Using WorldView-2 Imagery for Leucaena leucocephala mapping in Hengchun Peninsula, Taiwan

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ABSTRACT: *Leucaena leucocephala* is one of the invasive species in Taiwan which caused significant impact to local ecosystems and biodiversity especially in Hengchun Peninsula. In order to make this problem under control, it's necessary to understand the status and spatial distribution of Leucaena leucocephala for developing strategies to maintain local biodiversity. Traditionally, field investigation or manual interpretation on aerial photos is applied to map the growth area of this plant, but it is very time-consuming. For make this work more efficient, some automatic image classification methods are developed recently, but there is not enough information for detecting *Leucaena leucocephala* in the limited spectral bands.
Comparing to four traditional bands imagery, WorldView-2 satellite imagery introduces four new bands namely Yellow, Red edge, Coastal and NIR2. This paper aims to explore the contribution of the four newly added bands of WorldView-2 imagery to increase the class-pair separability of vegetation types. This study showed that the four newly added bands in WorldView-2 imagery are helpful to detect the *Leucaena leucocephala* during the dry season with band combination of NIR2, Red Edge and Yellow. Object-based image classification is practiced to classify the different vegetation types by using the spectral information of WorldView-2 and vegetation indices as feature. Experemental results demonstrate that the eight bands of WorldView-2 increase the overall classification accuracy over the case when only four traditional bands are utilized.

1. Introduction

Biological diversity is important to our ecological. The more abundant the species is, the more robust the ecosystems is. However, many kinds of alien species lack natural enemies, it cause great threat to native biological. Taiwan is located between the subtropical and tropical, rich in native plant species. Recently, some alien species which is easily breed and rapidly expanding, impact the local ecology. To prevent exotic species from invading local ecosystems, Long-term monitoring of the growth trend and the spatial distribution is an efficient way to develop prevention strategies. Traditionally, this task relies on field-based investigations that are usually time-consuming and very expensive. Remote sensing data with large ground coverage can provide spatial information of alien plant; this offers managers an effective tool to monitor this problem. The image classification technique in remote sensing is benefit to identify these alien species automatically and rapidly.
Leucaena leucocephala is one of the most serious invasive plant species and has colonized a great portion in the Heng-Chun peninsula in Taiwan. Recently, there are many studies related in the topic about *Leucaena leucocephala* classification using the high resolution satellite image in Taiwan, for example: SPOT(Chen, 2005; Chung & Lu, 2006; Kou, 2008), QuickBird(Tsai & Chou, 2006), IKONOS(Lee, 2003).
With the development of the satellite of remote sensing, the spatial and radiometric resolution of satellite image is increased dramatically providing more information to help us to identify the detail on the ground. The WorldView-2 imagery is used to classify the *Leucaena leucocephala* in this study. We choose Hengchun Peninsula as the study area because *Leucaena leucocephala* is the most widespread of alien invasive species on this area. From the imagery covered this area, we select a small portion of 1.6 km^2 to classify the image and evaluate the classification accuracy. The result showed that the new bands of WorldView-2 (Coastal, Yellow, Red edge and NIR2) can help to identify the *Leucaena leucocephala* in dry seasons. The Taiwan acacia can be easily distinguished from *Leucaena leucocephala*, while combining the common vegetation index SR and NDVI with eight band of WorldView-2. We collected the field survey data as ground truth data. It showed that the classification accuracy with WorldView-2 8 bands imagery

is higher than traditional 4 bands(Red, Green, Blue, NIR) verified with the ground truth data.

2. Study Area

The site of the study area – Hengchun peninsula is located in the southern Taiwan including part of the Kenting National Park. It is surrounded by the Pacific Ocean, the Taiwan Strait, and the Luzon Strait. Hengchun peninsula is part of the area southern extending from the Central Mountain Range in Taiwan, has a rich population of vegetation. The weather is like spring all the year within the study area. Seasonal rainfall concentrated in the June to September and it is relatively dry in winter and spring (October to the following year in April).

The main land cover in Hengchun peninsula is woodland and agricultural land. The dominant species of wild plants in this area used to be Taiwan acacia (*Acacia confusa*). *Leucaena leucocephala* was imported to Taiwan and had been developed for a wide range of economic applications in the past, like papermaking, animal forage, firewood and construction etc. But it was abandoned later and replaced by others material because of the Industrial restructuring. *Leucaena leucocephala* is a fast-growing deciduous tree. Because of its allelopathy and superior acclimation, it rapidly invaded local vegetation communities and gradually became a dominant species. We select a test area about 1.6 km^2 in Hengchun peninsula to perform image classification. The diagrammatic sketch is showed as Figure 1.

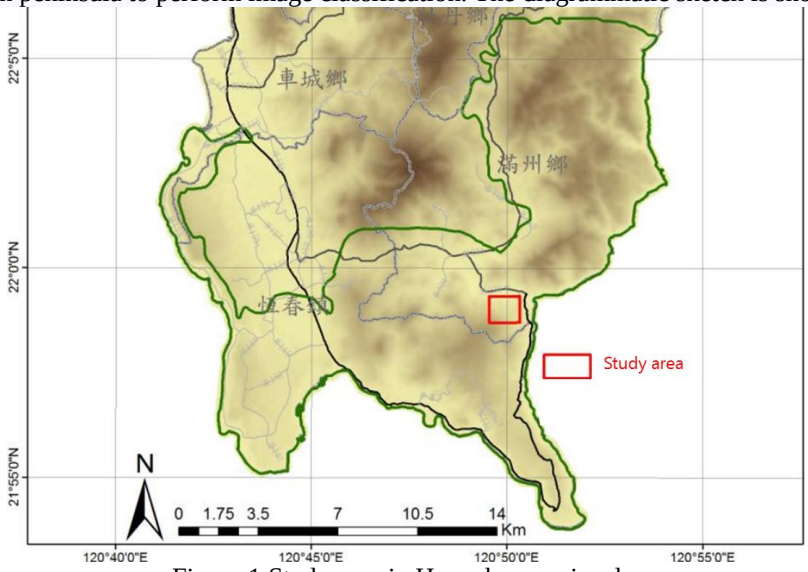


Figure 1 Study area in Hengchun peninsula.

3. Basic features of *Leucaena leucocephala*

Leucaena leucocephala, as a deciduous arbor, belongs to the family of mimosa which may grow to heights of 4-18 m breeds extremely fast. It leases mimosine that damages and hinders the growth of other species. *Leucaena leucocephala* will lose leaves in the dry seasons and the brown flat pods leave. We can see the plant is covered with brown color that can help us to identify the *Leucaena leucocephala* on satellite imagery (as Figure 2). The flat pods of *Leucaena leucocephala* which crack open automatically upon maturity are transferred with wind, making it difficult to stop its spreading. The purity of *Leucaena leucocephala* bushes is very high in the sense that virtually no other plants are found in these areas, resulting in poorer ecological adjustments and affecting the original environment strongly.

Figure 2 Brown *Leucaena leucocephala* in dry seasons.

4. Material

The main objective of this study is to explore how 8 bands multispectral image is benefit to classify *Leucaena leucocephala*. The primary material to analyze in this study is WorldView-2 multispectral high resolution satellite imagery. It is the first commercial satellite able to provide panchromatic imagery at 46 cm of spatial resolution and 8-band multispectral imagery at 1.84 m spatial resolution, launched by DigitalGlobe® . In addition to the standard multispectral BLUE, Green, RED and NEAR INFRARED 1 (NIR1) bands, the WorldView-2 sensor has for new bands COASTAL, YELLOW, RED EDGE, and NEAR INFRARED 2(NIR2). Bands characteristic is mentioned in official documentation (DigitalGlobe, 2010), COASTAL band(400~450nm), planned for bathymetric studies, for water color analyses; YELLOW band(585~625nm), significant for the "Yellowness" of vegetation; RED EDGE band(705~745nm), strategically centered at the onset of the high reflectivity portion of vegetation response so potentially significant in the measurement of plant health; NIR2 band(860~1040nm), partially overlapping the NIR1 band and sensitive to atmospheric water vapor absorption.

The WorldView-2 image use in this study was acquired in Oct, 2011. This is dry seasons in Hengchun peninsula, *Leucaena leucocephala* will lose leaves in this period. Figure **3** is the nature color WorldView-2 image in our study area, the brown part in Figure 3 is the *Leucaena leucocephala*. In Figure 4, we can see the different band combination of WorldView-2, the left part is (RED, YELLOW, COASTAL)and the right part is (NIR2, RED EDGE, COASTAL), two combination can also make the *Leucaena leucocephala*

Table 1 Specification of DigitalGlobe WorldView-2 satellite.

Feature		Specification
Orbit Altitude		770km
Swath Width		16.4km
Resolution	**Pan**	0.5m
	MS	2m
	Pans	0.5m
Band number		8
Revisit Frequency		About 1~3.7 days
Dynamic Range		11-bits/pixel
Geolocation Accuracy (CE90)		5m

Figure 3 Nature color combination of WorldView-2 imagery in study area(the borrow area is so-called Leucaena lucocephala).

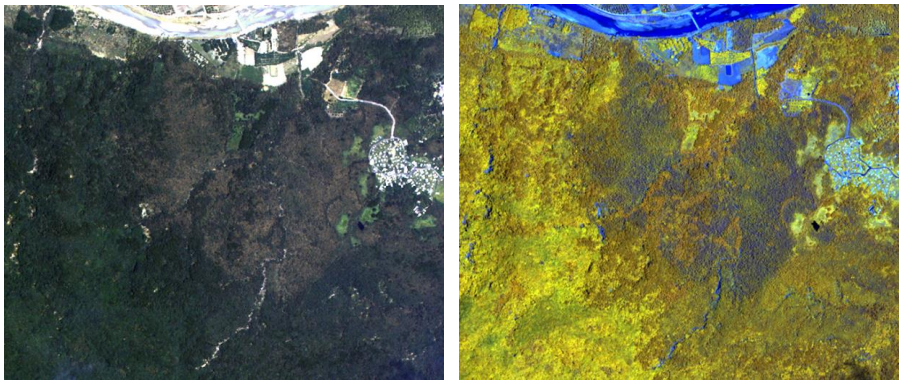


Figure 4 Band combination in WorldView-2 imagery(left:red, yellow, coastal; right:nir2, red edge, coastal).

5. Image Classification and procedure

In this study, we use eCognition9.0, known as the object-based image analysis (OBIA) software, to extract the scope of *Leucaena leucocephala* in WorldView-2 image. Multiresolution segmentation is the first step in OBIA. Thus it is a bottom-up region-merging technique starting with one-pixel objects to create the image object. The Scale Parameter is an abstract term that determines the maximum allowed heterogeneity for the resulting image objects. For heterogeneous data, the resulting objects for a given scale parameter will be smaller than in more homogeneous data. By modifying the value in the scale parameter value you can vary the size of image objects. We can also adjust the image layers weighting to investigate the contribution of 8 bands to distinguish between vegetation categories.
After image segmentation, a rule set is developed to perform the image classification of *Leucaena leucocephala*. The classification result was verified with ground truth data to assess the accuracy of *Leucaena leucocephala* mapping. And the pixel-based image classification is compared with the OBIA. Figure 5 is the flow diagram in this study.

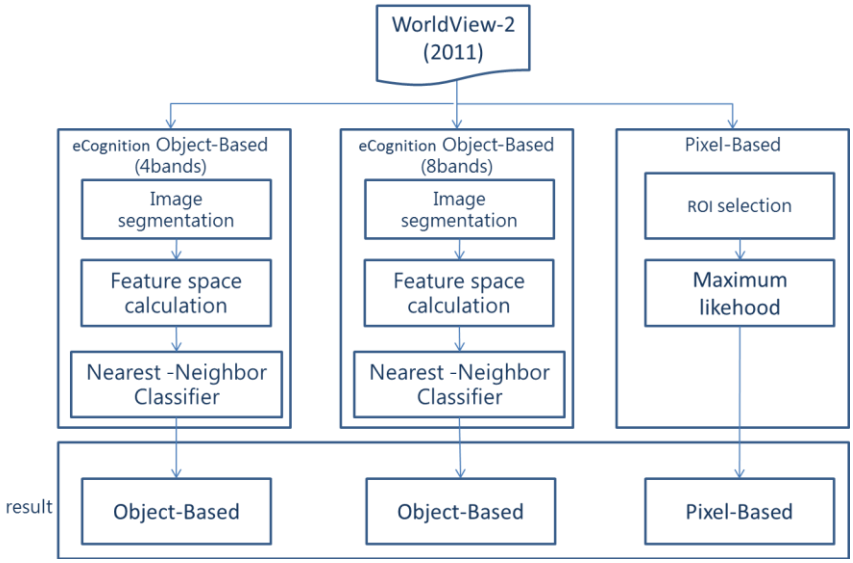


Figure 5 Flow diagram of Leucaena lucocephala classification in WorldView-2.

5.1. WorldView-2 vegetation index

The chloroplast of vegetation can reflect GREEN and NIR band, and absorb BLUE band and RED band under sunlight to perform photosynthesis. So the RED band and NIR band in multispectral image are often used to detect the vegetation. The Normalized Difference Vegetation Index (NDVI) and Simple Ratio (SR) are two simple index that can be used to analyze and assess whether the target being observed contains live green vegetation or not (Jensen, 2005). In this study, the vegetation index computed by WorldView-2 8 bands multispectral imagery is shown as Table 2. We use RED, GREEN, BLUE, and NIR1 bands in WorldView-2 to represent 4 bands image.

Table 2 Vegetation index calculated in WorldView-2.

	Index	
	SR	NDVI
4 bands	Red/NIR1	(NIR1-Red)/(NIR1+Red)
8 bands	Red/NIR2	(NIR2-Red)/(NIR2+Red)

5.2. Object-based image analysis(OBIA)

Object-based image analysis(OBIA) is quite popular image analysis methods in recent years. The main representative of software is Trimble's eCognition software. Comparing to 'traditional' pixel-based method, objects have geographical features such as shape and length, and topological entities, such as adjacency and others feature found within, (Trimble, 2014). These attributes make a knowledge base for the sample objects, which can be called upon in the classification process. Most papers claim that object based classification has greater potential for classifying higher resolution imagery than pixel-based methods (Willhauck et al., 2000; Mansor et al., 2002; Oruc et al., 2004). The first step of OBIA is to create image object by image segmentation, then develop rule set

5.2.1. Multiresolution segmentation

Segmentation algorithms are used to subdivide entire images at a pixel level, or specific image objects from other domains into smaller image objects. Image object is the unit of image classification, so image segmentation is the most important step in OBIA (Lin et al, 2011). Good classification results must be based on the good of image segmentation (Chuang, 2002).

Multiresolution segmentation (Baatz & Scahpe, 2000) is performed to create image object in this study. You can modify this calculation by modifying the scale parameter. And the scale parameter based on relative homogeneity criteria. In the same image, higher values for the scale parameter result in larger image objects(left of Figure 6), smaller values in smaller ones (right of Figure 6).

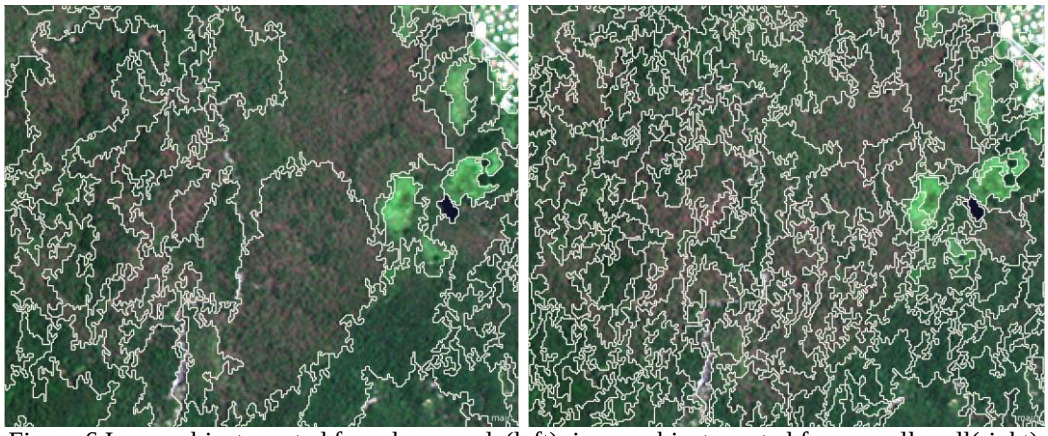
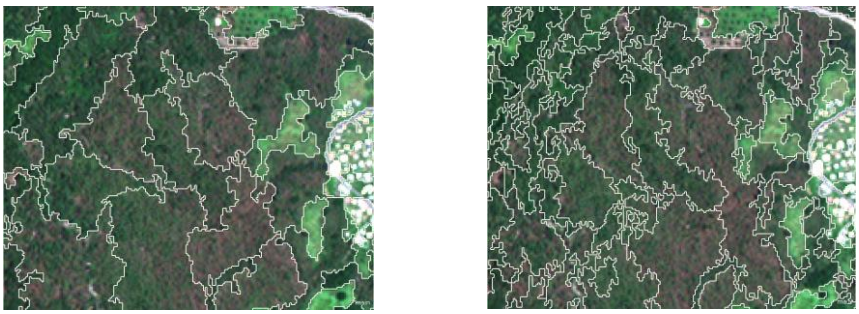


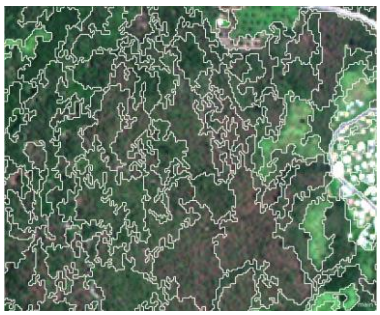
Figure 6 Image object created from large scale(left); image object created from small scall(right)

5.2.2. Image layer weighting

Image layers can also be weighted depending on their importance or suitability for the segmentation result. The higher the weight assigned to an image layer, the more weight will be assigned to that layer's pixel information during the segmentation process, if it is used. WorldView-2 is provided with the advantage of high spatial resolution and 8 bands. To understand if the 8 bands is benefit to distinguish different categories of vegetation, we adjust the weight parameters of different bands when performing multiresolution segmentation. We set the weights of image layer for WorldView-2 in multiresolution segmentation algorithm to simulate the segmentation result created from natural color (RED, GREEN, BLUE) , 4 bands(RED, GREEN, BLUE, NIR1) and 8 bands. Take nature color for example, we set the weight of RED, GREEN and BLUE as 1, the other bands of WorldView-2 as 0, and execute multiresolution segmentation to create image objects. The approach is the same for 4 bands and 8 bands segmentation. Comparing the segmentation result of 4 bands and mature color, we can find that the detail is more visible in the same scale parameter 40 by using 4 bands (as Fig.(a),(b)). Segmentation by using 8 bands (as Fig.(c)) can get much more detail than nature color and 4 bands image. In this study, the WorldView-2 8 bands was used for segmentation.



(a) Segmentation by nature color image (b) Segmentation by 4 bands image



(c) Segmentation by 8 bands image

Figure 7 Image object created by different image layer weights in scale:40

5.2.3. Rule set develop

Figure 8 is the flow diagram for image classification in this study. The threshold of NDVI is applied to classify vegetation and non-vegetation area in this study. And we use Nearest Neighbor (NN) classification algorithm to distinguish three kinds of vegetation (*Leucaena leucocephala*, *Acacia confusa*, other vegetation). First, three classes should be defined in Class Description of eCognition, then select training samples for three types of vegetation in vegetation area. Based on these samples, the algorithm searches for the closest sample image object by membership function in the feature space of each class we defined. If an image object's closest sample object belongs to a certain class, the image object will be assigned to it. User can select the features to be considered for the feature space. In this study, two sets of features: (4bands, NDVI, SR) and (8bands, NDVI_8, SR_8) is defined as the feature space.

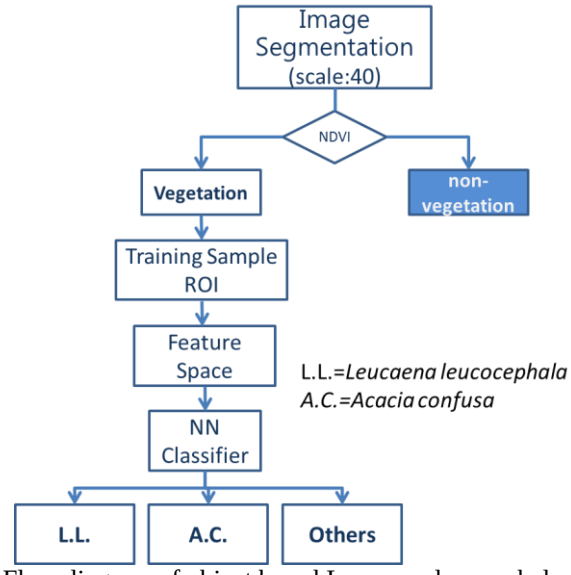


Figure 8 Flow diagram of object based Leucaena lucocephala classification

5.3. Pixel-based image classification

Pixel-based classification of WorldView-2 image of interest area was realized in two steps. In the first step, three main classes have been used as training areas for the classification procedure. In the second stage, supervised classification algorithms (Maximum Likelihood) have been applied respectively to the WorldView-2 image based on the determined training patterns and reference materials. Classifications have been performed by the related module of PCI Geomatica. Finally, the classification result of pixel based will compare with the result of object based.

6. Result and discussion

Three classes of vegetation were classified considering the process described in the previous section using WorldView-2 multispectral imagery in the study area. Four classification results were produced, that are: 8 bands (object based), 8 bands+texture(object based), 8 bands(pixel based), 4 bands(object based). The classification accuracy was assessed through the confusion matrix and kappa indices by ground truth data (as Figure 9). The training samples, show as Figure 10 , is created from field survey data.

With four classification results, we can explore the following topics: 1. Spectral resolution impact on the classification accuracy: comparison of 8 bands and 4 bands classification; 2. Different classification algorithm impact on classification accuracy: comparison of pixel based and object based classification; 3.Texture impact on the classification accuracy: comparison of 8 bands and 8 band with texture feature in object based classification.

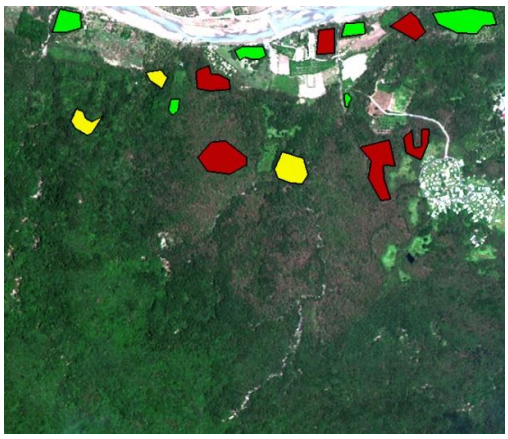


Figure 9 Ground truth data by field survey for each class(red: L.L.; yellow: A.C.; green:others)

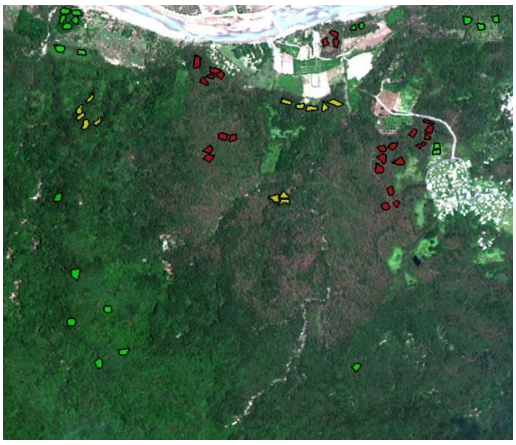


Figure 10 Training site selection for each class

6.1. Comparison of 8 bands and 4 bands classification

Two set of feature: A:(8bands, NDVI, SR), B:(4bands, NDVI, SR) were used in eCognition to perform object based image classification respectively. Figure 11 is the result. The error matrices of set A have been tabulated in Table 3. From Table 3, it can be seen that the overall accuracy of set A is 87.35%. Considering the producer's accuracy and user's accuracy and user's accuracy of individual classes, for the *Leucaena leucocephala*, the producer's accuracy is 85.06%, and the user's accuracy is 97.73%. This means 85.06 percent of *Leucaena leucocephala* is correctly identify and also 97.73 percent of the area that is classified as *Leucaena leucocephala* is truly this category. For the *Acacia confusa*, the producer's and user's accuracy is 89% and 72.81% respectively. By the result, we can say 89 percent of *Leucaena leucocephala* is correctly identified and 72.81 percent of the area that is classified as "*Acacia confusa*" is truly this category.

The error matrices of set B have been tabulated in Table 4. The overall accuracy of set B is 77.71%. The producer's accuracy of *Leucaena leucocephala* is 71.71%, and the user's accuracy is 94.36%. The producer's accuracy of *Acacia confusa* is 86.04%, and the user's accuracy is 81.51%. The overall accuracy of the set A is higher than set B 9.64%. Kappa values is also increase dramatically 0.122. It display that the classification error was improved when using 8 bands.

Table 3 Error matrice of 8 bands object based image classification

C\G.T.	A.C.	L.L.	others	Total	UA
A.C.	2234	612	222	3068	72.81%
L.L.	1	6140	141	6282	97.73%
others	275	462	3893	4630	84.08%
unclassified	0	4	58	62	
Total	2510	7218	4314		
PA	89%	85.06%	90.24%		
Overall Accuracy	87.35%				
Kappa	0.7992				

Table 4 Error matrice of 4 bands object based image classification

C\G.T.	A.C.	L.L.	others	Total	UA
A.C.	2024	1598	319	3941	51.35%
L.L.	84	5176	225	5485	94.36%
others	402	440	3712	4554	81.51%
unclassified	0	4	58	62	
Total	2510	7218	4314		
PA	80.63%	71.71%	86.04%		
Overall Accuracy	77.71%				
Kappa	0.6772				

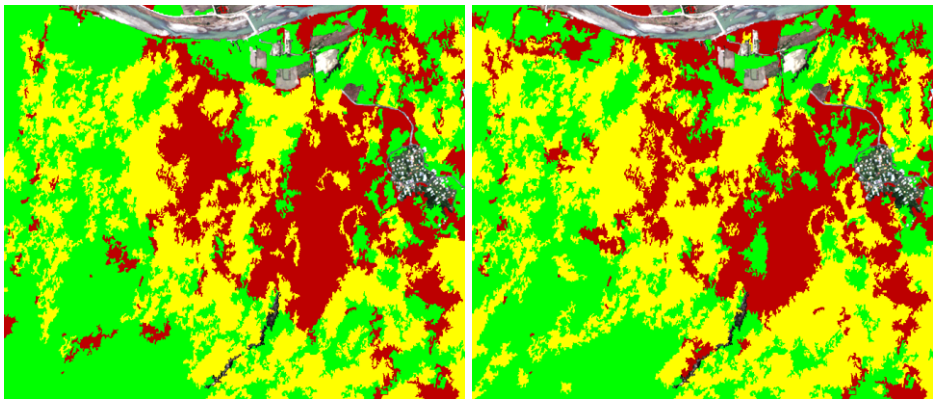


Figure 11 Result of objet based image classification(left: 8 bands; right: 4bands)

6.2. comparison of pixel based and object based classification

Figure 12 is the result of pixel based classification. The error matrices have been tabulated in Table **5** . From Table **5** , it can be seen that the overall accuracy is 84.65%. The producer's accuracy and user's accuracy of individual classes, for the *Leucaena leucocephala*, the producer's accuracy is 82.83%, and the user's accuracy is 96.23%. For the *Acacia confusa*, the producer's and user's accuracy is 87% and 69.11% respectively. Compare to Table **3** , the overall accuracy of pixel based classification is less than object based 2.7% and the Kappa value decreased 0.0421. It display that the accuracy of object based classification is better than the pixel based classification.

Table 5 Error matrice of pixel based image classification

C\G.T.	A.C.	L.L.	others	Total	UA
A.C.	2193	636	344	3173	69.11%
L.L.	17	5979	217	6213	96.23%
others	300	572	3714	4586	80.99%
unclassified	0	31	39	70	
Total	2510	7218	4314		
PA	87%	82.83%	86.09%		
Overall Accuracy	84.65%				
Kappa	0.7571				

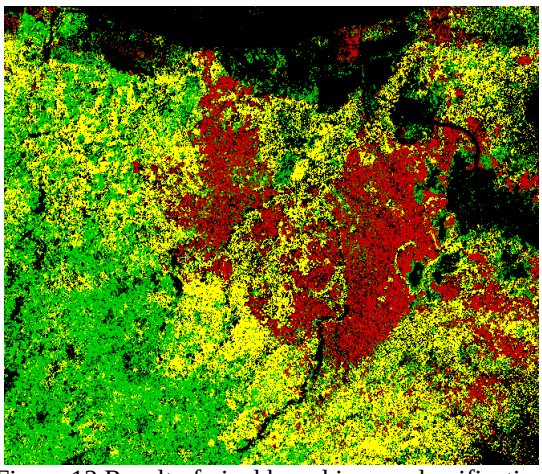


Figure 12 Result of pixel based image classification

6.3. comparison of 8 bands object based image classification with texture and without texture

Texture contains important information in image classification, as it represents the content of many real-world images. We added Grey-level co-occurrence matrices(GLCM) homogeneity to feature space when performing object based classification, and compared to the result without GLCM homogeneity. The result of object based 8 band image classification with GLCM homogeneity is shown in Figure 13. The error matrices have been tabulated in Table 6. From Table 6, it can be seen that the overall accuracy is 90.14%. Compare to Table 3, the overall accuracy increased 2.79% when GLCM homogeneity has added to the feature space. The kappa also increased 0.0435. It display that the accuracy of object based classification with texture feature is better than the same classification method without texture feature.

Table 6 Error matrice of 8 bands object based image classification(with GLCM homogeneity)

C\G.T.	A.C.	L.L.	others	Total	UA
A.C.	2423	363	213	2999	80.79%
L.L.	5	6309	117	6431	98.10%
others	82	542	3926	4550	86.29%
unclassified	0	4	58	62	
Total	2510	7218	4314		
PA	97%	87.41%	91.01%		
Overall Accuracy	90.14%				
Kappa	0.8427				

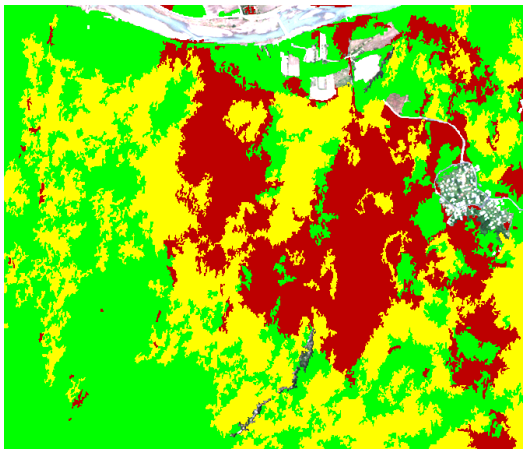


Figure 13 Result of 8 bands object based image classification(with GLCM homogeneity)

The three classification results above can obtained the following conclusions: 1. Number of bands is the most significant factor affecting the accuracy of *Leucaena leucocephala* classification. The overall accuracy of the 8 bands is higher than set B 9.64%; 2. The accuracy of object based classification is better than the pixel based classification. the overall accuracy of object based classification is better than pixel based 2.7%; 3. In addition to traditional spectral features, the object based classification method can add more feature, like texture, which can help to improve the classification accuracy. In our experiment, when GLCM homogeneity has added to the feature space, the overall accuracy is better than pixel based classification 5.49%.

7. Conclusion

The impact of alien species to ecological balance should not be underestimated. The *Leucaena leucocephala* which is the most serious invasion of exotic species in Taiwan was classified with WorldView-2 imagery in this study. The objective is to investigate the capabilities of Leucaena recognition with WorldView-2 satellite imagery. Hengchun Peninsula was chosen for the study area where is the main invasion area. Comparing the classification result of WorldView-2 8 bands multispectral imagery to four bands imagery simulated by 8 bands data, classification accuracy of 8 bands imagery was significantly higher 9.64% than the 4 bands, and the Taiwan acacia which is similar to *Leucaena leucocephala* can also be distinguished well.

We also compared two image classification methods – object based and pixel based image classification. The results showed that object based classification can produce complete outline shape when comparing to pixel based method. The overall accuracy of object based image classification is increase by 2.7% than pixel based image classification in this case. When considering the texture feature of objects, the overall accuracy can further increase 2.79%, namely increase by 5.49% than pixel based classification, which shows the advantages of object based classification.

Reference:

Baatz, M., and Schape, A., 2000. Multiresolution Segmentation-an Optimization Approach for High Quality Multi-scale Image Segmentation, in Angewandte Geographische Informationsverarbeitung XII, pp.12-23.

Chi-Bin Chen, 2005. Data mining techniques applied to Invasive Plant Research. Master's thesis, Department of Civil Engineering, National Central University, Taoyuan, Taiwan.

DigitalGlobe® , 2010. Basic Imagery Datasheet, from http://www.digitalglobe.com/

Fuan Tsai, Ming-Jhong Chou, 2006. "Texture Augmented Analysis of High Resolution Satellite Imagery in Detecting Invasive Plant Species", Journal of the Chinese Institute of Engineers, 29(4), pp. 581-592.

Jau-Tzong Lee, 2003. Study on the Spread and Invasion of Leucaena leucocephala in Hengchung Area. Master's thesis, National Pingtung University of Science and Technology, Pingtung, Taiwan.

Jensen, J. R, 2005. Introductory digital image processing: A remote sensing perspective (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall, Upper Saddle River, N.J., pp. 311 & 501.

Keng-Fan Lin, Yen-Wei Chiu, Chy-Chang Chang, Pai-Hui Hsu, 2011. Combining Aerial Images and LiDAR Data for Object-Oriented Land Feature Classification. 2011 Annual Conference of Taiwan Geographic Information System Forum.

Mansor, S., Hong, W. T., & Shariff, A. R. M., 2002. Object oriented classification for land cover mapping. Proceedings of Map Asia 2002, 7-9 August, Bangkok: GISDevelopment.

Oruc, M., Marangoz, A. M., & Buyuksalih, G., 2004. Comparison of pixel-based and object-oriented classification approaches using Landsat-7 ETM spectral bands. Proceedings of ISPRS Conference, 19-23 July, Istanbul.

Trimble, 2014. eCognition Developer 9.0 - User Guide. Munchen, Germany: Trimble Germany GmbH..

Willhauck, G., Schneider, T., De Kok, R., & Ammer, U., 2000. Comparison of object-oriented classification techniques and standard image analysis for the use of change detection betweeen SPOT multispectral satellite images and aerial photos. Proceedings of XIX ISPRS Congress, 16-22 July, Amsterdam.

Yu-Jyun Kuo, 2008. Impact of Land-use Change on Distribution of Invasive Leucaena leucocephala in Kenting National Park, Taiwan. Master's thesis, Institute of Ecology and Evolutionary Biology, National Taiwan University, Taiwan.

Yuh-Lumg Chung, Ming-Lun Lu, 2006. Using SPOT Imagery to Map the Invasive Distribution of Leucaena lucocephala in Kenting National Park. Taiwan Journal of Forest Science, 21(2), pp.167-177.

Yun-Han Chuang,2002. A research on combining Image Segmentation and Knowledge-based Classification using IKONOS images. Master's thesis, National Central University, Taoyuan, Taiwan.