การประมาณปริมาณความต้องการน้ำของมันสำปะหลังด้วยข้อมูลเชิงพื้นที่จังหวัดชลบุรี ประเทศไทย

Estimation of Cassava Water Requirements by using Geospatial Data in Chon Buri, Thailand

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Received : 11 August 2022
Revised : 6 September 2022
Accepted : 25 September 2022

บทคัดย่อ

ปริมาณความต้องการน้ำของพืชเป็นหนึ่งปัจจัยสำคัญในการเพาะปลูกพืช ซึ่งพืชจะใช้น้ำส่วนใหญ่ในกระบวนการคายน้ำทางใบและการระเหยน้ำจากดินหรือที่เรียกว่า การคายระเหยของพืช เพื่อการวางแผนและบริหารจัดการน้ำพืชและการเกษตรในพื้นที่ได้ใช้น้ำได้อย่างมีประสิทธิภาพและช่วยลดความเสียหายของพืชอันเนื่องมาจากการขาดน้ำ ในการศึกษาวิจัยครั้งนี้มีวัตถุประสงค์ในการประมาณค่าปริมาณความต้องการน้ำของมันสำปะหลังในพื้นที่อำเภอบางละมุง จังหวัดชลบุรี ประเทศไทย โดย ประยุกต์ใช้และศึกษาความสัมพันธ์ระหว่างค่าดัชนีพืชพรรณ NDVI, GNDVI, SAVI และ NDRE ที่ได้จากภาพถ่ายดาวเทียม Sentinel-2 กับค่าสัมประสิทธิ์พืชที่อ้างอิงจากกรมชลประทาน ประเทศไทย โดยการวิเคราะห์ถดถอยเชิงเส้นเพื่อพัฒนาสมการทำนายค่าสัมประสิทธิ์พืช (Kc) และคำนวณหาปริมาณการใช้น้ำของมันสำปะหลัง (ETc) จากผลคูณของ Kc ที่ได้จากการพัฒนาดัชนีพืชพรรณ และปริมาณการใช้น้ำของพืชอ้างอิง (ETo) โดยสมการของ Penman-Monteith ผลการศึกษากลุ่มตัวอย่างแปลงมันสำปะหลัง พบว่า ค่าปริมาณการใช้น้ำของมันสำปะหลังตามอายุของพืช 1-12 เดือน มีค่า 1.21, 1.23, 1.07, 1.52, 1.98, 2.29, 3.33, 3.69, 3.36, 2.86, 2.03, และ 1.51 มม./วัน ตามลำดับ โดยค่าการประมาณมีค่าใกล้เคียงกับค่าจริง และมีค่า RMSE = 0.15 แสดงให้เห็นว่าค่าการประมาณมีความสัมพันธ์อย่างมีนัยสำคัญและเชื่อถือได้

คำสำคัญ : ปริมาณการใช้น้ำพืช, ค่าสัมประสิทธิ์พืช, ปริมาณการใช้น้ำพืชอ้างอิง, สมการ Penman-Monteith, มันสำปะหลัง

Abstract

Agricultural, crop water requirements are significant with the one of the most crucial factors in crop cultivation. The main water is used by plant's foliar transpiration and soil evaporation also known as "Evapotranspiration". The water planning and management by the use of water efficiency and decrease crop damage from a water shortage is applied. This study is aimed to using the Sentinel-2 satellite imagery for determining the crop coefficient (Kc) and best fit correlation between the vegetation indices (VIs) and crop coefficient (Kc) in order to estimation of cassava water requirements by using geospatial data in Chon Buri, Thailand. The methodology first, Reference investigation data from the Royal Irrigation Department's (RID) crop coefficients and Vegetation Indies of NDVI, GNDVI, SAVI, and NDRE obtained by the Sentinel-2 image were determined. Second, the Kc was generated by linear regression analysis. Then, evapotranspiration of cassava (ETc) was estimated by the Penman-Monteith equation. The study found: the evapotranspiration of cassava varied with plant age, from 1 to 12 months were 1.21, 1.23, 1.07, 1.52, 1.98, 2.29, 3.33, 3.69, 3.36, 2.86, 2.03, and 1.51 mm/day, respectively. The estimated values were quite near to the real values which RMSE = 0.15 indicated that the estimations were of significant and reliable correlates.

Keywords : crop evapotranspiration ; crop coefficient ; reference crop evapotranspiration ; Penman-Monteith ; geospatial data (Cassava)

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Introduction

Human life depends heavily on water supplies. At present, there is an increasing demand for water resources, especially in agriculture and other industries. In addition to the changing climate, flooding occurs throughout the rainy season, and water scarcity occurs during the dry season. Cultivation tends to become more intense, therefore plant management to ensure appropriate water and nutrition. In a period of water resources are limited, using technologies to assist water management is among the most efficient in improving the quality of crops. Particularly in agricultural areas depend on rainfall. It is critical to understand the water requirements of the plants in the area (Londhe *et al*., 2022). For agricultural crop irrigation water management, the crop coefficient is a crucial amount of evidence for determining plant water requirements (Wullschleger *et al*., 1998). This is the value determined by the type and age of the plants retrieved from the Royal Irrigation Department's actual experiment in the plots. Therefore, water management based on good irrigation is critical for plant production. This includes enriching soil moisture for crop requirements as well as providing and transporting water depending on the suitability of each species of the plant (Chiemchaisri, 2007). Since water is one of the most important factors in agricultural productivity.

Currently, the equation has been developed to investigate the correlation between the vegetation index value of a satellite image and the crop coefficient (Kc) value. By this method, researchers can estimate the volume of water loss by calculating the water used from the plant at each stage of growth (Matteo *et al.,* 2021). The Kc value is assumed to varies with the plant growth stage in relation to fraction vegetation cover and vegetation index (Allen et al., 2005; Trout and Johnson, 2007). Most research has defined the Kc-NDVI correlation as a linear equation. By using Kc values from various sources, including FAO Irrigation and Drainage Paper No. 56 (FAO-56) and various measurement methods such as water balance, lysimeter (Irrigation Development Institute, 2011), and NDVI values from various satellites. For example, Estimation of Evapotranspiration ETc and Crop Coefficient Kc of Wheat, in south Nile Delta of Egypt Using integrated FAO-56 approach and remote sensing data. This is an estimate of the crop coefficient (Kc) and evapotranspiration (ETc) using SPOT-4 satellite data combined with meteorological data and FAO-56 approach. Reference evapotranspiration (ETo) were estimated using FAO Penman-Monteith and the tabular single crop coefficients were adjusted to the actual values from SPOT-4 images. To use Vegetation Indexes (NDVI and SAVI) to perform multiple linear regression analyzes to develop equations for predicting the crop coefficient (Kc) at each plant growth stage (Farg *et al*., 2012). And the research using vegetation indices from satellite images to estimate evapotranspiration and vegetation water use in North-central Portugal. To the feasibility of using vegetation indices Normalized difference vegetation index

(NDVI) and Enhanced vegetation index (EVI) from MODIS remote sensing data. The NDVI vegetation index outperformed the EVI in terms of reliability for water use from vegetation in the study area (Van der Slik, 2013). Including, applying an Optimized Two-Source Model to estimate evapotranspiration in sparse vegetation areas. This study optimized the core algorithms (canopy boundary resistance, aerodynamic resistance, and sparse vegetation coverage) and investigated an ET estimation method in the Shuttleworth-Wallace two-layer model based on the dry climate and sparse vegetation distribution characteristics of the drylands (SW model). This method should provide a more accurate and adaptable model for estimating ET in drylands (Li *et al.,* 2021).

The primary goal of this research is to estimate cassava water requirements by investigate the relationship between Vegetation Index; Normalized Difference vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), Soil-Adjusted Vegetation Index (SAVI) and Normalized Difference Red Edge index (NDRE) with Crop coefficient (Kc) referenced from the Royal Irrigation Department (RID). The linear regression and multiple regression equations are used to calculate crop evapotranspiration by multiplying crop coefficients retrieved from the vegetation index of Sentinel-2 satellite image with reference crop evapotranspiration (ETo) values. The study result is expected to improve guidelines for developing the application satellite image by remote sensing technology. For estimating geospatial crop water requirements. In addition, it can be utilized as supporting data for efficiently planning and managing water resources in a particular cassava-cultivated area, as well as effectively regulating the crop growth stage in relation to the availability of water.

Study area

Bang Lamung is a district in the southern part of Chonburi province, Thailand. There has a total area of 727 square kilometers or 454,375 Rai. According to agricultural production data from the Office of Agricultural Economics, which district has the most cassava cultivation in the eastern region with a total area approximately 55.3744 square kilometers or 34,609 Rai in 2020 and 55.44 square kilometers or 34,650 Rai in 2021. (Office of Agricultural Economics, 2021). These data indicate that the area under cultivation is growing, therefore the area was selected for this research. The study area included a total of 80 samples, which were distributed throughout the plantation area using simple random sampling. Additionally, the Department of Land Development's land use data was used to investigate the cassava cultivation plots and gather the coordinates of the plots as a database for the study, (Land Development Department, 2020) as shown in Figure 1.

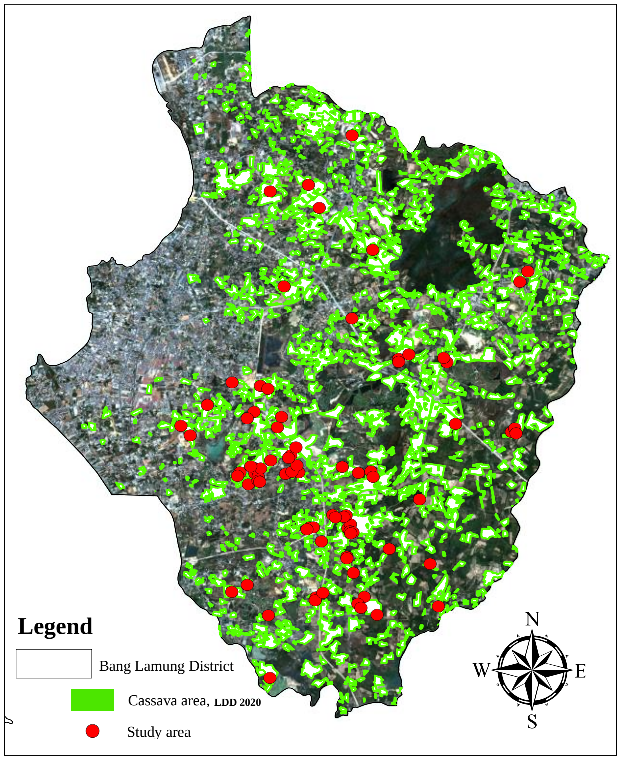

Figure 1 Study area and Cassava sample plots.

Data description

Sentinel-2 Satellite Image Data

The Sentinel-2A and Sentinel-2B satellite image data, the Multi-Spectral Imager (MSI) system has 13 bands, ranging from visible to shortwave infrared, with spatial resolutions of 10, 20, and 60 meters at various wavelengths which are repeated every five days (European Space Agency, 2020). In this study, Image data from the Sentinel 2A and Sentinel-2B satellites were collected between January 2020 and December 2021 from the European Space Agency (ESA) download form website at https://scihub.copernicus.eu/, (European Space Agency, 2021). By using the Level-2A Because the radiometric and atmospheric corrections were adjusted, and the satellite imagery with no more than 30% cloud cover was selected to obtain the data during the study period for the whole year.

Vegetation monitoring Data

The vegetation monitoring in this study relied on vegetation indices derived from satellite image band calculations to display data on plant coverage in the study area. The different vegetation indices can assist in establishing specific features or reduce levels of disturbance. The Vegetation Index is the most widely applied, that is the Normalized Difference Vegetation Index (NDVI). The Green Normalized Difference Vegetation Index (GNDVI) measures the "greenness" or photosynthesis of plants. This is one of the most widely used vegetation indices for determining crop water and nitrogen absorption. The Soil-Adjusted Vegetation Index (SAVI) was developed for the area with relatively vegetation less, similar to the NDVI formula, with an increased (L) constant to reduce the influence of the soil reflectance value. Normalized Difference Red Edge index (NDRE) is a method for determining the amount of chlorophyll in plants which should be used to determine whether the growing plant is healthy.

Crop coefficient Data

Crop coefficient data (Kc) for this study was gathered from research investigations on crop evapotranspiration which came from cultivating to harvesting at irrigation water consumption experiment stations that located in various areas (Irrigation Water Management Division, 2012), which can be downloaded from the website http://water.rid.go.th/hwm/cropwater/CWRdata/Kc/kc_en.pdf. The Kc values are divided according to the age of the plants for 12 months, as shown in Table 1 and Figure 2.

Tabel 1 Crop coefficient of cassava.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Kc	0.28	0.29	0.32	0.34	0.50	0.72	0.99	1.13	1.01	0.79	0.58	0.42

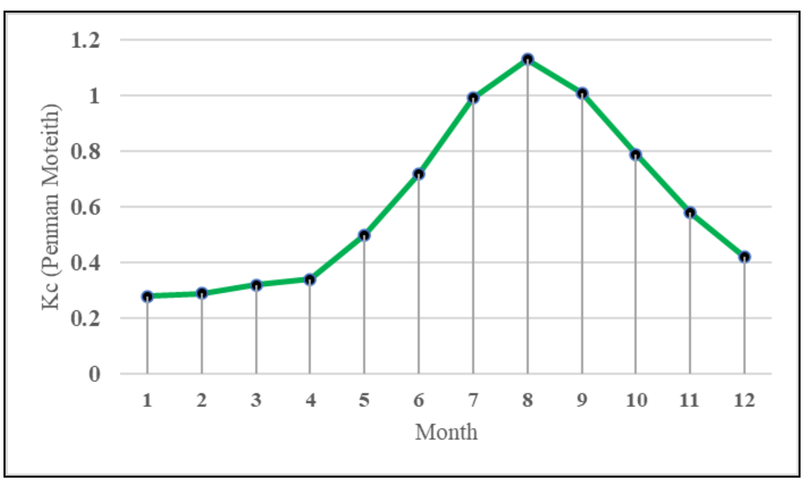

Figure 2 Crop Coefficient reference Royal Irrigation Department (Kc RID) of Cassava by Penman-Monteith.

Reference Crop Evapotranspiration Data

The Reference crop evapotranspiration data (ETo) is statistical data by the Royal Irrigation Department's irrigation water using section over 30 years, from 1981 to 2010, to determine the average climate, Air temperature, relative humidity, wind speed, and sun hours are all factors to consider. ETo was calculated by applying the Penman-Monteith method according to the FAO-56 manual (Allen *et al.,* 1998). Which, ETo data is available for download on the website http://water.rid.go.th/hwm/cropwater/CWRdata/ETo/ETo_PenMon_2011.pdf (Irrigation Water Management Division, 2011). Currently, the latest data has been updated for the years 1991-2020 from the Irrigation Department. There were 8 weather monitoring stations covering the study area, as shown in Figure 3. Using ETo data from 8 weather stations was used to estimate the study used ETo data from these stations to estimate spatial data using Inverse Distance Weight (IDW), which calculated data from each month throughout the year to cover the study area.

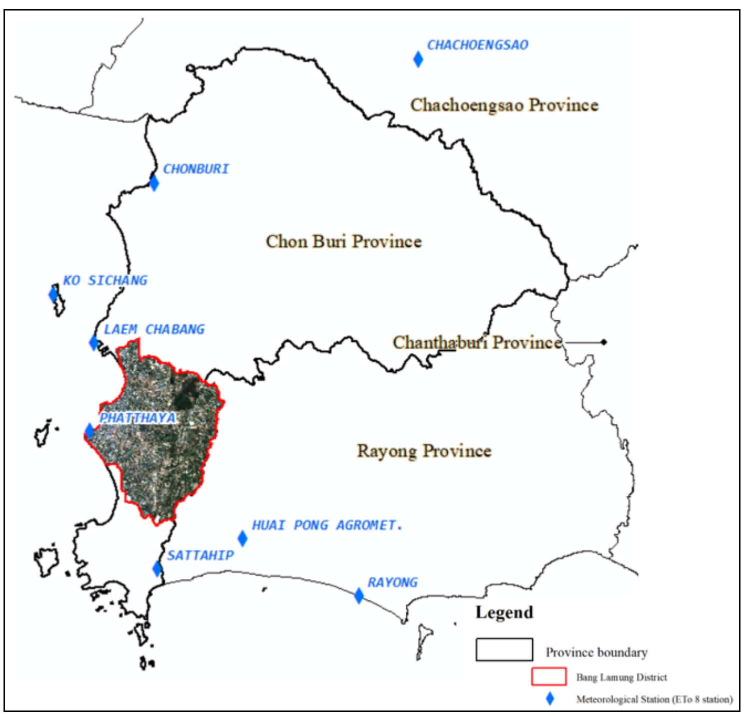

Figure 3 Position of meteorological stations in the study area.

Methods

The study method consists of various educational steps and processes, as shown in Figure 4, and the details of the steps are as follows.

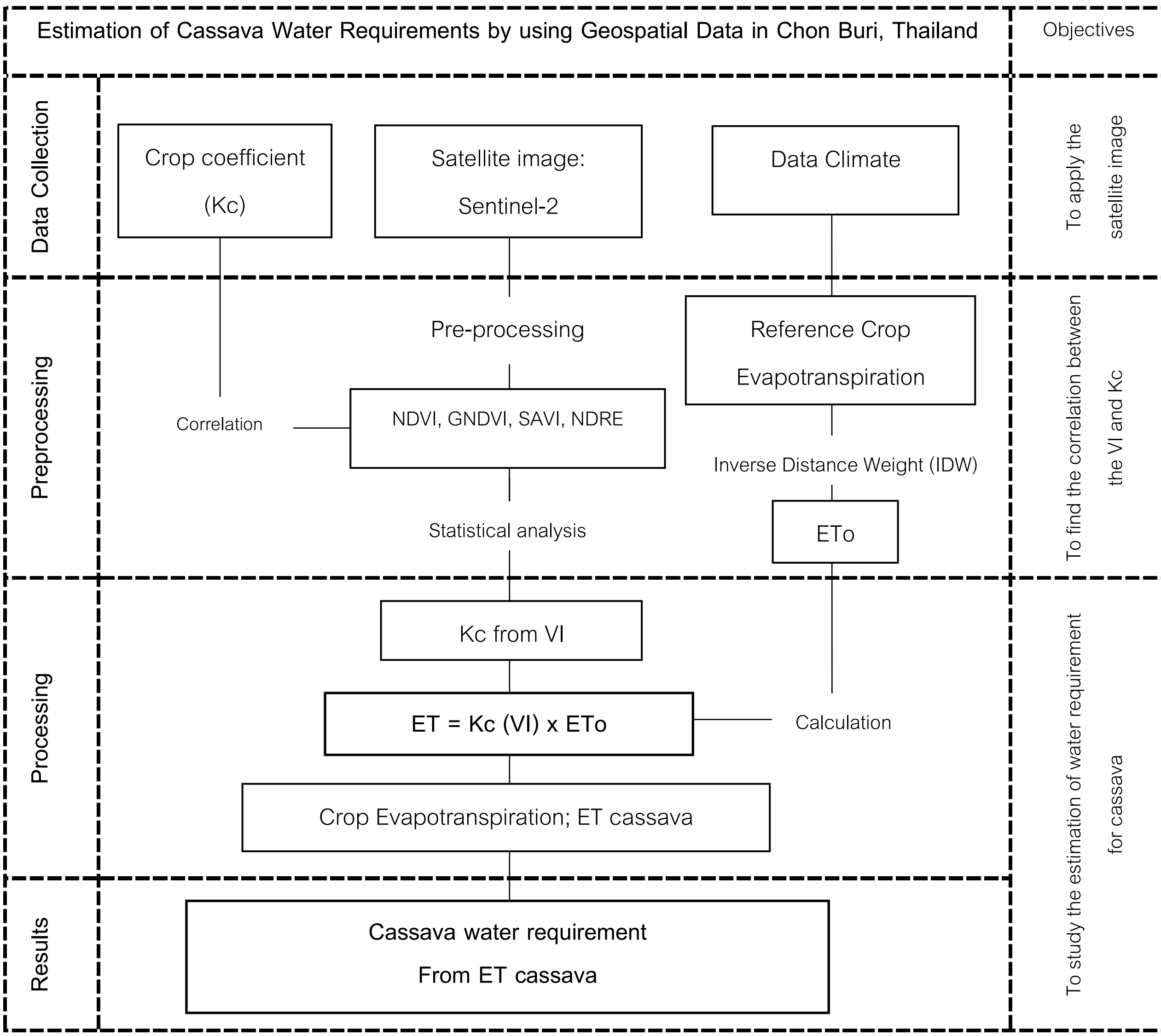

Figure 4 The methodology flowchart.

Data pre-processing

Prepare the satellite image data was selected from January 2020 to December 2021 by adjusting the image resolution to 1 0 meters and then calculating the vegetation index which using the Sentinel Application Platform (SNAP) program. When calculation vegetation index, using surface reflectance values from Sentinel-2 satellite image data in the Green Light Wavelength (Band 3), Red Light Wavelength (Band 4), Red edge Wavelength (Band 5), and Near Infrared (Band 8) (Chalermpong, 2017). In this calculation, all four indicators were used, namely, Normalized Difference Vegetation Index (NDVI) (Carlson, T. N. and Ripley, D. A. ,1997), Green Normalized Difference Vegetation Index (GNDVI) (Gitelson *et al*.,1996), Soil-Adjusted Vegetation Index (SAVI) (Hue ,1988) and Normalized Difference Red Edge index (NDRE) (Earth Observing System. ,2020.), as equations:

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

$$GNDVI = (NIR - Green)/ (NIR + Green) \quad (2)$$

$$SAVI = (1 + L) * (NIR - Red)/ (NIR + Red + L) \quad (3)$$

$$NDRE = (NIR - RedEdge) / (NIR + RedEdge) \quad (4)$$

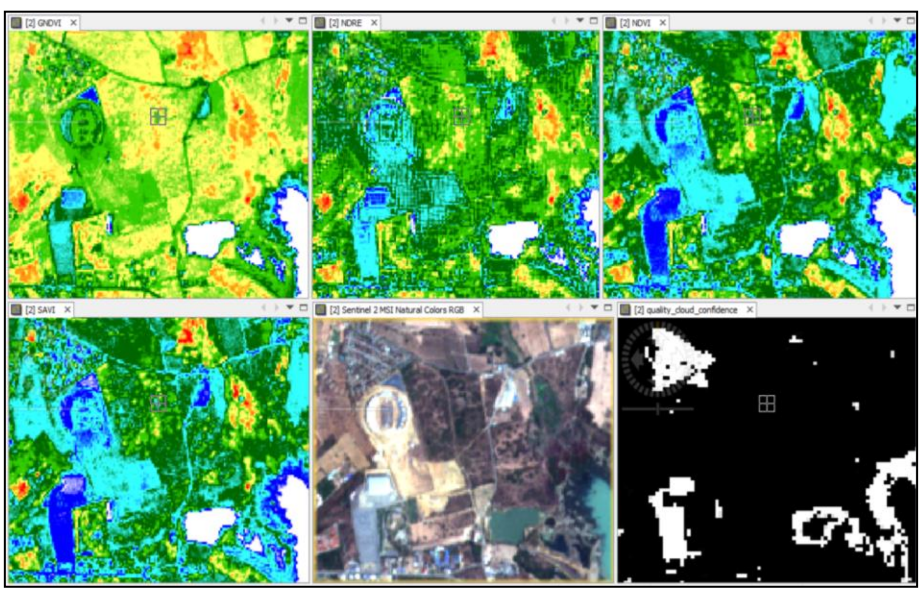

Figure 5 Vegetation index calculation by SNAP.

The determination of correlation between crop coefficient and vegetation index using linear regression analysis. To determine the correlation between the cassava crop coefficient specified by the Royal Irrigation Department with the mean of the Vegetation Index data of the cassava sample plots from Sentinel-2 satellite image. These are obtained from the study's predictive of the start of planting to the start of harvesting, which used samples of planting plots by planting started in March 2020, and harvesting ended in February 2021.

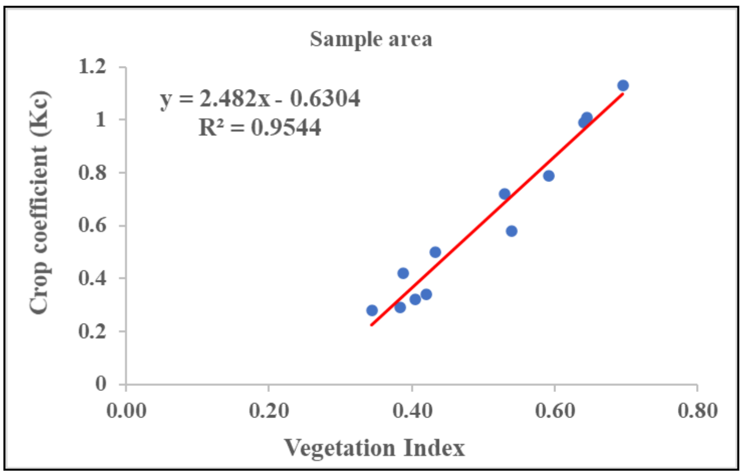

Figure 6 The correlation between the vegetation index and crop coefficient (Kc RID).

<u>*Data processing*</u>

The crop evapotranspiration calculated from the ET of sample plots and then calculating the mean value. The ET value obtained by multiplying; the Kc value based on the monthly plant growth period by the ETo value of the area planted during that period. Kc value derived from the development of a correlation equation between the mean vegetation index from satellite images (Kc predicted) and the Kc value referenced by the Royal Irrigation Department (Kc RID), ETo calculated from the Penman-Monteith formula, and the IDW method was used to estimate spatial data. As shown in the equation 5.

$$ET = Kc * ETo \quad (5)$$

Where ET = Evapotranspiration

Kc = Crop coefficient

ETo = Reference crop evapotranspiration

The accuracy was assessed by comparing the percentage difference between the Kc RID value and the Kc predicted mean. This included a comparison of the percentage difference between the mean ET calculated using Kc RID values and the mean ET calculated using the Kc predicted value of the sample plots. Included a comparison of the percentage difference between the mean ET calculated using Kc RID values and the mean ET calculated using the Kc predicted value of the sample plots. Furthermore, to assess the discrepancy of the results, the inconsistencies in statistics evaluated with the Root Mean Square Error (RMSE). Those are a prevalent error measurement method that is simple to interpret. To assess the accuracy was used the RMSE of this method, when the resulting value is low indicated that the model was rather accurate. (Chuchip K., 2018).

Results

Crop coefficient

The simple linear regression correlation the result as shown in Figure 7 and Table 2.

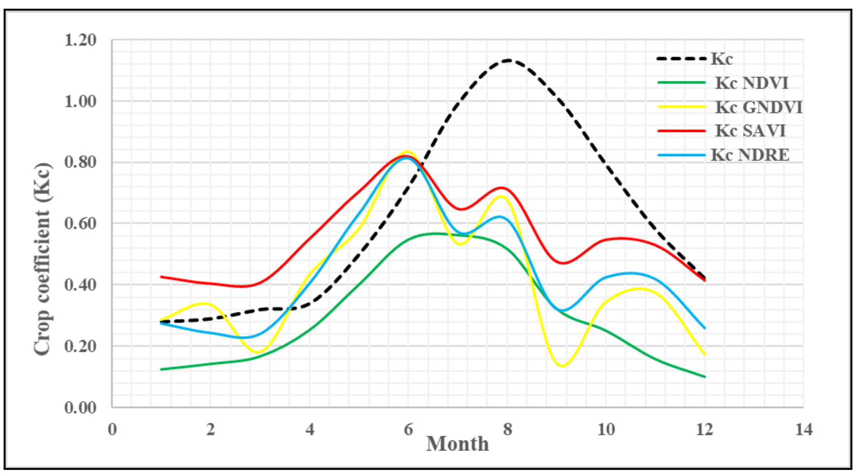

Figure 7 Comparison correlation of vegetation index and crop coefficient (Kc RID)

Tabel 2 Equation to predict by simple linear regressions.

Vegetation Index	Prediction equation	R^2
NDVI	y = 1.5914 X – 0.0797	0.91
GNDVI	y = 2.482 X – 0.6304	0.95
SAVI	y = 3.4253 X + 0.1249	0.90
NDRE	y = 1.9944 X – 0.0585	0.92

As a result, Figure 7 and Table 2, the stepwise linear model was used to statistically analyze the data in order to generate the linear equation for Kc prediction from NDVI, GNDVI, SAVI, and NDRE. To investigate the correlation, the study divided crop evapotranspiration by growth period, as shown in Table 3. And models were used to predict the Kc value based on R^2 values, with choosing 1-6 months and 7-12 months models, as shown in table 4.

Tabel 3 Equation to predict the water crisis of cassava.

Growth stage	Kc prediction equation	R^2
1-12 Month	Kc = -2.64+(2.86*NDVI) + (-1.80*GNDVI) +(11.69*SAVI) + (-9.34 NDRE)	0.65
1-6 Month	Kc = -0.11 + (0.94*SAVI)	0.91
7-12 Month	Kc = -3.21 + (-3.24*GNDVI) + (-3.16*NDRE) + (11.94*SAVI)	0.98

Tabel 4 Cassava crop coefficient predicted value.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Kc predicted	0.29	0.27	0.27	0.41	0.55	0.66	0.97	1.12	0.99	0.86	0.60	0.40

Cassava water requirement

The estimation of crop evapotranspiration (ET) outcomes following; the average ET value computed from Kc predicted by the Royal Irrigation Department. Figure 8 shows that the germination and maturation time for cassava is 1-3 months, hence the ET by Kc predicted value is low at this stage. The period in starch accumulation and cassava tuber enlargement is 6-10 months, and crop evapotranspiration will gradually increase in relation to the stage of growth that during times. Crop water requirements tend to rise in stages, with 8 months being the peak of growth and high-water demand. And, during the 11th and 12th months, when the production remains constant until harvest, crop water requirements tend to steadily decrease until harvest. Furthermore, when considers the average crop evapotranspiration of the sample plots over the growing season, representing an area of approximately 373.94 Rai or 598,304 square meters. The ET calculated which used Kc prediction values was 26.08 mm/day and accounted for 116,968 cubic meters of crop water requirement. While ET calculated using Kc referenced by the Royal Irrigation Department was 25.81 mm/day and accounted for 115,757 cubic meters of crop water requirement, there was a 1.05 percentage difference.

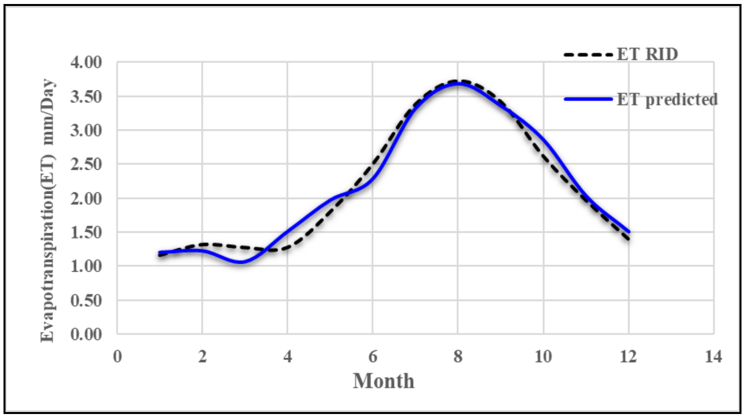

Figure 8 Comparison of ET estimated with Kc predicted with mean ET calculated by Kc RID.

Accuracy assessment

As a results, the comparison resulted of the percentage difference of Kc referenced from Royal Irrigation Department with Kc predicted mean values are monthly (start planting - ending harvest) from sample plots, as shown in table 5 and Table 6.

Tabel 3 Compare the percentage difference of ETc RID with ETc by Kc predicted.

Month	ETc RID	ETc predicted	Percentage difference
1	1.16	1.21	4.00
2	1.31	1.23	7.00
3	1.27	1.07	19.00
4	1.27	1.52	16.00
5	1.80	1.98	9.00
6	2.50	2.29	9.00
7	3.39	3.33	2.00
8	3.73	3.69	1.00
9	3.42	3.36	2.00
10	2.61	2.86	9.00
11	1.96	2.03	3.00
12	1.39	1.51	8.00
Total	25.81	26.08	1.00

Tabel 4 Root Mean Square Error.

Data	RMSE
Kc from the vegetation index predicted	0.04
ETc from Kc predicted	0.15

Discussion

The spatial vegetation coefficients were developed in this study using a linear regression analysis method to establish the correlation between the vegetation index from satellite images and the vegetation coefficient. Which the correlation equation for predicting crop coefficients revealed that the correlation curve with linear regression method that used one variable to predict, resulted in variability and instability in predicting crop coefficients. Subsequently, stepwise multiple linear regression using multiple variables was analyzed to predict different growth stages of Kc from NDVI, GNDVI, SAVI and NDRE for each growth stage, these were divided by cassava water demand range, which SAVI index correlates with cassava life span 1 -6 months. As that is a modified index to reduce soil reflection, the decision coefficient of equation R^2 = 0.91. Where GNDVI, NDRE, and SAVI were related to cassava ages 7-12 months, the decision coefficient of equation R^2 = 0.98 from the predicted crop coefficient that was found to be consistent in the same direction.

Calculating the crop evapotranspiration by method Penman-Monteith From the predicted crop coefficient multiplied by the ETo value of the study area, it was found that the crop evapotranspiration of cassava was similar to the crop evapotranspiration calculated from the Kc value, referring to the Royal Irrigation Department. According to the accuracy results, the percentage difference was within the acceptable range. Including the calculation of the square root of the mean square error (RMSE), the error is close to zero. It demonstrated the accuracy of applying remote sensing technology based on satellite imagery for spatial measurement of crop evapotranspiration (Chansuwan, 2021). According to the results of the study, cassava had not been planted and harvested at the same time in the plots of the study area. The analysis of the Vegetation Index at 12 months revealed unusual values because this study was conducted in non-irrigated areas. Further studies on farmland in irrigated areas as a database should be conducted in order to gather the most consistent data.

Conclusions

The determination of crop water requirements for addition to traditional methods, it can be used to predict crop coefficients, the correlation between Kc and the vegetation index was calculated using satellite images that can be used as a model to monitor crop evapotranspiration conveniently and quickly in specific area. Since the data in the model is open asses that is simple to access and process. The remote sensing can be used to monitor spatial levels by satellite image. It has the benefit of the ability to investigate cover to a wide area, and cultivation data can be continuously monitored due to the orbital re-imaging of the sensinel-2.

In this study, the spatial vegetation coefficient method of cassava (Kc cassava) was applied to determine the cassava evapotranspiration (ET cassava) by the method of using the vegetation index to find the correlation with the crop coefficient (Kc RID). Then calculated the water requirement of cassava that found it was a consistent value. The Kc values were obtained from the Kc predicted equations of the indices NDVI, GNDVI, SAVI, and NDRE. The RMSE values for the calculated predicted Kc throughout the growing season, divided from the growth periods of 1-6 months, and 7-12 months, were 0.65, 0.91, and 0.98, respectively. However, it was considered that the ETc predicted values computed using those equations for the sample plot of cassava which were between 1.07 and 3.69 (Total 26.08), these values were consistent in the same direction as the values of ETc RID of the value between 1.16-3.39. (Total 25.81), the results of estimated casava evapotranspiration from RMSE method were 0.15. Therefore, the geographic ETc of cassava in Bang Lamung District, Thailand revealed that crop evapotranspiration can be applied in a variety of disciplines. In addition to irrigation in water supply management and allocation of irrigation water, land development. Furthermore, in the field of agricultural extension services, there are multiple areas where the general information in this segment can be applied in future developments.

Suggestions

In this study, the estimation of cassava water requirement outside of irrigated areas was investigated and revealed that an agricultural area depended on rainfall, there was no definite management of irrigated areas. An additional study should be conducted in the cultivated area in the irrigated area to determine cassava evapotranspiration throughout the growing season. Furthermore, new studies necessitate the collection of data such as soil resources, water availability in the area, and economic conditions affecting cultivation as a database for future research.

Acknowledgements

This dissertation was completed successfully with great kindness and assistance from the professors at the Faculty of Geoinformatics, Burapha University and the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University as a consultant, the thesis offers suggestions, insightful comments, and assists in resolving the shortcomings. And I would like to thank to the Royal Irrigation Department, Land Development Department that contributed data in this research until the thesis is complete.

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