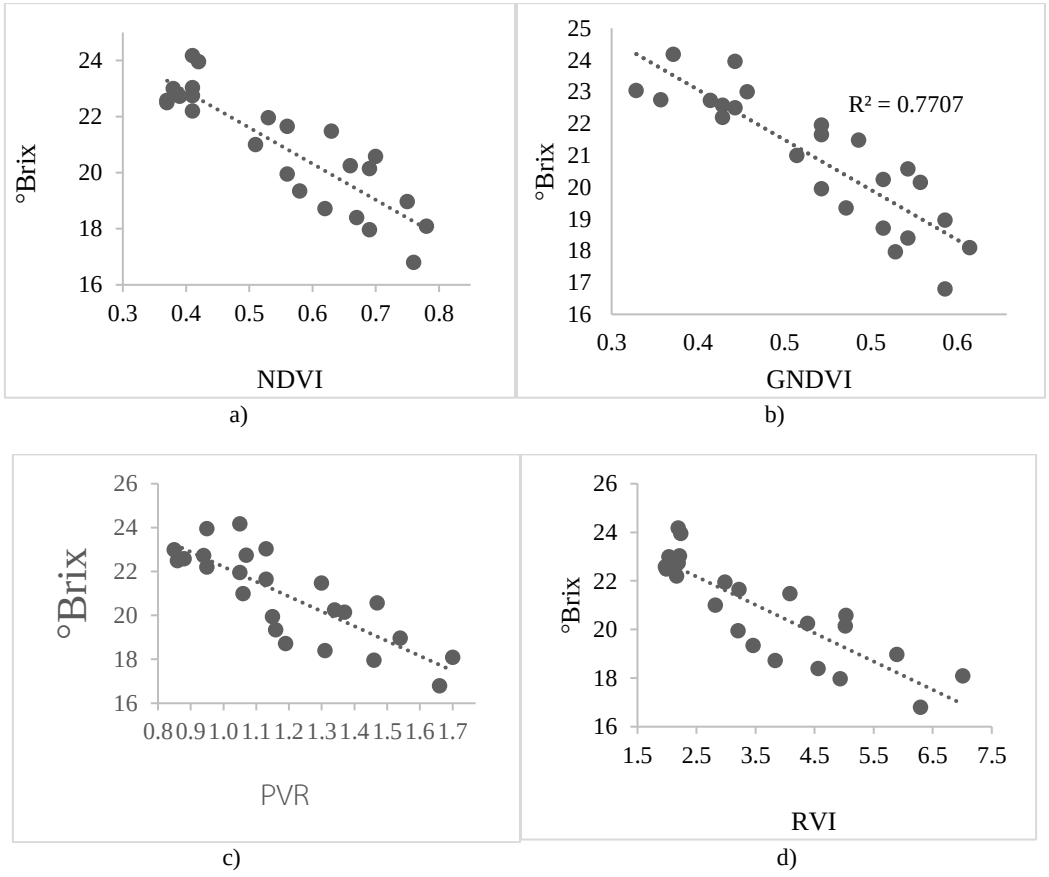

Figure 8 a) Relationship between °Brix and NDVI, b) °Brix and GNDVI, c) °Brix and PVR, d) °Brix and RVI

Table 1 Summary table of plant index values of the test plot

VI	Model	r	R^2
NDVI	y = -12.873x+27.397	0.8793	0.7731
GNDVI	y = -22.482x+31.832	0.8779	0.7707
PVR	y = -6.7706x+28.649	0.8163	0.6663
RVI	y = -1.1643x+25.088	0.8584	0.7369

3.2 The performance inspection results from the sample conversion

The performance inspection results from the sugarcane plot in Ban Phai District, Khon Kaen Province, revealed that the BIAS of the GNDVI plant index is 0.40, while the RVI is 0.50. The standard error of prediction (SEP) for the GNDVI crop index is 1.64, and for RVI, it is 1.61. The predictions of °Brix for the Ban Phai samples were quite accurate, as they were compared to actual °Brix values collected by post-testing. However, a high standard deviation (SP) was observed due to the distance between the sugarcane rows, which affected the ground images and resulted in discrepancies. The experiment was conducted at 3:30 PM, using a UV Moni Geo Design tool to measure light intensity. Low light conditions at this time caused light to be absorbed by the sugarcane leaves rather than reflected, which impacted the results. Detailed findings are summarized in Table 2.

Table 2 Summary table of °Brix, SEP, and Bias values in the sample plot, Ban Phai District, Khon Kaen

Sample field Measured °Brix	VI	field 1 (20.18)	field 2 (21.71)	field 3 (22.06)	field 4 (23.58)	field 5 (24.06)	field 6 (24.00)	Bias	SEP
Predicted °Brix	NDVI	21.98	21.88	22.49	21.99	21.96	21.74	0.59	1.64
	GNDVI	22.29	22.10	22.47	22.23	22.09	22.01	0.40	1.64
	PVR	24.92	24.96	25.37	24.88	24.93	24..73	-2.37	1.63
	RVI	22.11	22.08	22.36	22.08	22.05	21.93	0.50	1.61

In the performance inspection results from the sugarcane plot at Saraburi Sugar Factory in Kham Phan Subdistrict, Wang Muang District, Saraburi Province, the BIAS of the GNDVI index was found to be 2.80, while the RVI was 4.86. The SEP for the GNDVI index was 0.80, and for RVI, it was 1.55. This data was converted for the Saraburi Sugar Factory samples, but the interpretation of °Brix was affected by a delay in collecting the °Brix samples, which were gathered two weeks after the experiment. During this period, light intensity was significantly higher, allowing for more light to reflect off the sugarcane leaves. Results are summarized in Table 3.

Figure 3 Summary table of °Brix, SEP, and Bias values in the sample plot, Wang Muang District, Saraburi

Sample field Measured °Brix	VI	field 1 (22.07)	field 2 (21.90)	field 3 (23.13)	field 4 (23.40)	field 5 (22.70)	field 6 (21.60)	Bias	SEP
Predicted °Brix	NDVI	17.27	17.67	18.08	19.08	19.06	18.90	4.12	1.34
	GNDVI	20.38	19.29	19.89	19.17	19.89	19.39	2.80	0.80
	PVR	12.97	17.38	18.39	22.51	22.03	21.90	3.26	3.25
	RVI	14.92	16.05	17.34	19.10	19.22	19.01	4.86	1.55

Based on the study results, the most appropriate indicators for the °Brix equation, derived from wave cameras installed on the drone, can be summarized by the SEC and SEP for both the test and sample plots. The GNDVI plant index yielded the best values, as detailed in Table 4 and illustrated in Figure 9.

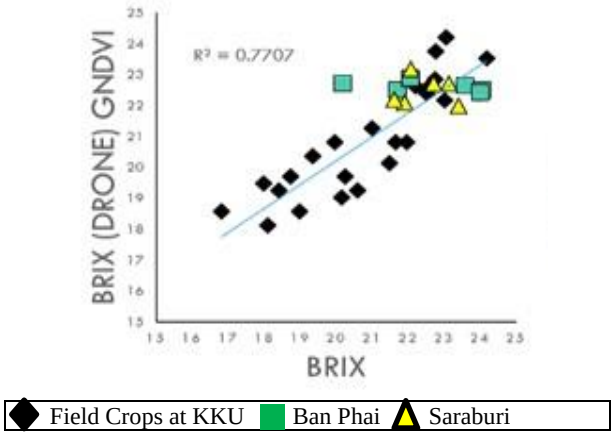

Figure 9 Graph of the relationship between °Brix obtained from actual measurements and °Brix predicted for the sample plot and the test plot

Table 4 Summary table of SEC and SEP values

VI	R^2	Field Crops at KKU (SEC)	Ban Phai (SEP)	Saraburi (SEP)
NDVI	0.7731	0.98	1.64	1.34
GNDVI	0.7707	0.99	1.64	0.80
PVR	0.6663	1.19	1.63	3.25
RVI	0.7369	1.06	1.61	1.55

4. Conclusions

The result of the equation and testing of the equation found that the GNDVI plant index has an equation. Y = -22.482x+31.832 and the coefficient of consideration (R^2) is 0.77. Tested in the sample plot of Ban Phai, Ban Phai District, Khon Kaen Province. The Bias and Sep of the GNDVI plant index is equal to 0.40 and 1.64 ° Brix respectively. And in the sample of the Saraburi Sugar Factory Promotion area, Kham Phan Subdistrict, Wang Muang District Saraburi has the Bias and SEP values of GNDVI plant indexes, equal to 2.80 and 080 ° Brix respectively, with a map of the ° Brix, which uses the GNDVI crop index in the sample plot. This research can be taken to Can be used to check the sugarcane plots Which is a rough inspection Because in the test, there are tests in the test such as in the sample plot of Ban Phai Sep, there is a high value because there are a lot of distance between sugar cane rows, resulting in the

analysis of the photo of the soil, so it is inaccurate. And test at 15.30 h. From the measurement of light with low light intensity, causing the light that hits the sugarcane leaves Not reflected back and in the sample plot of the Saraburi factory promotion area There is a prediction of the ° BRIX is not precisely because the factory has collected the ° BRIX after the test for about two weeks. And in the factory storage data of the factory, do not tell the storage position in the sugarcane plots, causing the image to crop the image in the Pix4d program in the edge area. This may cause discrepancy in predicting the ° ° in the plot and the Sep has a low value due to the test from 11.00-13.00 hrs. There is a very high light intensity, causing the light to fall into the sugarcane leaves.

5. Acknowledgements

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