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Object-Based vs. Pixel-Based Classification of Mangrove Forest Mapping in Vien An Dong Commune, Ngoc Hien District, Ca Mau Province Using VNREDSat-1 Images

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Abstract

Many researches have been performed comparing object-based classification (OBC) and pixel-based classification (PBC), particularly in classifying high-resolution satellite images. VNREDSat-1 is the first optical remote sensing satellite of Vietnam with resolution of 2.5 m (Panchromatic) and 10 m (Multispectral). The objective of this research is to compare two classification approaches using VNREDSat-1 image for mapping mangrove forest in Vien An Dong commune, Ngoc Hien district, Ca Mau province. ISODATA algorithm (in PBC method) and membership function classifier (in OBC method) were chosen to classify the same image. The results show that the overall accuracies of OBC and PBC are 73% and 62.16% respectively, and OBC solved the "salt and pepper" which is the main issue of PBC as well. Therefore, OBC is supposed to be the better approach to classify VNREDSat-1 for mapping mangrove forest in Ngoc Hien commune.

Keywords

Object-Based Classification, Pixel-Based Classification, VNREDSat-1, Mangrove Forest, Ca Mau

1. Introduction

The visual interpretation combining with pixel-based classification (PBC) basing on *in-situ* ground truth collection used to be the most common approach to classify remote sensing images. This method is easy to carry out and provide the results quickly but it

depends strongly on the experience of interpreters and often faces a lot of obstacle, particularly when being used with high-resolution images. Recently, object-based classification (OBC) has been considered as the answer for the subjectivity of visual interpretation [1]. In 2000, Walter and Fritsch proposed OBC for the first time, basing on view point that: human vision can distinguish the thematic objects through groups of image pixels [2]. The rapid development of this approach was confirmed broadly and since then, OBC has become more and more popular in high-resolution image classification [3] [4] [5].

In comparing with PBC, OBC has two main differences. Firstly, the algorithms of OBC are operated basing image objects, which are groups of pixels having spectral similarity, not single pixels like PBC. Secondly, classifiers of OBC are flexible ones using fuzzy logic, which is a mathematical approach to quantify uncertain statements, instead of exact identification. This classification uses membership functions to assign each object to suitable class. A membership function (with a range covering the interval (0, 1)) runs on the domain of all possible values, where 1 expresses a complete assignment to a class and 0 expresses absolutely improbability. The degree of membership depends on the extent to which the objects meet the class given conditions. As such, comparing with PBC, the classification result of OBC is more visual, can imitate the perceptual ability of human eyes and can describe the unity of land covers, so the interpretation and the identification of image object become easier also [6].

There have been many studies conducted to compare the results of two classification techniques. Robert C. Weih *et al.* used both OBC and PBC to process SPOT 5 image, and the overall accuracies of PBC and OBC provided by this research are 78.2% and 82%, respectively [7]. According to Dingle Robertson *et al.*, it is very easy to see that OBC produces the better classification result, particularly where land cover is homogenous, therefore performed better in temporal analysis of land cover change [8]. However, the finding of Whiteside *et al.* indicated that even with spatially heterogeneous land covers, which are represented by a lot of single pixels on image, the accuracy of PBC is lower than OBC also, because the scattered distribution of pixels in classification result of PBC lead to the mismatching between ground truth points and the pixels classified into that class [9]. In addition, OBC is supposed to be the appropriate technique to identify land cover type which has clear border such as agricultural land, while the advantage of this method is not so distinct when being applied on class having not so clear boundary [10]. Moreover, Zu-Tao Ouyang *et al.* assessed the accuracy of OBC and PBC after classifying Quickbird image and this author noted that the advantages of OBC dominate ones of traditional classification, especially with high and very high resolution images [11]. Also, according to Dennis *et al.*, comparing with PBC, OBC shows the dominance of ability to describe a general shape of land cover [12].

In Vietnam, OBC has been applied broadly for forest mapping in recent years. Tran *et al.* (2014) used OBC and SPOT 5 images to discriminate 7 forest statuses for 4 communes in Huong Son district, Ha Tinh province [13]. In addition, Nguyen *et al.* used SPOT images to assess land use/land cover change in Tien Yen district, Quang Ninh

province by OBC, which was applied to classify 9 land cover types from images achieved in 3 dates: 2000, 2005 and 2010, and the overall accuracy is above 80% [14]. Furthermore, Vu (2011) used OBC which runs basing on open source software for forest cover mapping in two districts in Son La and Hoa Binh provinces [15]. Trinh *et al*. compared OBC with PBC in processing Worldview 2 image which has very high spatial resolution 46 cm [16]. The finding revealed that the overall accuracies of OBC and PBC are 81% and 73%, respectively. However the comparison is very simple, mainly basing on error matrix calculated from 30 ground truth points. Few reports focus on mapping mangrove forest in the South of Vietnam [17] [18] and analyzing the spectral discrimination of common mangrove species in Ca Mau province [17].

VNREDSat-1 is the first optical Earth Observing satellite of Vietnam, which was launched into the orbit on May 7, 2013. Its primary mission is to monitor and study the effects of climate change, forecast and take measures to prevent natural disasters, and facilitate the management of Vietnam's natural resources. Having similar spatial resolution with SPOT 5 image, 2.5 m (Panchromatic) and 10 m (Multispectral), VNREDSat-1 is considered as high resolution remote sensing data.

The objective of this research is to compare two classification approaches using VNREDSat-1 image for mapping mangrove forest in Vien An Dong commune, Ngoc Hien district, Ca Mau province, where has the largest remaining area of mangrove forest, with high fragmentation and scattered distribution along the coast. This study is not only the first one using data provided by Vietnamese satellite for mangrove forest mapping, but also the first one applying both PBC and OBC on VNREDSat-1 image. And the result is expected to provide user orientation for this very first remote sensing data of Vietnam.

2. Study Area

Vien An Dong is a commune belonging to Ngoc Hien district, Ca Mau peninsula with area of 135.67 km^2. The topography here is relatively flat, but strongly separated by interlacing river and canals system. Similarly to other regions in Ngoc Hien district, this area is directly affected by the local tide regimes (uneven tide) which is high tide every year, coinciding with the dry season (from November to April next year), creating favorable habitats for many species. In terms of forest ecosystem, major mangrove species here are Avicennia and Rhizophora. Regarding general distribution based on landscape characteristics, the Avicenna genus dominates the outermost coastal belt of the mangrove forests coping with high or medium tides and high levels of salinity. Hence, it is generally considered as the pioneers of mangrove ecosystems. The majority of mangrove area in this study site is however (re)planted and mainly homogeneous Rhizophora forests (**Figure 1**).

3. Data and Methods

3.1. Data

The mangrove forest mapping of Vien An Dong commune was carried out basing two

VNREDSat-1 images achieved in October and November 2013, which acquired by purchased from the National Remote Sensing Centre. These two images were registered in VN2000 coordinate system and the pre-processing of VNREDSat-1 image was performed by ENVI software (Table 1).

3.2. Methods

Basing on the research objectives and the ability to provide information about the land covers of VNREDSat-1 image, land cover classification category was compiled including 7 types: high-density mangrove forest; medium-density mangrove forest; low-density mangrove forest; shrubs and young mangrove tree; settlement; aquaculture; water body, and no data (clouds and shadow of cloud). In this study, unsupervised classification (for PBC) and membership function (for OBC) were selected to classify VNREDSat-1 image (Figure 2). Both OBC and PBC are applied on high spatial resolution image (10 m).

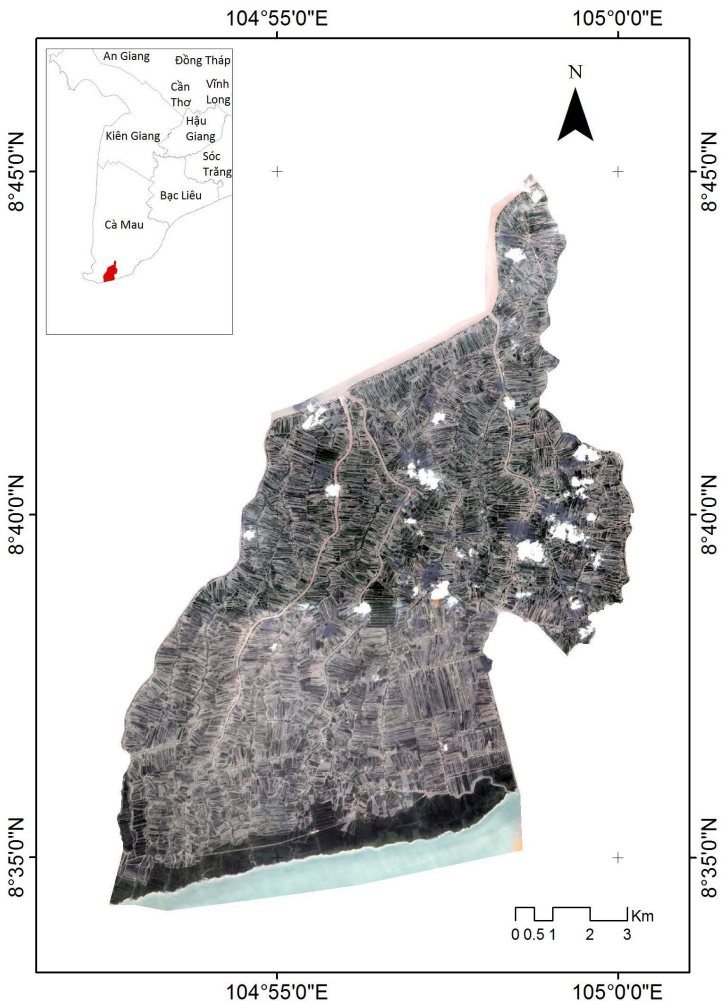


Figure 1. True color composite VNREDSat-1 image for Vien An Dong commune, Ngoc Hien district.

Table 1. The bands of VNREDSat-1 image.

Band	Wavelength
PAN	0.45 - 0.75 μm
4 bands	• Band 1: 450 - 520 nm (Blue) • Band 2: 530 - 600 nm (Green) • Band 3: 620 - 690 nm (Red) • Band 4: 760 - 890 nm (NIR)

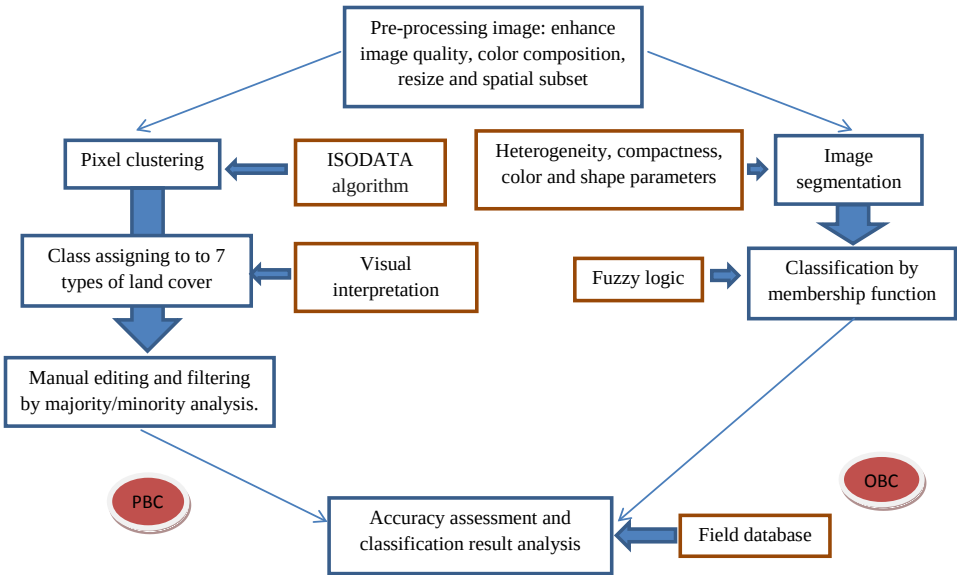


Figure 2. Procedure of mangrove forest mapping using VNREDSat-1 image by OBC and PBC.

3.2.1. Pixel-Based Image Classification Approach

PBC is operated basing on spectral characteristics of single pixel such as average DN value, maximum and minimum DN value, variance or standard deviation. Two main classification methods of PBC are supervised and unsupervised classification. The unsupervised classification method based on natural groupings of the spectral properties of the pixels, without the user specifying how to classify any portion of the image. Number and name of the classes are relatively determined.

In the unsupervised classification method, the most important step is grouping pixels. This is the process to group pixels having spectral similarity, called clustering algorithm. This technique includes two types: hierarchical and non-hierarchical. The hierarchical clustering criterion is based exclusively on the spectral information of each object, in this case a set of image pixels or class. Pixels are grouped till the spectral distance is the shortest and the required cluster is reached. For non-hierarchical method, the process begins with number of clusters is assigned temporarily, and then the pixels are analyzed and merged till the separation among clusters is the highest. Afterward, the centers of clusters are calculated again and the number of clusters could be adjusted. This process run until the number of clusters becomes stable. The ISODATA is one of the basic iterative optimized algorithms, the most widely one used for non-hierarchical

clustering. The main parameters needed to run ISODATA classification are the minimum and maximum numbers of clusters, the maximum number of iterations and a convergence threshold value. The process will stop when the percentage of change of cluster is smaller than convergence threshold. To classify VNREDSat-1 image for Vien An Dong commune, we chose 100 number of classes and 15 iterations. The ISO-DATA method is flexible in processing, and has ability to eliminate class which is too small; and to merge similar classes into a larger one. This algorithm is very useful in identifying spectral classes of data.

When the automatic clustering finishes, we has 100 clusters which are assigned to 7 types of land cover. And then, to improve the accuracy, the classification results will be manual edited and filtered by majority/minority analysis [19]. The aim of this step is to merge single pixels and confused pixels into classes containing them. The level of filter depends on the filter window-Kernel Size, in which the center pixel in the kernel will be replaced with the class value that the majority of the pixels in the kernel has. Window filter (size 3 × 3 pixels) is selected to majority analysis for post classification processing.

3.2.2. Object-Based Image Analysis

OBC uses not only reflectance spectral of objects but also other information such as structure, size and shape. The principle of this method is creating thematic objects including group of pixels which human eyes can distinguish. OBC has two typical characteristics. Firstly, the preliminary step of OBC is segmenting image into pixel groups basing on homogeneity, structure and shape and producing image objects. These objects are the basic unit of image processing, not single pixel. Another characteristic is hierarchical inheritance, it means that each class can include sub-classes. So although each class is classified by a different algorithm, classes in a same group will inherit the common characteristics of the group.

Besides, the OBC has another advantage is fuzzy logic. Fuzzy logic is applied to assign objects to defined classes. In fact, the boundary of land cover is difficult to determine, and is considered to be "fuzzy", so identifying them on remote sensing image is increasingly challenging. In terms of fuzzy logic, it takes advantage of similar probability between an object with defined training sample or selected threshold for determining suitable class for this object. Fuzzy classification is one of soft classifiers and it is widely used with high resolution image [20]. This soft classifier takes into account the uncertainty of the classification results.

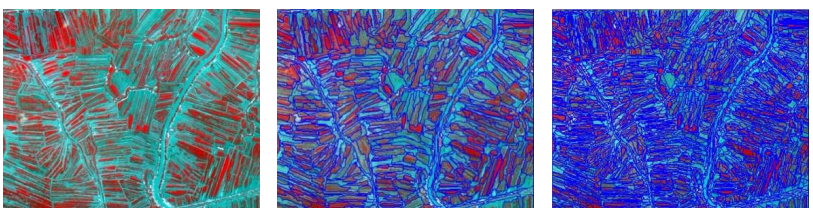
Generally, OBC includes two main steps. The first step is segmentation basing on some parameters such as heterogeneity, compactness, color and shape. Scale parameter is the most important one in segmentation. It is understood as the extent of detail of segmentation and it decides the size of objects and whether it includes more or less sub-objects. The next step is classification. There are two main methods of classification basing on fuzzy logic: classifying by membership function (is called threshold classification) and nearest neighbor classifier (is called sampled classification) [21]. Nearest neighbor classifier uses a group of training samples. The basic principle of this approach is selecting sample object representing for each class and then running the algorithm to find

similar objects regarding spectra, structure and shape. Meanwhile, membership function uses the rule set including criteria which are created to distinguish an object with others if they belong to different classes. This rule set bases on the membership function to describe the threshold of the parameters such as spectra, shape, structure, and spatial relations with other objects. In this study, threshold classification is selected for process VNREDSat-1 image because this technique is considered as the similar one to un-supervised classification of PBC, while sampled classification of OBC is equivalent with supervised classification (**Figure 3**).

Image segmentation was conducted two times, corresponding to two hierarchical levels. The first one has aim to discriminate vegetation and non-vegetation classes basing on threshold of NDVI. When this step finishes, the second level runs to identify sub-classes of non-vegetation class such as Aquaculture, Settlement... and the sub-classes of the vegetation one including high-density mangrove forest; medium-density mangrove forest; low-density mangrove forest; shrubs and young mangrove tree basing on GNDVI and Maxdiff. Finally, the third hierarchy is to re-divide the classes before manual editing. The rule set is shown in **Figure 4**.

4. Results and Discussion

PBC and OBC results are depicted in **Figure 5**. It is very easy to see that being compared with the results provided by OBC, the result of PBC shows "salt-and-pepper" appearance which occurs when small areas of anomalous pixels cause the noise of image even after applying majority filter. Also, OBC results describe the continuity of the land cover and this point is considered as advantages and disadvantages of this approach at the same time. Because in PBC, very small and separated pixels different from their neighbors would represent as "salt and pepper", and they may be classified correctly or mistakenly. Those correctly classified "salt and pepper" would be useful to describe land cover types having scattered distribution, while OBC reduces the "salt and pepper" effect by merging pixels into neighboring objects, and this generalizations may lead to losing some important detail information. Therefore, the scattered land cover like shrub tend to be generalized, and merged into a larger adjacent class if this class and shrubs do not have the clear discrimination about spectral and shape. In other words, classes which do not have the clear border and homogeneous distribution like shrub show the drawback of OBC and this statement agrees with finding of Gao and Mas [10].



Fasle color composition VNRED Sat-1 image | Scale: 50 , Shape: 0.2 Compactness: 0.5 | Scale: 20, Shape: 0.5 Compactness: 0.2

Figure 3. VNREDSat-1 image with two levels of scale, shape and compactness.

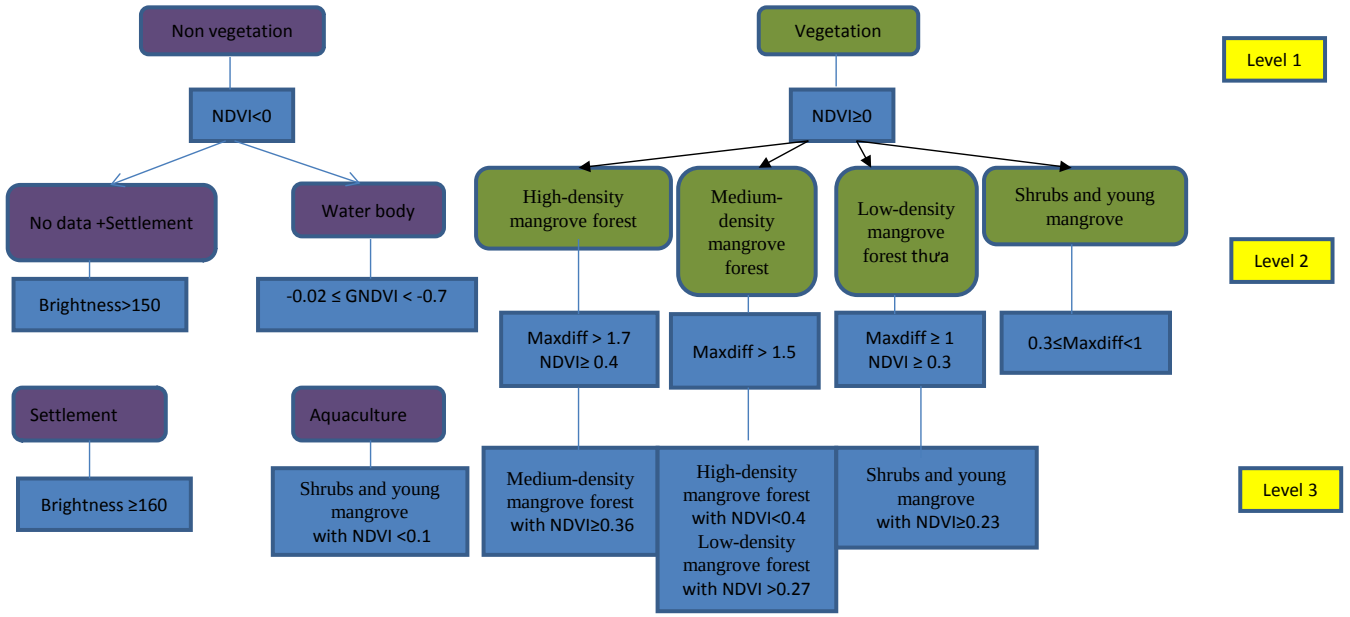


Figure 4. The rule set to classify VNREDSat-1 image.

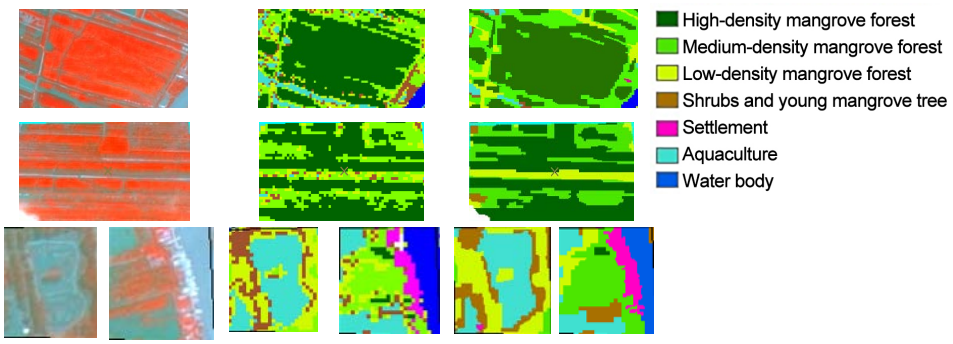


Figure 5. Classification results.

In this study, an evaluation classification was carried out based on 74 samples collected from field trip in 2015 and in order to determine accuracy of classification results, confusion matrixes were calculated for both PBC and OBC approaches. Comparisons of the accuracy assessment showed that OBC analysis attains higher overall accuracy and higher land cover class accuracy (producer's accuracy and user's accuracy) for most of the classified land cover class. As we see in Table 2, the overall accuracy for PBC and OBC are 62.16% and 73% respectively. Similarly, the Kappa coefficient of PBC (0.59) is lower than one of OBC (0.7) also. In terms of PBC, information classes of Settlement, Aquaculture and Water body have both high producer's and user's accuracy while ones of low-density mangrove forest, medium-density mangrove forest and shrubs and young mangrove tree are relatively low. The reason is the confusion between 2 pairs: shrub/low-density mangrove forest and low-density/medium-density mangrove

forest. For example, high percentage of the Shrub is incorrectly identified into low-density mangrove forest. Besides, a large proportion of low-density forest is classified as medium-density forest and high-density forest as well, causing the lowest accuracy of this class. In the same way, regarding OBC, low-density and medium-density forest have the highest percentage assigned to incorrect classes. Moreover, the user's accuracy of water body is reduced because of the confusion of this class with Shrub as well.

Although theoretically, PBC has higher extent of spectral uniformity because it is operated mainly on spectra of pixel, **Figure 6** shows the revert phenomenon. Five classes from classification results provided by OBC and PBC were extracted to ROI in order to calculate the standard deviation of DN from 12 bit VNREDSat-1 image. As we can see, between two approaches, almost the classes identified by PBC have the higher

Table 2. Accuracies of PBC and OBC.

	(PBC)		(OBC)	
	Producer's acc	User's acc	Producer's acc	User's acc
High-density mangrove forest	57.14	66.67	64.29	75
Medium-density mangrove forest	60	56.3	64.71	68.75
Low-density mangrove forest	42.86	42.86	60	64.28
Shrubs and young mangrove tree	64.71	55	87.5	70
Settlement	100	100	100	100
Aquaculture	71.43	100	100	80
Water body	100	100	83.33	100
	Kappa coefficient = 0.59 Overall Accuracy = 62.16%		Kappa coefficient = 0.7 Overall Accuracy = 73%	

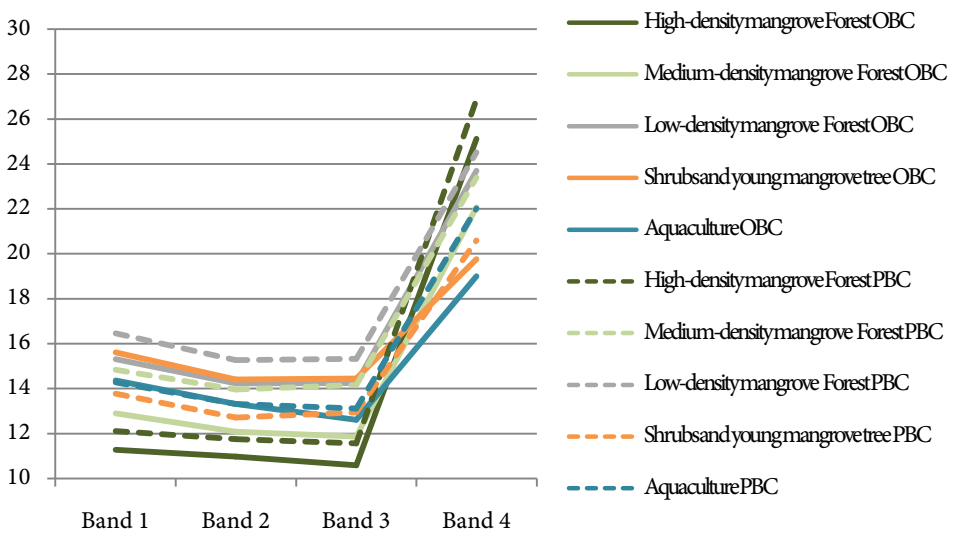


Figure 6. Standard deviation of five classes from OBC and PBC results on 4 bands of VNREDSat-1 image.

standard deviation of DN, except shrub. In other words, shrub of OBC has very low extent of spectral uniformity, so it confirmed again that this class reveals the disadvantage of OBC. High-density forest shows the highest homogeneity of DN value in both PBC and OBC while the lowest ones belong to shrub and low-density forest. This finding is matched with accuracy of classification results mentioned above also. Furthermore, among 4 bands, near infrared one performs the least extent of spectral uniformity in both OBC and PBC, while the vegetation identification mainly bases on this band, so this can be considered as an obstacle for forest mapping. Therefore, it needs to further analysis the rule set of OBC, including the indexes in terms of structure, shape and relationship with neighboring objects to facilitate forest mapping.

5. Conclusions

The results showed that OBC classifier produced a higher overall accuracy (73%), whereas the output of PBC produced 62.16%. As we can see through the producer's and user's accuracy, regarding water body, settlement area and aquaculture, both of two approaches perform good classification results. However, OBC provides the better ability to classify forest statuses and the outputs of OBC show the higher extent of spectral uniformity. Besides, because the characteristic of OBC is using parameters such as heterogeneity, compactness, shape, so for the high homogeneity class as High-density forest, this classification method shows the outstanding advantage. Meanwhile, in term of land cover type having high fragmentation, PBC seems to be the more effective technique. In addition, algorithms of PBC run basing on single pixels, so the result provided by this method is influenced strongly by "salt and pepper" effect, although the filters were applied. In terms of OBC, when segmentation image is operated, the structure and shape of objects have been taken into account, so this approach shows its strengths and is more advantageous than PBC to process VNREDSat-1 image for forest mapping in Vien An Dong commune, where mangrove forest is characterized by high fragmentation.

In next research plan, to improve the accuracy and ability to analyze image objects of OBC, rule set should be developed more, including the conditions of the structure, shape and relationship with neighboring objects. At the same time, combining with field data, the understanding of study area and reference data would increase classification accuracy of both PBC and OBC also.

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