PRELIMINARY STUDY OF DIGITALIZING POTENTIAL PADDY LOT SAMPLE USING SPACE BASED TECHNOLOGY FOR CROP CUTTING SURVEY (CCS)

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ABSTRACT: Various efforts have been carried out by government agencies to increase data quality in rice production. Conventionally, Crop Cutting Survey (CCS) is an important tool to provide data for determining average paddy yield production in Malaysia. However, it is time-consuming and costly. Still, this tool is very crucial for national paddy development and planning purposes. Realizing that, Malaysia Space Agency (MYSA) with the Department of Agriculture Malaysia (DOA) have taken the initiative to develop the Geospatial Information System (Mak-GeoPadi) to identify precise and up-to-date areas of paddy granary all over Malaysia. The main objective of this study is to map potential CCS paddy lot sample map over IADA Barat Laut Selangor study area. For that purpose, data from high-resolution optical satellite such as Pleiades satellite, multi-temporal radar images, such as Radarsat-2 satellite and cadaster lot, have been used for analysis. High-resolution optical data were used to classify active paddy parcel, miscellaneous paddy parcel and non-paddy parcel. Multi-temporal Radarsat-2 images together with cadaster lot were used to identify actual planted paddy area. Satellite image classification methods use algorithms that applied systematically the entire satellite image to group pixels into meaningful categories to determine actual paddy planting area. Paddy actual planted area in each lot can be analyzed using satellite image classification methods. Results indicate high-resolution optical data and Radarsat-2 time-series images were highly beneficial in identifying paddy planting area. Backscatter range (sigma naught) less than -11 can differentiate paddy from other crops. Potential paddy lot sample can be mapped to be used for CCS which is based on active paddy parcel and actual planted paddy area. This paper shows promising result in the sampling of CCS lot which needs further study in order to digitalize the CCS technique in Malaysia.

1. INTRODUCTION

Rice is one of the most important crop and food for more than three billion people worldwide. Despite the large global cultivated rice area and growing rice production in many countries, the total demands often exceed the production due to many reasons (Mostafa al.,2014). Therefore, rice area mapping and determining average paddy yield production is important for security of supply to match increasing of demands (Mostafa al., 2014). Conventionally, Crop Cutting Survey (CCS) is an important tool to provide data for determining average paddy yield production in Malaysia. CCS is a field-based survey wherein farm households or plots are selected using appropriate sampling methodologies, either from a list frame or frame, and involves the actual harvesting of crops from a small area within the farmer's plot (Lea Rotairo et al., 2019). CCS yield estimation depended upon data collection technique from ground-based field visits. Such technique is often subjective, costly and is prone to large errors, leading to poor crop assessment and crop area estimation (Reynolds et al., 2000). Paddy cultivation management required a lot of human resources, time consuming and coverage limitation, which is not practical at a large spatial extent and for long-term monitoring and analysis (He et al., 2018). In Malaysia, there are four major activities during paddy growth period or phenology, namely ploughing, irrigating, planting and harvesting. Location and phenological stages of paddy crops are useful for policymakers to protect crops and minimize productivity loss (Minh et al., 2019). In case of any irregularity like late/early irrigation and delayed planting, the effects are visible at the end of production, when the production is lower than expected (DOA, 2014).

To face this challenge, Malaysian Space Agency (MYSA) in a collaboration with Malaysian Department of Agriculture (DOA) utilize the multi-temporal of Radarsat-2 C-band with HH polarization to determine paddy planting status. The objectives are:

1. To develop a methodology for determining CCS paddy lot sample using satellite based technologies towards an effective management in paddy industry; and
2. To map potential CCS paddy lot sample map over IADA Barat Laut Selangor study area

The methodology is developed by using data from high-resolution optical satellite such as Pleiades satellite, multi temporal radar images such as SAR data Radarsat-2 satellite and cadaster lot have been used for analysis. The use of SAR technology is crucial given cloud obstruction views from space is common phenomena for region where rice is grown in the tropics due to cloud insensitive feature of radar-based earth observation (Tri Setiyono et al.,2000). When SAR data time-series are acquired on a regular basis and tuned according to the rice season period and crop practices then information on not only the rice area, but also when and where fields are prepared and irrigated, the phenological rice field status such as flowering, tilling, plant senescence and harvesting and related dates of irrigation, peak of rice season, and harvesting can all be detected. These are crucial spatial-phenological inputs for an accurate rice growth modelling (Tri Setiyono et al., 2000).

2. METHODOLOGY

2.1 Study area

This study was conducted at Integrated Agriculture Development Area (IADA) Barat Laut Selangor, which located at Selangor State cover an area of approximately 20,030 hectare of rice granary area (Figure 1). The site is characterized by its flat topography and wide variety of agricultural crops and plants including rice, oil palm, vegetables, and fruits. The fields are generally small and are clearly delineated by the ditches, rice field boundary and roadways, which separate them. There are two planting season which are Main-Season (July until December) and Off-Season (March until June) and the weather is cloudy and rainy most of the year, making the soil moisture content quite high. This site also among the highest paddy yield production in Malaysia which produce around 10 tonne/ha per season.

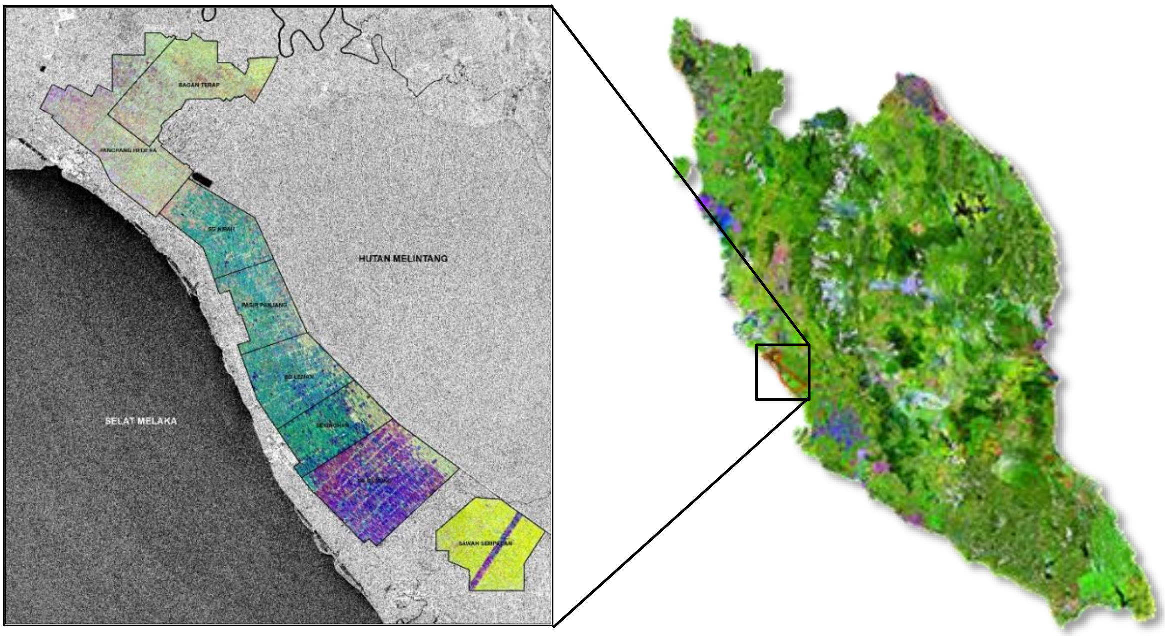


Figure 1: IADA Barat Laut Selangor Granary Area

2.2 Data collection

In the paddy and rice industry, it is important to know the actual total area planted with paddy and the growth stage for each paddy plot. This helps to provide accurate measurement of yield, land use prediction, farm monitoring, and to predict the expected harvest (Sarena et al, 2019). The paddy plant is a unique short-term crop with a maturity period of 90– 140 days post germination (Sarena et al, 2019). Within this period, it undergoes physically distinct life-stages can be seen in two-week intervals. On the contrary, the physical characteristics of a permanent water body, such as a road, an oil palm estate, a forest, a home stay the same over the same two-week intervals. Therefore, theoretically, a satellite image shooting a light beam (of a certain wavelength) over a cultivated paddy plot should be able to detect the physical changes of a paddy plant over time and have it differentiated from a non-paddy surface (Sarena et al, 2019). The use of this technology in paddy cultivation is demonstrated through the use of highresolution optical satellite such as Pleiades satellite, multi temporal radar images such as SAR data Radarsat-2 satellite.

Paddy's cultivation practices in Malaysia is twice a year based on double cropping as shown in Table 1. The multi-temporal Radarsat-2, C-band, HH polarization image used as shown in Table 2. According to Zhang, Yang, Liu, & Wang, (2017) et al. and Phan et al (2018)., among the SAR signals at different polarizations, horizontal (HH) and vertical (VV) polarizations, the HH backscatter signals are higher and more dominated by specular reflection for the rice canopy and water surfaces rather than the VV backscatter. The National Digital Cadastral Database (NDCDB) lot was acquired from Department of Survey and Mapping Malaysia (JUPEM) as an authority department in land surveys.

Table 1: Paddy crop calendar IADA Barat Laut Selangor

Stage	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
1	Off-season	Off-season	Off-season	Off-season	Off-season	Main-season	Main-season	Main-season	Main-season	Main-season	Main-season	Off-season
2	Off-season	Off-season	Off-season	Off-season	Off-season	Off-season	Main-season	Main-season	Main-season	Main-season	Main-season	Main-season
3	Main-season	Off-season	Off-season	Off-season	Off-season	Off-season	Off-season	Main-season	Main-season	Main-season	Main-season	Main-season
4	Main-season	Main-season	Off-season	Off-season	Off-season	Off-season	Off-season	Off-season	Main-season	Main-season	Main-season	Main-season

(Yellow) Off-season (Blue) Main-season

Table 2: Multi-temporal RADARSAT-2, C-Band, HH Polarization Acquisition Date

Date Imagery	
Main-Season	Off-Season
16 July 2019	24 December 2019
30 July 2019	14 January 2020
23 August 2019	24 January 2020
8 September 2019	7 February 2020
19 September 2019	2 Mac 2020
26 September 2019	12 Mac 2020
10 October 2019	5 April 2020
20 October 2019	19 April 2020

2.3 Pre-processing

Radarsat-2 pre-processing including re-project, terrain correction and image calibration was done automatically using EASI Modelling PCI Geomatics script which is develop together with MacDonald, Dettwiler and Associates (MDA). The overall methodology flowchart as shown in Figure 2.

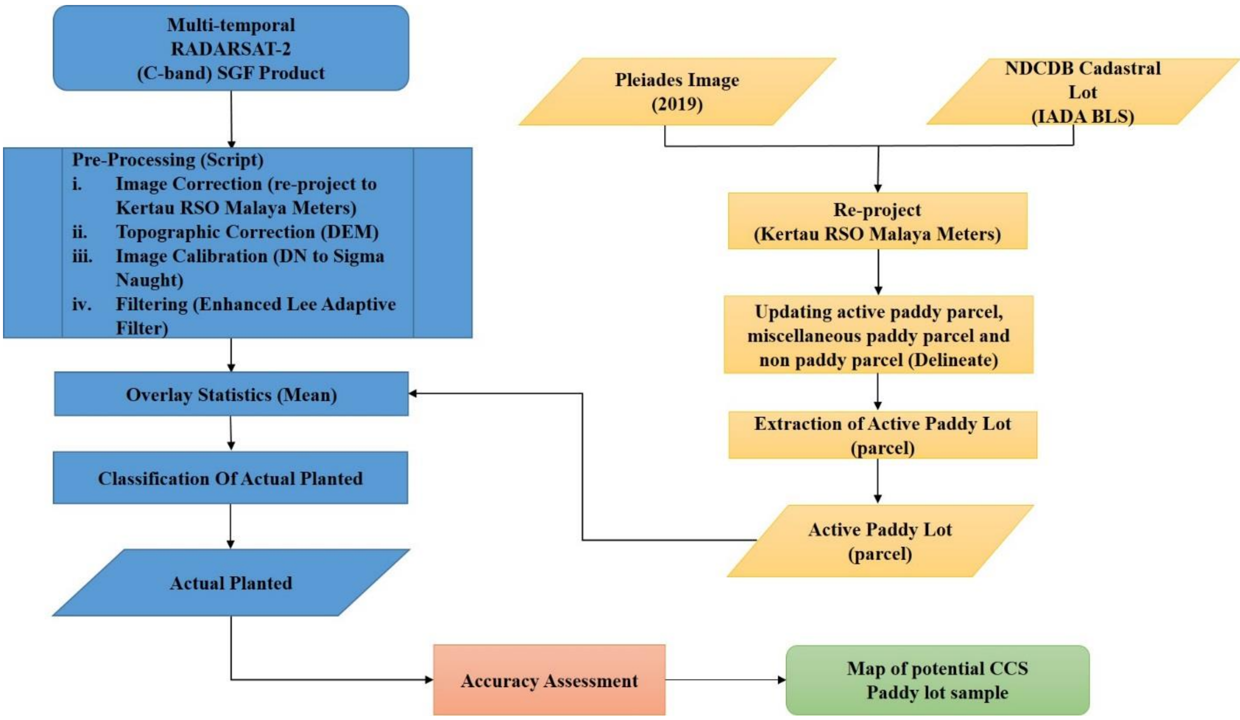


Figure 2: Methodology flowchart to extract potential CCS paddy lot sample

2.3.1 Image Geometric Correction

Geometric corrections are made to correct the inconsistency between the location coordinates of the raw image data, and the actual location coordinates on the ground or base image (Chintan et al,.2015). Geometrically corrected imagery can be used to extract accurate distance, polygon area, and direction (bearing) information (Chintan et al, .2015).The multi-temporal SAR Georeference Fine (SGF) RADARSAT-2 (ascending) images was used and geocoded into Rectified Skew Orthomorphic (RSO) Malaya Meter to match with the cadastral lot for overlay processing.

2.3.2 Topographic Correction

Topographic correction is essential pre-processing step in satellite imagery of any satellite to remove the topographic effects such as different illumination due to irregular shape of mountain regions and results in leading to an inaccurate classification into different land cover classes due to different topographic positions (Sartajvir et al,. 2012). DEM provides basic topographic information of the target area of the scene to facilitate specific algorithm to reduce the topographic effects of the scene. This study was used digital elevation Model (DEM) at 30 m resolution as input variable for paddy classification such as land cover related information and many studies have used elevation data as input variable for land cover classification.

2.3.3 Image Calibration

The image digital numbers were converted to backscatter coefficients (dB) to facilitate making absolute comparison behavior of rice as a function of time (Shao et al., 2001). We run the conversion using Equation (1):

$$\sigma^{\circ}=10*\log_{10}DN^{2} \tag{1}$$

Where DN is the digital number of the Radarsat-2 image.

2.3.4 Filtering

High quality images of Earth produced by synthetic aperture radar (SAR) systems have become increasingly available, however, SAR images are difficult to interpret. Speckle reduction remains one of the major issues in SAR imaging process, although speckle has been extensively studied for decades. For speckle reduction filters, it is important to know whether the speckle noise process is stationary or not white or correlated noise (Shuyan Lang et.al, 2016). Enhance Lee Adaptive Filter, one of the well-known despeckling filters, was applied in this study to remove noise with 3 x 3 window size.

2.4 Image Processing

2.4.1 Updating Paddy Parcel

Cadaster lot were used to identify actual planted paddy area using Pleaides images. Paddy Parcel was delineated into active paddy parcel, miscellaneous paddy parcel and non-paddy parcel (DOA, 2004). This process was done together with DOA and IADA Barat Laut Selangor as an authority department regarding to the study area.

2.4.2 Extraction of Sigma Naught

In the PCI Geomatics (Overlay Statistics) environment, the cadastral lot was overlay with Radarsat-2 images to extract the sigma naught by individual lot. The mean statistical function was used for statistical analysis.

2.4.3 Image Classification

In the ArcGIS Software, the value of sigma naught was classify into two (2) different classes, which are planted and not planted for each individual lot for the purpose of monitoring the actual planted of paddy planting reflected to the paddy crop calendar.

2.5 Accuracy Assessment

Classification accuracy is the main measure of the quality of thematic maps produced and required by users, typically to help evaluate the fitness of a map for a particular purpose. The accuracy of image classifications has also been central to studies that have sought to evaluate different classification approaches and a suite of issues connected with class discrimination. Although seemingly a simple concept, classification accuracy is a very difficult variable to assess and is associated with many problems (Foody 2002). For the accuracy assessment, all of the ground data points, the standard deviation value from multi- temporal Radarsat-2 images were utilized. A total of 120 sample points were located using stratified random sampling for two classes (Planted Paddy Parcel and Not Planted Paddy Parcel), where the number of points is stratified to the distribution of the classification classes.

3. RESULT AND DISCUSSION

3.1 Crop Phenology

The backscattering coefficient (dB) value for paddy and other crops are clearly distinct as seen in Figure 3. The dB value was recorded low at 20 day of planting (DoP) and high at 100 DoP for paddy crop. The low dB value could be attributed to the irrigating activities, while the high dB value could specify the presence of paddy crops such as during the planting phase. The phenology for the other crops such as oil palm, vegetable, silver shine, plant cover and fruit tree were consistently high between -5 to -11 dB. Therefore, the unique phenological changes of paddy crops especially during irrigating stages can be utilized for discriminating between paddy crop and other crops and objects.

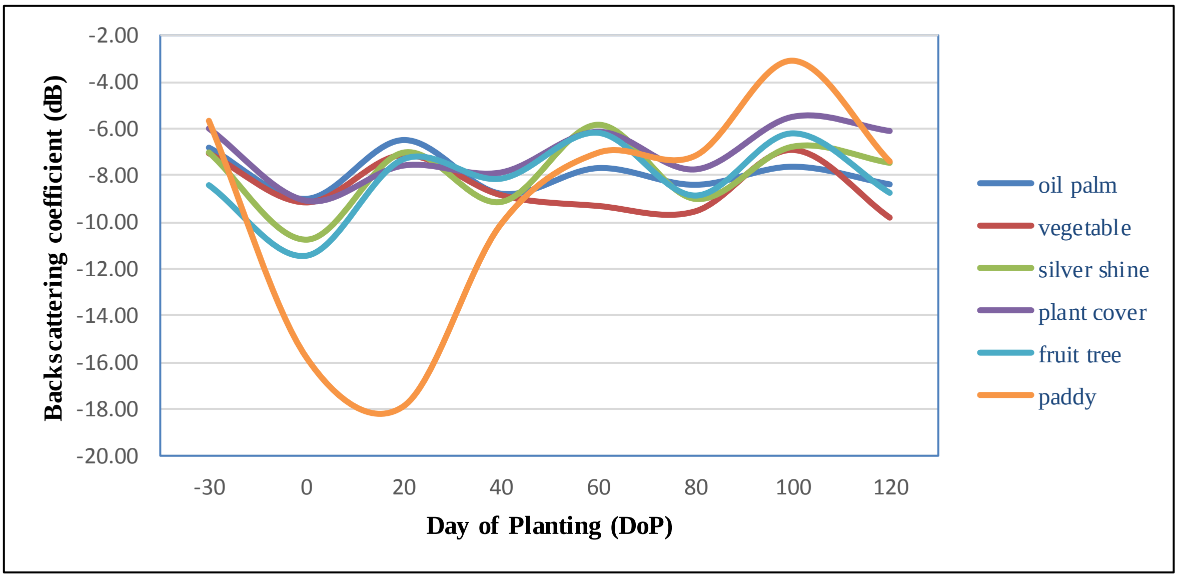


Figure 3: Comparison of Radar Backscattering Value for different Crop Type

3.2 Standard Deviation in Backscattering Coefficient

Figure 4 shows the standard deviation trends for samples collected for both off and main season. Meanwhile, Table 3 indicate the standard deviation and ground verification pictures. Result indicates low standard deviation (< 1) shows that the data points tend to be very close to the mean and a high standard deviation (≥1) indicates that the data points are spread out over a large range of values. The standard deviation was derived from backscattering coefficient data where the dB value during ploughing that was between -10 to -7, irrigation which is from -11 to -23, the middle growth stage after 45 DoP, which is from -6 to 0 and harvesting period, where a decrease in dB was noticed (Minh et al., 2019), which is from -10 to -5, the dB value was quite similar to ploughing activities, since the paddy areas turns into bare and dry field or covered with paddy straw. Therefore, rice crop calendar is crucial to avoid miss classification (Nguyen & Wagner, 2017). The dB value start drop to during irrigation, which is from -11 to -23, water surfaces are homogenous, causing reflected radar pulses to be weak (Tian et al., 2018). The overall results demonstrate that standard deviation for planted status in active paddy parcel greater or equal to 1 (≥1) while standard deviation less than 1 (< 1) will indicates the parcel was not planted with paddy. Crop cutting survey handbook indicated that finding a parcel that have planted with paddy were crucial in determining the CCS sample lot and if the parcel were not planted, they need to find other substitute lot (DOA, 2004).

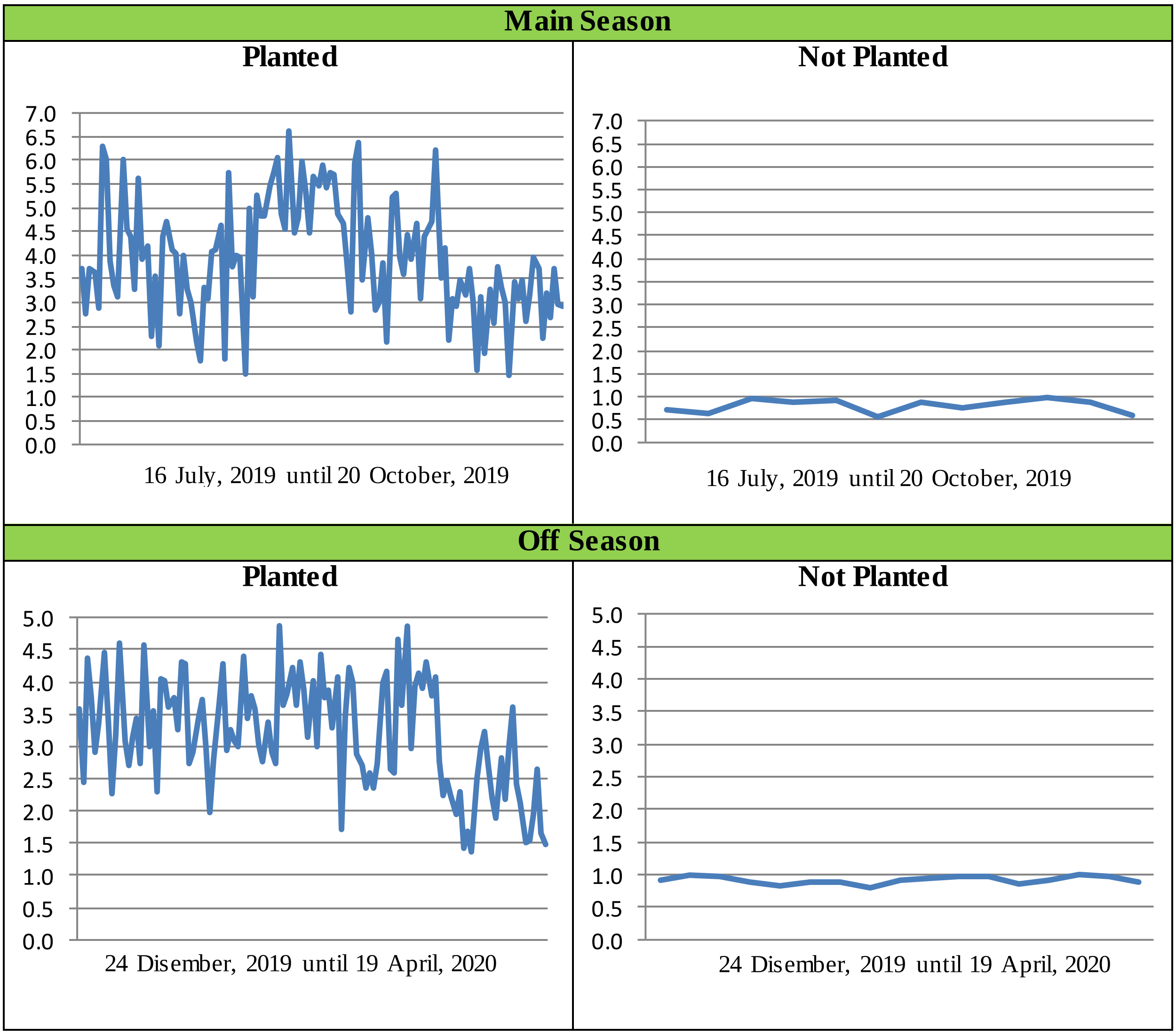
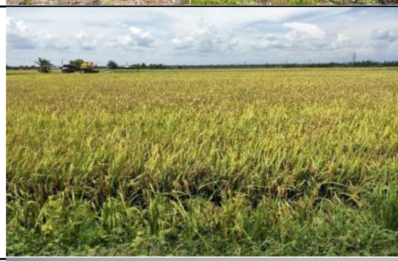


Figure 4: Standard Deviation trends of lot samples for 2 classes (Planted or Not Planted) during planting season

Table 3: Standard Deviation in Backscattering coefficient range of paddy parcel

Paddy Parcel Planted Status	Standard Deviation (σ)	Ground Characteristics	
Planted	3.5811		
Planted	6.8005		
Not planted	0.9918		
Not planted	0.9161		

1.1 Crop Cutting Survey Paddy Sample Map and Accuracy Assessment

Figure 5 shows the capability of multi-temporal Radarsat-2 images in classifying potential Crop Cutting Survey Paddy Sample Map using the standard deviation derived from dB range as identified in table 3. The map was derived from the paddy parcel planted status for both main and off season. Potential CCS sample lot were determine if both season were planted with paddy. For accuracy assessment, 120 sample were collected for both main and off season. The overall classification accuracy reached 97.5% and the map indicate that 98.5% of the paddy parcel lot is suitable for Crop Cutting Survey Sample.

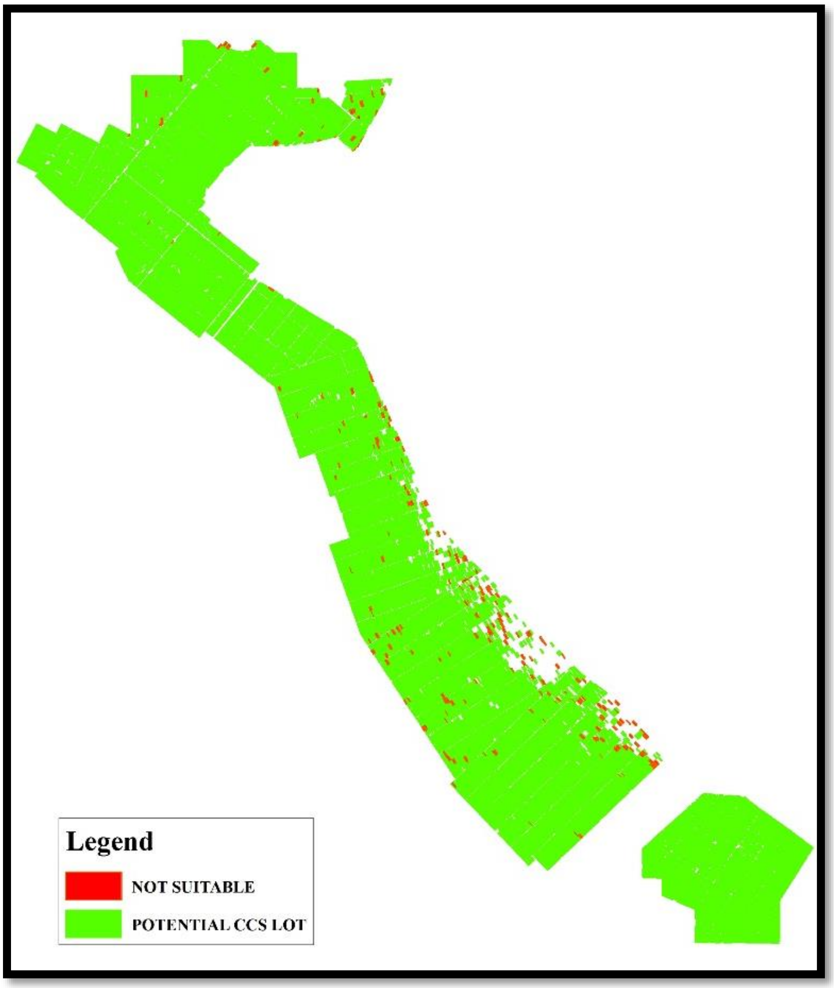


Figure 5: Potential Crop Cutting Survey Paddy Sample Map

Table 4: Accuracy Assessment

Class	*Main Season*	*Off Season*	*Overall Accuracy*
Planted	119	115	97.50%
Not Planted	1	5	2.50%
Total	120	120	

As shown in table 4, the overall accuracy achieved were 97.50% for actual planted paddy classification. From table 3, not planted sample were verified as vegetables crops like ladies fingers and yam and were planted during off season. There were planted sample which were verified as oil palm and thus will hinder the process of CCS lot selection as the agriculture officer on field need to find a substitute lot (DOA, 2004). Thus, selection of CCS sample lot from the Potential Crop Cutting Survey Sample Map will reduce the selection process. CCS process is a long process of finding suitable lot, carrying the survey such as paddy varieties, sowing techniques and fertilizer application but the process can be simplify by introducing satellite based technologies to the survey as it will provide fairly accurate paddy area especially in vast geographic area (FAO, 2018).

4. CONCLUSION

This study indicate that Radarsat-2 time-series images were highly beneficial in differentiating actual paddy planting and determining the CCS paddy lot sample with an accuracy of 97.50%. This accurate actual planted paddy planting and classification are the requirement of agricultural management and policy-making. More study need to be done regarding digitizing the CCS techniques in Malaysia with inclusion of satellite based technologies, GIS and Web-based System. The effectiveness study by DOA shown that the monitoring through satellite images saves time by 50% compared to field survey and monitors 100% of the total granary.

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