Sentinel-2 based Remote Evaluation System for a Harvest Monitoring of Sugarcane Area in the Northeast Thailand Contract Farming

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Keywords: Sentinel-2, Harvest Activity Detection and Remote Sensing for Agricultural Monitoring.

Abstract: Sugarcane is one of five important agricultural crops (Rice, Cassava, Sugarcane, Hevea, and Palm) and its critical to Thai's economy. From these important, several decades that government pays attention to support the industry and help to stabilize the sector, enabling sugarcane mills to maintain their profitability even during times of depressed sugar prices in the world market. This role of sugarcane supply chain consists of the growers, millers and associated logistics personnel. Each miller has thousands of smallholders who grow sugarcane with their contract but the farmer can sign more than one contract each crop season depending on various factors such as prices and a loaning rate. Highly these competitive need an efficient monitoring procedure to control their contract in a harvesting peak period. The monitoring of the farmland requires tracking of them at an individual level that almost impossible for field visits. The initiated idea of this research is from the study of the European Common Agricultural Policy (CAP) that plan to use remote sensing data (Control with Remote Sensing: CwRS) for controlling and monitoring agriculture land in growing season support a subsidy administration in the post-2020 timeframe. From the aims of the control with remote sensing in CAP and also in this sugarcane industry, the purpose of this study is checking the claimed parcels in an office in order to reduce the number of field visits. This paper introduces an approach for that objective which using Sentinel-2 data for a harvest detection. An algorithm (or a processing chain) in which demonstrated in this paper are an atmospheric correction, vegetation harvest index processing, data composite (cloud-free and the bare soil inspection), and geostatistical calculation of farmland for harvesting indicator. The results show an ability of the detection using remote sensing and the discussion for future improvement are explained in a conclusion.

1 INTRODUCTION

Thailand is the world's second-biggest sugar exporter which product 14.3 million tons in 2017. Every year, sugarcane business activities are involving a farming and contract management. These contract between mill and growers which mostly are the smallholders. At the end of the season (harvest period), mill sends their employee to monitor for keeping a contract in which grower should send their products to the factory with at least following the value that declared.

Over the last few years, Sentinel data become a key technology in which EU community used to support the monitoring of agricultural area responding to the food security policy such as the European Common Agricultural Policy (CAP). The use of those satellite data reduces a field visit and shift operation from sample inspections to large-scale monitoring (Kanjir et al., 2018) For example, DHI GRAS has recently completed a pilot study together with the Danish Agrifish Agency that utilizes Sentinel data within the field of grass mowing and catch crop monitoring (European Space Agency). Another example is the SEN4CAP project that aims to provide, validated algorithms, products and best practices for agriculture monitoring relevant for management of various of CAP measurements on crop diversity, activity identification, detection of fallow land, catch crops, land abandonment, and so on (Devos et al., 2017).

On the same objective of those considering remote sensing data to support the monitoring of agriculture activities and environment-related phenomena in Thailand agriculture industry. This study demonstrates the utilization of using Sentinel technology for implementation in the sugarcane industry Thailand, the details of that implementation can be explained in the following sections.

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2 OBJECTIVE

The aim of this study is to develop the methodology in a parcel-based technique for a sugarcane harvesting activity detection at a farm level of sugarcane industry's Thailand using Sentinel-2 data.

3 STUDY AREA

The study area is located in the northeast of Thailand (Figure 1), where sugarcane is mainly cultivated under rain-fed conditions. Planting time is at the end of the rainy season, October-November. The remaining moisture in the soil supports the germination of cane and guarantees its survival through the dry season. The age of sugar cane in which planted during November-December to the March-May, will be 4-6 month. Then the coming rainy season will enable the sugarcane to root deeply into the soil and grow. The sugarcane will be strong and can endure dryness when there is a shortage of rain, which may occur during July-September. Agriculturists in this region regard planting during this period more suitable than planting in May, because it more expense of mowing weeds and it is easy to find species.

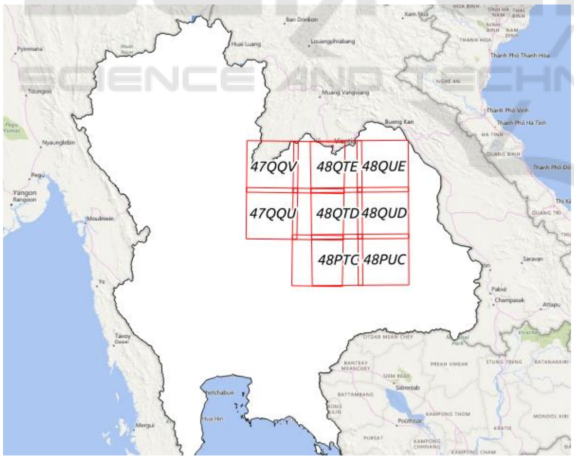


Figure 1: Northeast of Thailand, the study area.

4 SATELLITE DATA

Ministry of Industry controls the period for crushing sugarcane in 2018 (production year) by allowing the mills to start crushing at 15th of November 2018 until the end of May or June. Thus, Sentinel-2 data during December 2018 were collected from the Copernicus Open Access Hub (https://scihub.copernicus.eu/) for these harvest monitoring process. The plantation area, which is in a mill's contract, is used to be a boundary of sugarcane farm for processing Sentinel-2 data to determine the cut during the investigation period.

5 ALGORITHM

This study uses Sentinel-2 to detect the harvest activity at a farm level. Bare soil appearance is a key for determining that occurs from a cut activity and various Vegetation Indices (VIs) can be used to detect those cutting of sugarcane. Index characteristics which convenient to indicate the cut (the plant is disappearing) are the ability that can eliminate another factor out of plant appearance factor. These external factors are solar and viewing geometry, soil background, and atmospheric effects (Rondeaux et al., 1996). Some of these can be controlled. The spectral reflectance of plant canopy is obtained with a soil influenced value and depending on plant density. In the harvest period, plant density in reflection data between plant and no plant (bare soil) can be extended by soil contribution adjustment. Another factor i.e., atmospheric effects uses SEN2COR, a processing tool, provides atmospheric, terrain, and cirrus correction of Top-Of-Atmosphere Level 1C to create Bottom-Of-Atmosphere Level 2A product from Sentinel-2 data. Subsequently, L2A product produced another layer such as a Scene Classification (SC) map, the cloud mask will be used in a composite process to create 15 days period image (cloud-free) for cutting detection by using geostatistical of pixels in a land parcel at the end of the algorithm.

5.1 Scene Classification and Atmospheric Correction

Scene classification and atmospheric correction are the processes in SEN2COR, the main output is the Cloud Screening (shadows, cloud shadows, and cirrus) (Louis et al., 2016). The classified result contains 11 classes, only vegetation (no. 4) and bare soils (no. 5) as demonstrated in Figure 2 are selected for the processing algorithm in this study which is used determining a cut activity over the sugarcane pixels. Clouds, cloud shadows, and cirrus are masked and not included in an analysis process in order to avoid an error of the interpretation.

Atmospherically corrected images from SEN2COR were first evaluated with the sampling fields. The comparison of pixels over 10 sampling

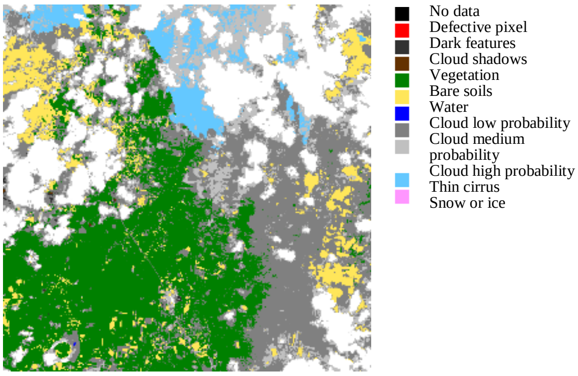
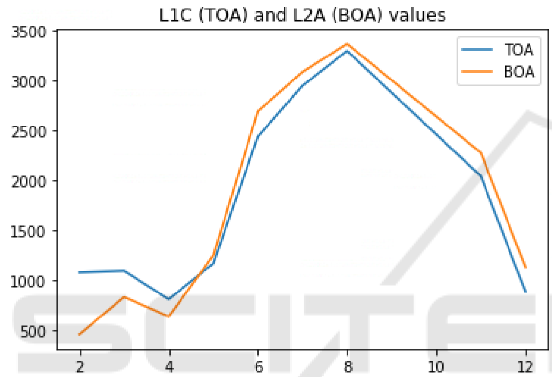
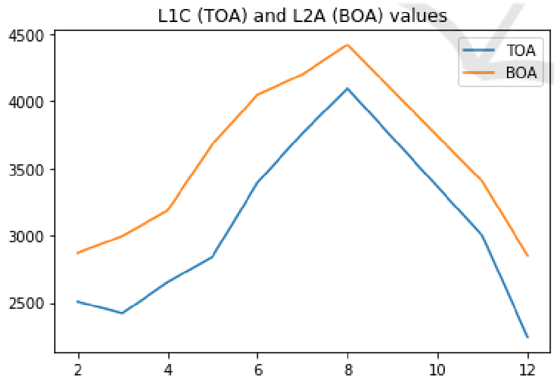


Figure 2: Scene Classification image in which only vegetation and bare soils are selected for the procedure of the detection.



(a)



(b)

Figure 3: Illustration of the comparison between the TOA reflectance and BOA reflectance signature. The example (a) shows a plot of the sugarcane experimental field, 05 December 2018, (b) shows a plot in a cloudy day over the vicinity area, 12 December 2018.

on 05 December 2018 shows that the different radiance typically peaks in the green reflectance and lower values in the Red Edge, NIR, and SWIR (Figure 3a). But the comparison on a cloudy day on 15 December 2018 shows the difference radiance typically more different and quite symmetrically shape (Figure 3b). Thus, NDVI or SAVI indices from which TOA or BOA might not significant difference in term of the ratio of the difference between calculated bands especially on the harvest activity detection.

5.2 Soil Adjusted Vegetation Index (SAVI)

In a theory, SAVI is more reliable than Normalized Difference Vegetation Index (NDVI) in some circumstance due to reducing the influence of the soil spectra in the reflectance. The soil contribution through the reflectance is depending on plant density, row effects, canopy geometry, wind effects, and so on (Rondeaux et al., 1996). Experimental study reveals that a given type of soil variability, the (bare) soil reflectance at one wavelength is often functionally related to reflectance in another wavelength in linear relation (Jasinski and Eagleson, 1990). Several vegetation indices i.e., soil-adjusted vegetation index (SAVI), transformed soil-adjusted vegetation index (TSAVI), modified soil-adjusted vegetation index (MSAVI), and environment monitoring index (GEMI) have been developed using the coefficient of these relationship for reducing the effect of soil (Huete, 1998). The selection of index for using depend on the known of the coefficients of the soil line and that cannot be generalized because of its variability.

For the detection of a harvest activity, SAVI which was developed from (Huete, 1998) is selected for use in this study due to its generalized of the related coefficient. The study of those canopy background adjustment factor in Thailand does not exist thus the recommended factor from Sentinel Hub (L=0.48) (European Space Agency) is used as the following equation.

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

First, the evaluation between SAVI and NDVI was performed in three different types of covering of sugarcane i.e. high density (P01), intermediate density (P03) and low density (cut) (P02). The following graph (Figure 4) demonstrated that NDVI is lower reflectance and convinced that the ability of SAVI is better for detecting the harvest over the land parcel using the threshold method.

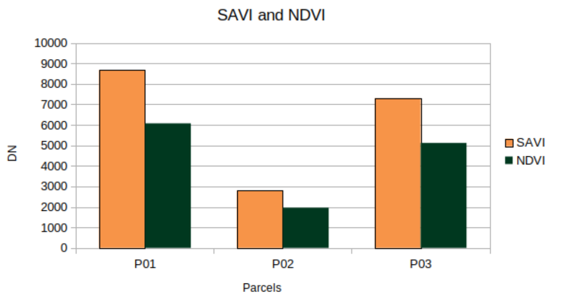


Figure 4: Comparison of SAVI and NDVI over the land parcel i.e., high density (P01), intermediate density (P03) and low density (cut) (P02).

5.3 Cloud-free Data Composite

The problems of single date remote sensing analysis such as cloud contamination, atmospheric attenuation, surface directional reflectance, and view and illumination geometry were studied and proofed that can be reduced by the composite of multi-dates. For many decades Maximum Value Composite (MVC) procedure has been implemented by increasing the number of acquisitions into a single composite image for reducing those factors. Since the upcoming of Sentinel-2 (S2A and S2B), the high spatial resolution and its revisit frequency of 3 -5 days, the data can be used to monitoring agriculture at a farm level. Sentinel-2 for Agriculture Project (Sen2-Agri) Bontemps et al., (2015) provides the international community for finding the best practices to process Sentinel-2 data in an operational manner into relevant earth observation (EO) agricultural products and recommended 7 to 10 day basis for cloud-free surface reflectance composite.

Due to Thailand located in the tropical zone, an annual average rainfall reports 116 mm based on 1981-2010 period (Thai Meteorological Department, 2015), the test of data composite shows a minimum of 15 day is suitable for the northeast of Thailand to implement the cloud-free reflectance (Figure 5).

Northeast of Thailand mostly done by the labors which three parties are involved in relation to cutting interval, sugar mill owners, cane farmers, and truck operators. During the peak season, supply is higher than the capacity of the mills. At that time hundreds of trucks can be seen queuing in front of the mills, waiting to unload sugarcane (Chetthamrongchai, 2001). This condition making the crushing interval by 4-5 months (December to April). The composite image of cutting activity is invert of the traditional composite by using the

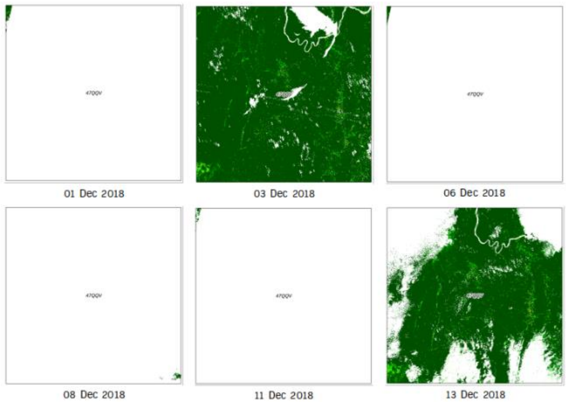
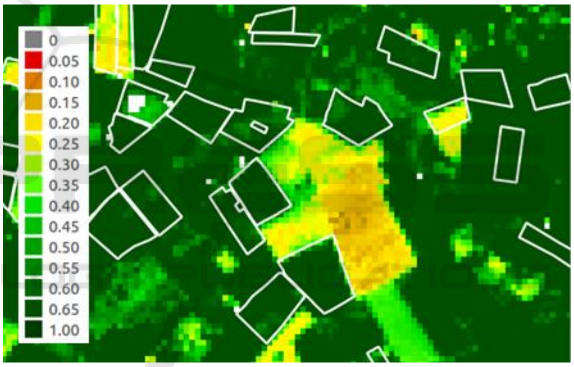
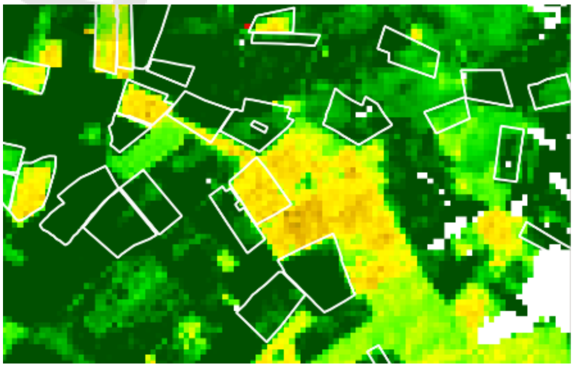


Figure 5: The cloud masked image interval 15 days of S2A and S2B composition of SAVI.

Minimum Value Composite (MinVC) for the cutting detection. Figure 6 (a)-(e) show the time-related cutting activity over the farm parcel. In this study, 15 day period with MinVC is used to produce a pre-processing cloud-free data for the next step.

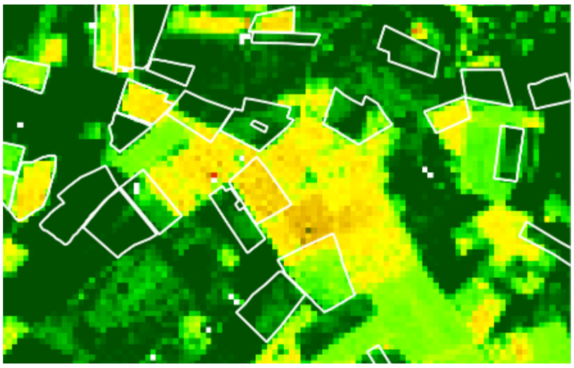


(a)

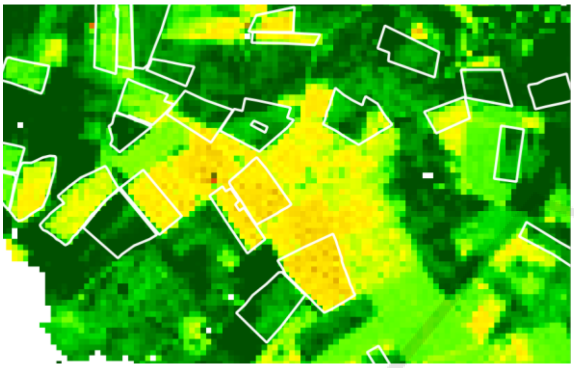


(b)

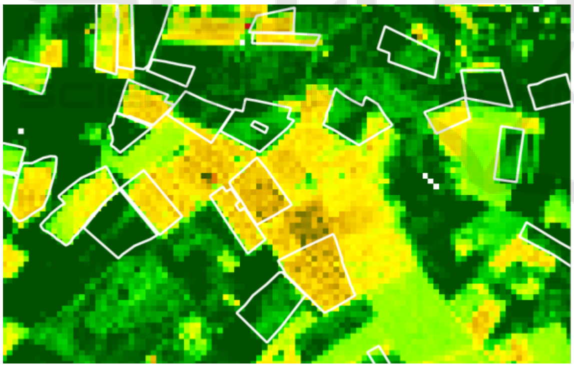
Figure 6: SAVI images of (a) 03 Dec 2018, (b) 13 Dec 2018, (c) 18 Dec 2018, (d) 23 Dec 2018, and (e) 28 Dec 2018.



(c)



(d)



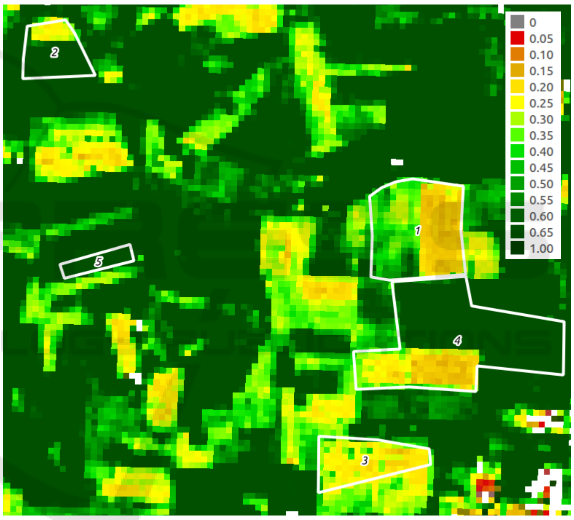
(e)

Figure 6: SAVI images of (a) 03 Dec 2018, (b) 13 Dec 2018, (c) 18 Dec 2018, (d) 23 Dec 2018, and (e) 28 Dec 2018 (cont.).

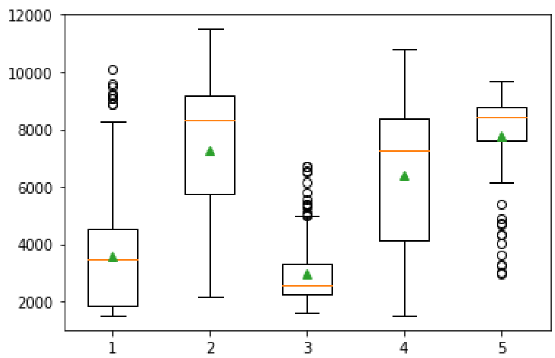
5.4 Geostatistical of Parcels

From the farm contract of sugarcane in Thailand, an area or a parcel of land is known from field estimation using mobile GNSS. Thus, statistical of pixels can determine using that GIS information. The vector polygon is translated into pixels mask for extracting the SAVI data which locates inside the parcel.

Pixels inside a farm parcel are extracted and calculated in the term of descriptive statistics, min, max, mean, median, standard deviation, and percentile. Figure 7 demonstrates the geostatistical calculation on the five parcels which have three types of activities, (T1) “no cut yet”, (T2) “in progress”, and (T3) “finish”. From the calculation, mean and median can be used to indicate "in progress" which close to "finish", but cannot distinguish the difference between "in progress" and "no cut yet". The values such as min, max, and percentile are an indicator which can distinct "no cut yet" and "in progress". From this inspection, the cutting in a certain part of a parcel does not make a significant change on mean and median, but min value is significantly changed until finish the cutting the values, max, median, and mean are less than the threshold value of bare soil (0.4 or 4,000 in this study).



(a)



(b)

Figure 7: (a) SAVI at 18 Dec 2018 and five farm parcels, (b) boxplot of the farm parcels.

5.5 Thresholds for Cutting Activity

The required statuses of the cut activity for the mills' utilization are "no cut yet", "in progress", and "finish" as described in the previous section. The status of each parcel performs in 15 days period by composited SAVI. The suitable threshold for this study is as follows.

Table 1: Thresholds of the three types of the cutting activities.

Status	Min	Mean	Percentile(75)
no cut yet	> 4000	> 4000	> 5000
in progress	< 4000	> 3000	> 4000
finish	< 4000	< 4000	< 4000

In Table 1, the statistical key features which are used to indicate the status “no cut yet” and “finish”, are Min and Percentile (75). When grower starts their cutting sugarcane a min value is decreased to the value less than 3000 until percentile (75) decreasing to lower 4000, the status then will be changed to “finish”.

6 PROCESSING SYSTEM

Most agriculture parcels in Thailand are mostly smallholder farms that area is between 2 – 3 ha and frequently change their plant type responding to a unit cost, product price, weather, and the policy of government subsidy and so on. Cause of this behave of Thai's agriculture and thus requires the time related potential technique for observations spread over time. For supporting this requirement of agriculture remote sensing, Harvest Monitoring through Remote Sensing (HMRS) was designed and developed to aim the investigate the harvest of sugarcane farmland from analyzing Sentinel-2 dataset, using fully open source or free software, library, and programming language i.e., custom Python script, Linux shell scripts, GDAL (Geospatial Data Abstraction Library), OGR (OpenGIS Simple Features Reference Implementation), Numpy, Matplotlib, SEN2COR. The workflow scripts (Figure 7) are explained as follows.

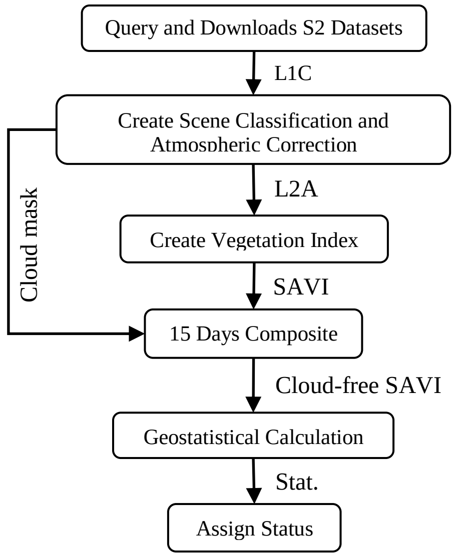


Figure 8: Harvest Monitoring through Remote Sensing (HMRS) workflow.

6.1 Query and Downloads S2 Datasets

Copernicus Open Access Hub provides OData API for accessing Sentinel datasets over core protocols i.e., HTTP and REST with an ability to handle a large set of client tools for performing a query and retrieving the Sentinel data (European Space Agency). The python script is executed every day for querying dataset using $filter function with a grid name and date in order to retrieve an observation data as following example.

```
https://scihub.copernicus.eu/dhus/odata/v1/
Products?$filter=substringof('T47QQV',Name)
+and+ substringof('_MSIL1C_YYYYMMDD',Name)
```

6.2 Create Scene Classification and Atmospheric Correction

SEN2COR toolbox is executed the command L2A_Process for producing the scene classification image and performing atmospheric correction into the 20m resolution image. From the lack existing of suitable experimented parameters for Thai regional area for processing L2A, thus the default parameters are used in this system as follows.

Table 2: L2A_Process parameters.

Processing Parameter	Value
Nr_Process	AUTO
Aerosol_Type	RURAL
Mid_Latitude	SUMMER
Ozone_Content	331
WV_Correction	1
WV_Watermask	1
Cirrus_Correction	TRUE
BRDF_Correction	0
BRDF_Lower_Bound	0.22
Smooth_WV_Map	100
WV_Threshold_Cirrus	0.25

6.3 Create Vegetation Index

A little quite improve here is a conversion of data type from float SAVI to integer SAVI, in which putting into the equation for a smaller GeoTiff and the coordinate reference system is still used UTM WGS84 as same as the source Sentinel-2.

The naming of SAVI product that should explain here is the design on the support of manual selection by the researcher that the name supports the sort in which area are grouped and date-time can be sorted ascending or descending. This naming aims to build and initiate the compact system in order to have an ability for the improvement in the future for a new analysis model. The naming is as following structure.

TZZGGG_YYYYMMDDTHHMMSS_VVVV.tif

ZZ = zone number
GGG = grid characters
YYYY = datatake sensing year
MM = datatake sensing month
DD = datatake sensing date
HH = start hour of sensing
MM = start minute of sensing
SS = start second of sensing
VVVV = index name

In order to build a cloud-free image for the next composite procedure, Scene Classification (SCL) is used here as the mask array in order to filter only vegetation and bare soil pixel by using pixel class number 4 and 5 respectively.

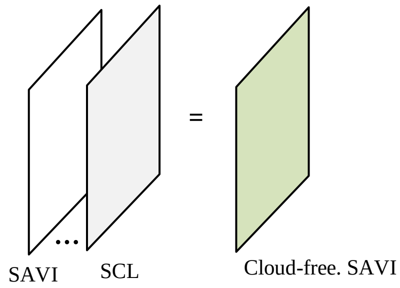


Figure 9: Filter vetgetation or bare soil from source SAVI.

6.4 15 Days Composite

The 15-day images are investigated in order to select the minimum SAVI each pixel series for building the 15 days composite image. If no SAVI found the pixel is set to no data value.

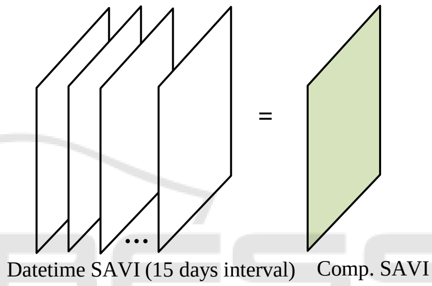


Figure 10: SAVI composite for harvest detection.

6.5 Geostatistical Calculation

First, OGR is used to read the features from land parcels of sugarcane then each parcel is selected to create a raster mask array, thus SAVIs from a composite image in which the same location of the mask is extracted from the source into the calculation procedure as demonstrated in Figure 10. Numpy, average, mean, median, min, max, and percentile are the functions which are used to calculate the geostatistic for the status determination

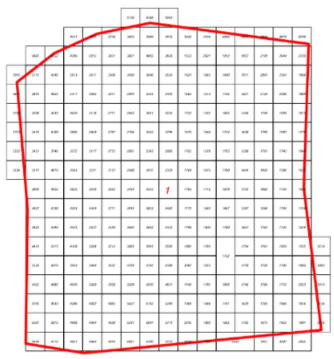


Figure 11: Pixels masked using farm polygon for geostatistical calculation.

6.6 Assign Status

The threshold parameters i.e., min, mean, and percentile (75) (Table 1) are used to assign a status, "no cut yet", "in progress", and "finish" in the final step. Then, status information is sending to the GI System for utilization in the final step.

7 CONCLUSIONS

This paper presents a proof of concept of using Sentinel-2 data in the harvest monitoring of sugarcane fields. SAVI can be used as a cutting indicator in harvest period of farm plants. In rainfed agriculture such as Thailand, recommended the minimum of 15 days composite for cloud-free image analysis. Geostatistics is a powerful tool for interpretation in various ways to identify the human activities which perform on farmland as demonstrated in this paper.

REFERENCES

European Space Agency, (n.d.). *Open Access Hub*. (European Union) Retrieved 1230 2018, from https://scihub.copernicus.eu/userguide /ODataAPI

European Space Agency, (n.d.). *ESA Sentinels Help Monitor Grasslands for Agricultural Subsidy Checks in Europe.* Retrieved 12 25, 2018, from http://www.dhi-gras.com/news/2017/4/7 /successful-demonstration-of-using-sentinel-1-and-2

Thai Meteorological Department, (2015). *The Climate of Thailand.*

Rondeaux, G., Steven, M., Baret, F., (1996). Optimization of Soil-Adjusted Vegetation Indices. *Remote Sensing of Environment*, *55*(2), 95-107.

Holben, B. N., 2007. Characteristics of maximum-value composite images from temporal AVHRR data. *International Journal of Remote Sensing, 7*(11), 1417-1434.

Huete, A. R., 1988. A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment, 25*(3), 295-309.

Louis, J., Debaecker, V., Pflug, B., Main-Knorn, M., Bieniarz, J., Mueller-Wilm, U., Cadau, E., Gascon, F., 2016. SENTINEL-2 SEN2COR: L2A PROCESSOR FOR USERS. *Living Planet Symposium.* Prague, Czech Republic.

Jasinski, M. F., Eagleson, P. S., 1990. Estimation of Subpixel Vegetation Cover Using Red-Infrared Scattergrams. *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING*, *28*(2), 253-267.

Chetthamrongchai, P., Auansakul, A., Decha Supawan, D., 2001. *assessing the transportation problems of the sugar cane.* Economic and Social Commission for Asia and the Pacific.

Sentinel Hub. (n.d.). Retrieved 12 30, 2018, from https://www.sentinel-hub.com/develop/documentation/eo_products/Sentinel2EOproducts

Bontemps, S., Arias, M., Cara, C., Dedieu, G., Guzzonato, E., Hagolle, O., Inglada, J., Matton, N., Morin, D., Popescu, R., Rabaute, T., Savinaud, M., Sepulcre, G., Valero, S., Ahmad, I., Bégué, A., Wu, B., Abelleyra, D., Diarra, A., Dupuy, S., French, A., Akhtar, I. H., Kussul, N., Levourgeois, V., Page, M. L., Newby, T., Savin, I., Verón, S. R., Koetz, B., Defourny, P., (2015). Building a Data Set over 12 Globally Distributed Sites to Support the Development of Agriculture Monitoring Applications with Sentinel-2. *Remote Sensing, 7*, 16062-16090.

Kanjir, U., Đurić, N., Veljanovski, T., 2018. Sentinel-2 Based Temporal Detection of Agricultural Land Use Anomalies in Support of Common Agricultural Policy Monitoring. *Geo-Information.*

Devos, W., Fasbender, D., Lemonine, G., Loudjani, P., Milenov, P., Wimhardt, C., 2017. *Discussion document on the introduction of monitoring to substitute OTSC.* European Commission.