行政院國家科學委員會專題研究計畫　期中進度報告

航遙測技術於檜木老林結構特徵及其光譜指標之研究(1/2)

計畫類別：個別型計畫
計畫編號：NSC94-2313-B-034-007-
執行期間：94年08月01日至95年07月31日
執行單位：中國文化大學景觀學系暨研究所

計畫主持人：鄭祈全

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報告類型：精簡報告
報告附件：出席國際會議研究心得報告及發表論文
處理方式：本計畫可公開查詢

中　華　民　國　95年5月6日

行政院國家科學委員會補助專題研究計畫 □ 成 果 報 告
■期中進度報告

（計畫名稱）

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成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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執行單位：中國文化大學景觀學系暨研究所

中　華　民　國　　95 年 5 月 6 日

Application of Photogrammetry and Remote Sensing on Structure Characteristics and Spectral Indices of Old-Growth Cypress (1/2)

Chi-Chuan Cheng[1], Hsiao-Wen Juan[2]

Abstract

This research focused on the classification of old-growth cypress in Chilan Mountain District using photogrammetry and remote sensing techniques. The content includes two parts. The first part is to collect the old-growth characteristics (e.g., snags and gaps) using digital photogrammetry and then process cluster analysis based on the collected old-growth characteristics. The second part applied image level slicing and unsupervised classification to extract the old-growth cypress forests and then to classify them into different types of old-growth based on the result obtained from cluster analysis. The results indicated that 2,041 snags and 970 gaps were firstly collected and clustered into three categories. They are named as old-growth with less snags and gaps, old-growth with more snags, and old-growth with more gaps. In addition, assessing the extraction and classification of old-growth cypress forests using image level slicing and unsupervised classification was satisfactory. The accuracy of old-growth classification was about 75.2%.

Keywords: Old-growth, Photogrammetry, Remote sensing.

摘 要

本研究旨在應用航遙測技術，進行棲蘭山地區之檜木老林分類。研究方法分為二大部分，一為利用航測技術測繪枯立木與孔隙二項老林特徵，並應用群落分析法進行老林特徵之分群；二是利用規整差異植生指標(NDVI)，以影像切割與非監督分類方法萃取 SPOT 影像上之檜木老林，並結合航測之老林特徵分類結果，進行老林影像分類。研究結果如下：(一)根據立體航測測繪所得之枯立木 2041 株和孔隙 970 個等老林特徵資料進行群落分析，檜木老林可分為老林特徵少、老林枯立木多與老林孔隙多三個群落；(二)利用影像切割和非監督分類方法所萃取的檜木老林，其分類準確度為 75.2%，結果還算滿意。

關鍵字：老林、航測、遙測

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1. Introduction

Old-growth forests preserve the massive biodiversity and maintain the stability of ecosystem because of its structural heterogeneity and rich bio-legacy. It becomes an important issue in the ecosystem research. However, most previous researches on old-growth topics emphasized the stand structure characteristics, like Spies et al. (2002) and Stewart et al. (2003). In the area of applying remote sensing on old-growth forest mostly focused on traditional image classification, for example, Niemann (1995), Fiorella & Ripple (1993), Hussein & Hashim (1997) and Lu (2003) classified old-growth forests based on the spectral differences of stand ages and species compositions, but no further investigation about the effect of old-growth structure characteristics on image classification.

In Taiwan, the old-growth research is just paid attention. Chen (2003) and Hong et al. (1999) tried to estimate the forest health of old-growth cypress in Chilan Mountain District, but less study focuses on the use of remote sensing techniques to classify old-growth cypress. Because the cypress is a glacial plant and the Chilan Mountain District is a sanctuary to the old-growth cypress in Taiwan, this research chose the old-growth cypress in Chilan Mountain District as the study area. The objective was to classify the old-growth cypress forests in a large scale. However, most forested areas in Chilan Mountain District are steep and lots of bushy vegetation and massive woody debris on the ground. This causes the ground inventory more difficult and dangerous.

To overcome the above problem, the most efficient and economical technique is based on remote sensing to collect the forest spectral values and other parameters. However, to collect the stand characteristics of old-growth cypress such as gaps and snags, the resolution of remote sensing is limited. Therefore, the integrated approaches such as digital photogrammetry and remote sensing may be needed. As for the use of digital photogrammetry, the material includes orthogonal images and aerial photos. Although using aerial photos will take much time to prepare the stereo models under digital photogrammetry, it can provide higher resolution and more identifiable geometry information than orthogonal images, which means that the stereo models can effectively reduce the errors caused by misinterpretation. For this reason, this study will integrate digital photogrammetry with remote sensing together. The former was applied to collect the old-growth structure characteristics such as gaps and snags, and the latter was focused on the large-scale image classification based on the spectral information of old-growth cypress.

2. Research Area and Materials

The study area is located in the Chilan Mountain District. The total area is about 3,000 ha including 14 forest compartments shown as Figure 1. The topography of Chilan Mountain is from northeast to southwest. The highest monthly average temperature is 27℃ and the lowest monthly average temperature is 13℃. The annual precipitation is 1,700 ~2,500 mm and the weather is heavy wet. The primary flora community of cypress forests is composed of two types. They are *chamaecyparis obtusa var. formosana* and *chamaecyparis formosene*. The natural cypress forests in this area are famous for many giant living trees, numerous whiting snags, and the exquisite forest (Forest Conservation Service, 2003).

The research materials used in this study are color aerial photos taken on three different dates, (i.e., 24 October 2001, 11 January 2002, and 24 June 2002) and SPOT images on July 26, 2002.

3. Method

The research method including two major parts is shown as Figure 2. The first part is to collect the structural characteristics of old-growth cypress (i.e., snags and gaps) using digital photogrammetry and then cluster old-growth cypress into different structural types based on those characteristics. The second part is to extract the old-growth forests using image level slicing and unsupervised classification and further to classify them into different types of old-growth using SPOT image.

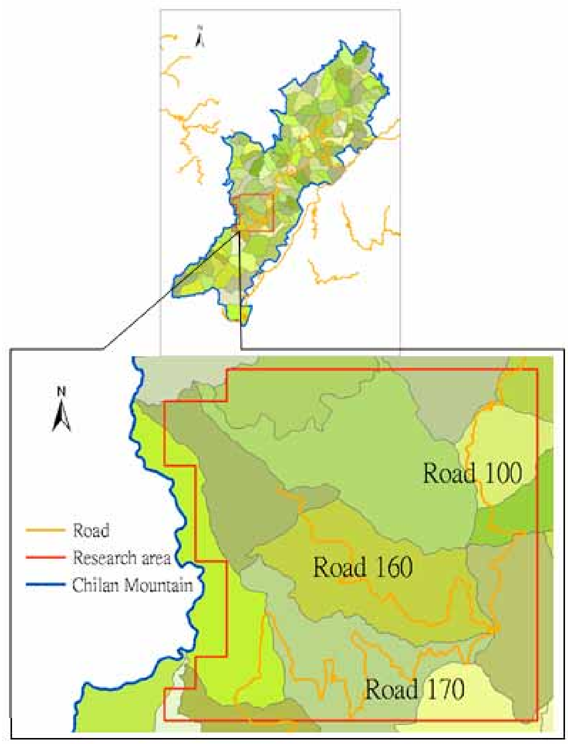

Figure 1. Research area

1) Collection of old-growth structure characteristics and cluster analysis

Firstly, the gaps and snags of old-growth characteristics were delineated and digitized separately under the stereo models produced by digital photogrammetry. The mapping criteria are as follows. Only dead trees are identified as snags excluding partially dead trees; the gaps are identified as broken and not continuous areas excluding the area of landslides and washouts. According to the above criteria, the distribution maps of the snags and gaps are generated, respectively. Meanwhile, those maps have to be transferred into raster form for cluster analysis.

During the count of snags and the area calculation of gaps, a grid size with 125m by 125 m was assumed to improve the effective calculation. The reason to use 125m is because the SPOT resolution is 12.5m. With the numbers of snags and the areas of gaps, cluster analysis was then performed after the data normalization. However, the cluster analysis used in this study is a non-hierarchical k-means approach and the FASTCLUS procedure of SAS is applied. During the process, the cubic clustering criterion (CCC) is used to determine the optimal number of clusters according to its turning point.

2) Extraction and classification of old-growth cypress forests

From the SPOT image, clearly the old-growth forest is a little dark. Therefore, this study firstly applied image level slicing to extract the forested area according to the Normalized Difference Vegetation Index (NDVI). The unsupervised classification was then used to classify the forested area into old-growth and non-old-growth areas. Finally, the extracted old-growth forest was classified into different types of old-growth forests with the assistance of clustering results. As for the classification process, the supervised approach with the maximum likelihood classifier was used.

4. Result

1) Collection of old-growth structure characteristics and cluster analysis

2,041 snags and 970 gaps were collected under digital stereo models. The total area of gaps was 306,702m^2. Among those gaps, the area of minimum one is 0.01m^2 and the maximum one is 5,025m^2. The gap ratio for the entire area was approximately 1%.

The number of snags and the area of gaps were firstly standardized and then clustered by k-means cluster analysis. Figure 3 is the trend of CCC value. From Figure 3, it is clear that a turning point is at five, which means the optimal number of clusters is five. Therefore, the snag-gap chart for each grid size was then plotted as Figure 4. Obviously the five clusters obtained from cluster analysis can be regrouped into three clusters. They are named as cluster with less snags and gaps, cluster with more snags, and cluster with more gaps. However, to coincide with the name of old-growth, the three clusters are renamed as old-growth with less snags and gaps, old-growth with more snags, and old-growth with more gaps. Figure 5 is the snag-gap chart after regrouping. To show the spatial distribution of these three clusters, the clustering output was overlaid with the grid map (each grid is 125m x 125m) and shown as Figure 6. In this figure, blue, red, and green colors represented old-growth with less snags and gaps, old-growth with more gaps, and old-growth with more snags, respectively. In addition, it is clear that the old-growth forests with less snags and gaps occupy the largest area, which means most old-growth forests in this study area are higher vigor and less structure characteristics of snags and gaps.

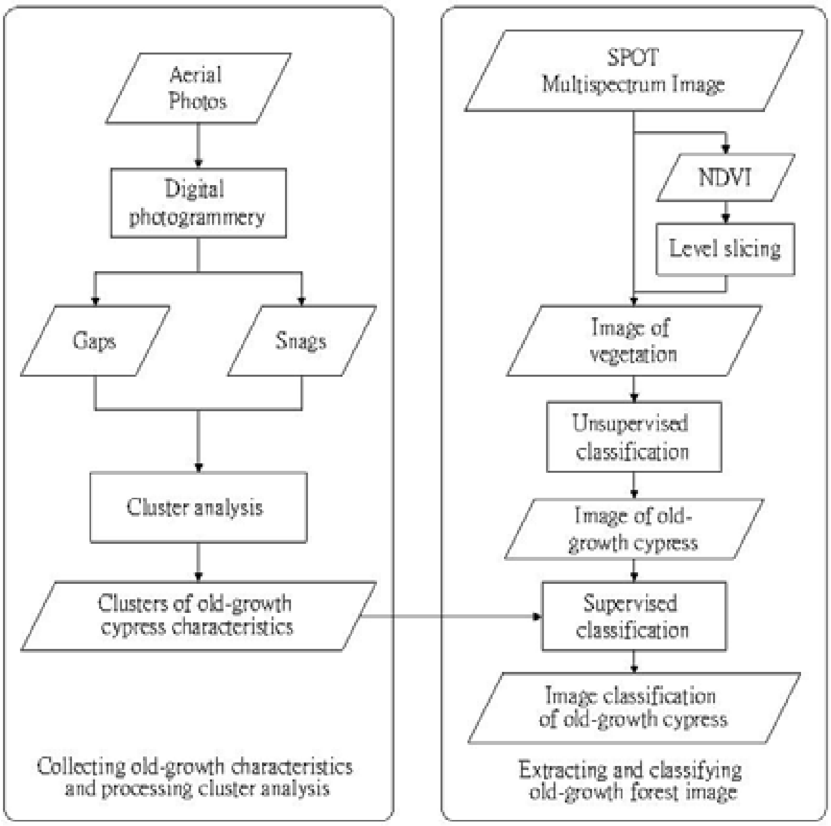

Figure 2. Research flowchart

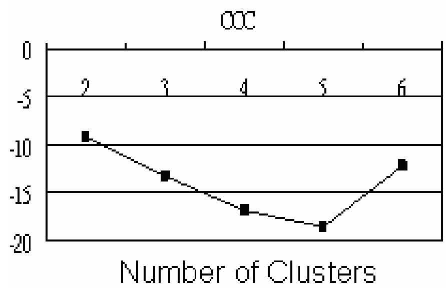

Figure 3. The curve of CCC value

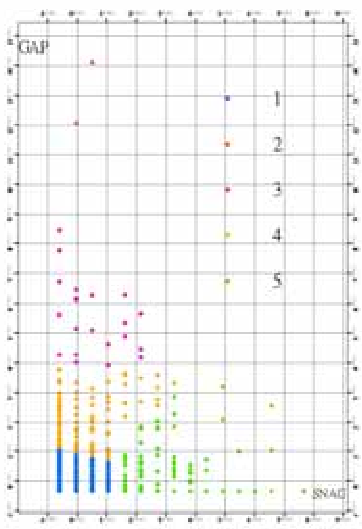

Figure 4. Snag-gap distribution

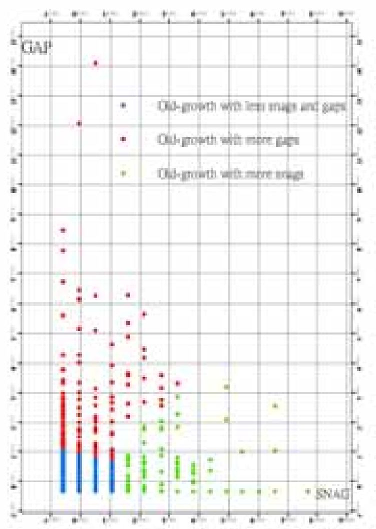

Figure 5. Snag-gap distribution after regrouping

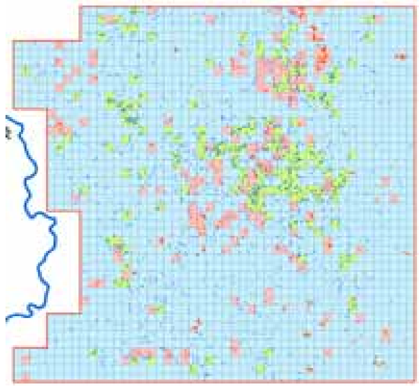

Figure 6. Cluster map

2) Extraction and classification of old-growth cypress forests

Figure 7 is the histogram of NDVI value. After a comparison with SPOT image, the result indicated that the NDVI value for non-vegetation area such as shadow, the bare soil etc was ranged from -0.07 to 0.5 and the NDVI value for vegetation area was larger than 0.5. Therefore, the NDVI value with 0.5 was regarded as a threshold to differentiate between vegetation and non-vegetation in this study area. With this criterion, level slicing was used to extract the vegetation area. Then unsupervised classification was applied to classify the extracted vegetation area into old-growth and non-old-growth forests. Figure 8 is the output. The Figure illustrated that black, gray, and white colors represented non-vegetation, old-growth, and non-old-growth, respectively.

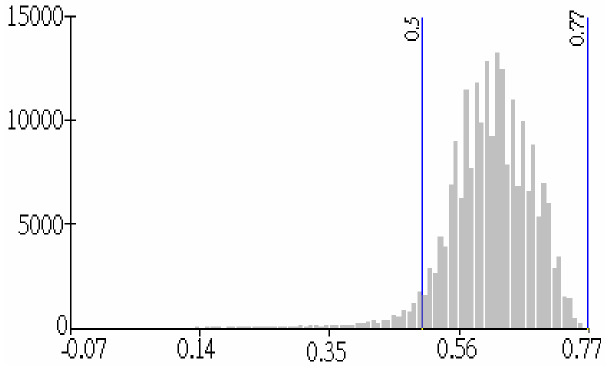

Figure 7. Histogram of NDVI

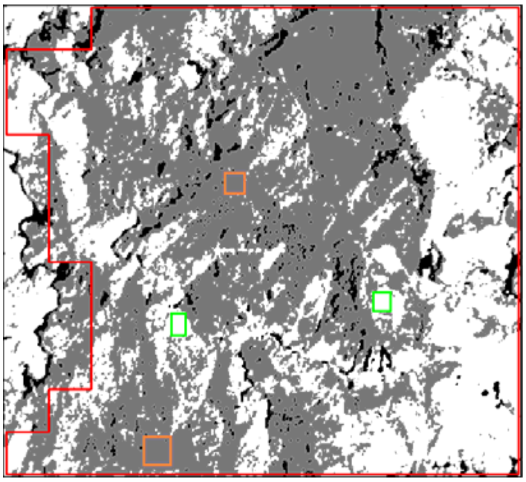

Figure 8. The extracted image of old-growth

Furthermore, four test areas shown as Figure 8 were chosen to estimate the accuracy of the classified old-growth forests. The orange and green colors represent old-growth and non-old-growth, respectively. Table 1 is the error matrix obtained from supervised classification with the maximum likelihood classifier. The result indicates that the accuracy of self-classification was 99.88%.

Further to estimate the accuracy in addition to test areas, the result of unsupervised classification was overlaid with orthophotos and the output was shown as Figure 9. Four sampling plots which have clear border between old-growth and non-old-growth were chosen to inspect whether the classified result was coincided with the orthophotos or not. From Figure 9, it is clear that the old-growth forests have rougher texture and more shadow, but non-old-growth forests have smoother texture and less shadow. This result explains that the output of unsupervised classification is quite reasonable.

Table 1. The error matrix of self-classification in test areas

Classified / Original	Old-growth	Non-old-growth	Total Pixels
Old-growth	1037	2	1039
Non-old-growth	1	1474	1475
Total pixels	1038	1476	2514
Accuracy $= \frac{1037 + 1474}{2514} \times 100\% \approx 99.88\%$			

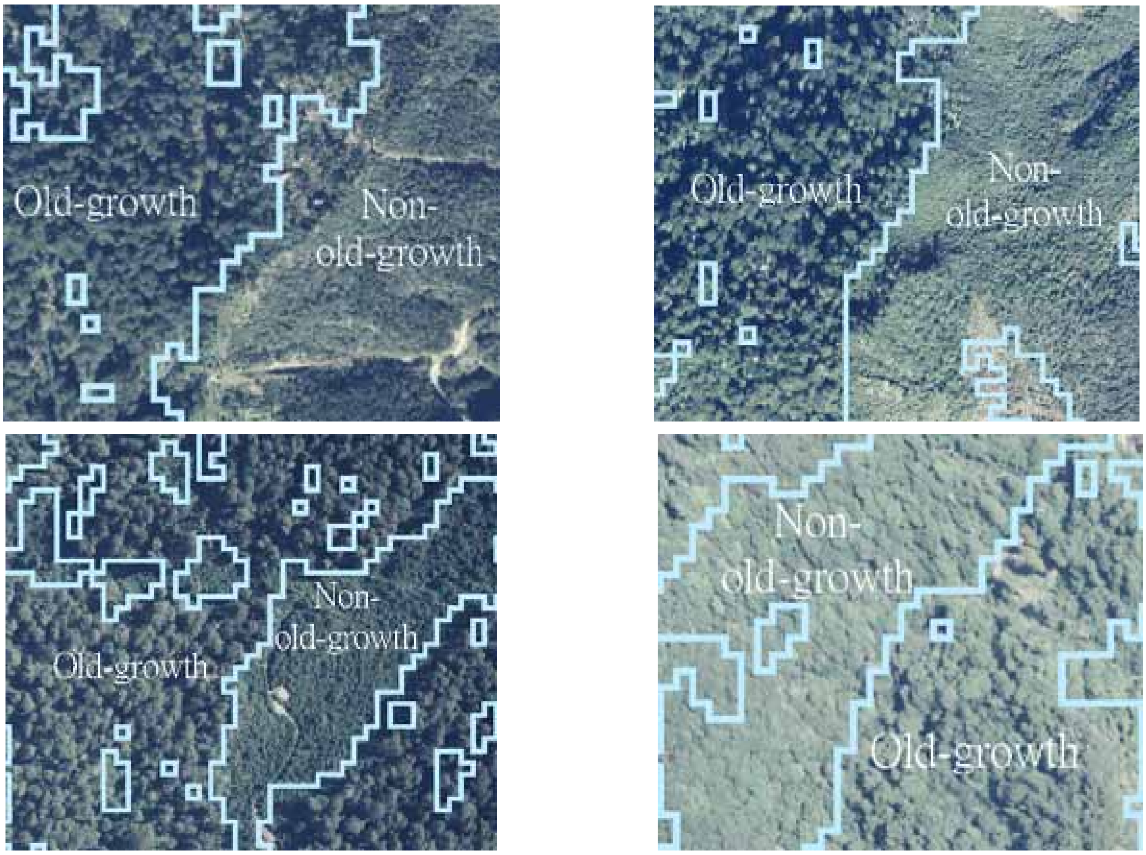

Figure 9. Inspection of the accuracy using the classified old-growth and orthophotos.

After the estimation of extracted old-growth forests, supervised classification was used to classify the entire study area into different types of old-growth forests. In this step, training samples shown as

Figure 10 were selected according to three clusters obtained from clustering analysis. Clearly, 8 training samples with blue color represent old-growth with less snag and gap. As for old-growth with more snags and old-growth with more gaps, they are represented by green and red colors, and each has 4 training samples. Table 2 is the error matrix based on above 16 training samples. The result indicated that the accuracy of self-classification was 87.5% and looked satisfactory. As for the classification of the entire study area, Table 3 showed that the classification accuracy was 75.2%. This classification result can be explained by the classification map shown as Figure 11. The Figure pointed out that among three clusters, the classification accuracy of old-growth forests with less snags and gaps is higher than the other two old-growth, that is, misclassification is mostly occurred in old-growth with more snags and old-growth with more gaps.

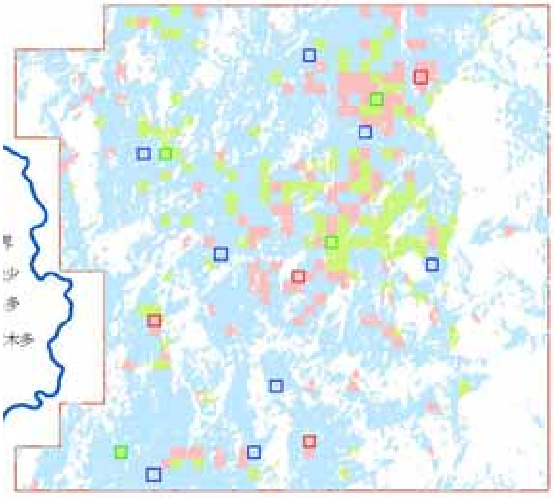

Figure 10. Supervised samples

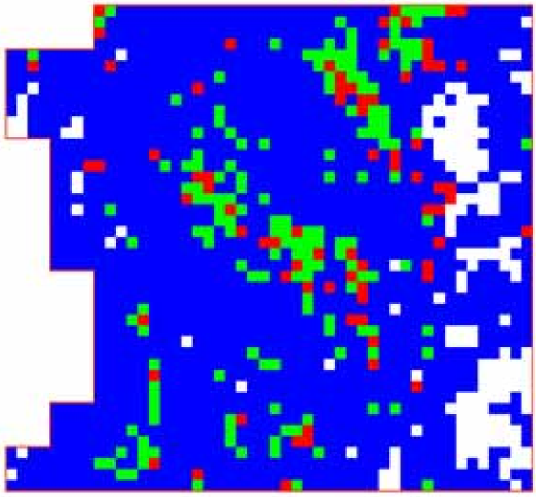

Figure 11. Result of supervised classification

Table 2. Error matrix of self-classification based on 16 training samples.

Classified / Original	old-growth with less snags and gaps	old-growth with more gaps	old-growth with more snags	Total count
old-growth with less snags and gaps	8	0	0	8
old-growth with more gaps	0	4	2	6
old-growth with more snags	0	0	2	2
Total count	8	4	4	16
Accuracy $= \frac{8+4+2}{16} \times 100\% = 87.5\%$				

Table 3. Error matrix of supervised classification based on the extracted old-growth forests.

Original \ Classified	old-growth with less snags and gaps	old-growth with more gaps	old-growth with more snags	Total count
old-growth with less snags and gaps	1286	107	123	1516
old-growth with more gaps	54	15	7	76
old-growth with more snags	117	27	18	162
Total count	1457	149	148	1754
Accuracy $= \frac{1286+15+18}{1754} \times 100\% = 75.2\%$				

5. Discussion

Most of natural old-growth forests in Chilan Mountain District are cypress. Based on the structure characteristics delineated by digital photogrammetry, the old-growth cypress are clustered into three clusters, for example, old-growth with less snags and gaps; old-growth with more snags, and old-growth with more gaps, respectively. Comparing these three clusters from their age status, it can be seen that old-growth with less snags and gaps > old-growth with more snags > old-growth with more gaps.

As for image classification, the numbers of land cover types have to be determined before the classification. Therefore, the first task in this study was to determine and differentiate three kinds of land types. They are: (1) non-vegetation, (2) vegetation and non-old-growth, and (3) vegetation and old-growth. Then NDVI, image level slicing, and unsupervised classification were integrated for extracting the old-growth cypress.

In comparisons among three old-growth clusters, the accuracy of supervised classification was 75.2%. The result indicated that misclassification was mostly happened in the old-growth with more snags and old-growth with more gaps. The reason may be because the spectral value for each grid size is calculated by the average of 100 pixels from the original image. In fact, this operation will decrease spectral variations among different clusters and then indirectly cause the misclassification.

6. Conclusions

As mentioned earlier, the Chilan Mountain District is a sanctuary of the old-growth cypress in Taiwan. To understand and survey the old-growth cypress, a couple of important issues are how to identify the old-growth characteristics and what kinds of techniques can be used to largely survey the old-growth cypress. It is well known that photogrammetry and remote sensing are useful techniques for large area survey, but less study focuses on the use of remote sensing to identify and classify the old-growth cypress in Taiwan. Therefore, this study applied digital photogrammetry and remote sensing to extract and classify the old-growth cypress. The result indicated that digital photogrammetry was a useful technique to collect the structural characteristics of old-growth cypress (e.g., snags and gaps). The old-growth cypress in the Chilan Mountain District can be clustered into three clusters according to snag and gap characteristics. They are old-growth with less snags and gaps, old-growth with more gaps and old-growth with more snags, respectively. In addition, the number of old-growth with more gaps and old-growth with more snags are few, which means little disturbance is happened in the old-growth cypress of Chilan Mountain District. Meanwhile, the old-growth cypress can be differentiated by integrating level slicing, NDVI, and unsupervised classification. And the classification accuracy for three different types of old-growth cypress was 75.2%. The result seems satisfactory.

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計畫成果自評：

本計劃核定為二年，內容分為二大項目，一為應用航遙測技術於檜木老林結構特徵之研究，另一為利用第一年有關檜木老林結構特徵之成果，進行檜木老林光譜指標之萃取，並據以分類整個棲蘭山林區之檜木老林。本年度為第一年，故研究重點放在應用航遙測技術於檜木老林結構特徵之研究，其執行內容與原計劃程度相符，並達成預期的目標如下：(一)利用航測技術量測枯立木與孔隙二項老林特徵，並應用群落分析法進行不同老林特徵之分群；(二)利用規整差異植生指標(NDVI)，以影像切割與非監督分類方法萃取 SPOT 影像上之檜木老林，並結合航測技術所獲得之老林特徵資訊，完成試區之老林影像分類。

由於老林具有生物遺產的特性，國外對此方面的研究頗為重視，反觀國內，棲蘭山林區具有豐富的檜木老林，可算是台灣重要、珍貴的生物資源，但國內對於老林的定義以及應用航遙測技術區劃與分類檜木老林的研究均闕如，因此本研究成果具有學術與應用上的價值，該第一年研究成果經整理後將投稿於學術期刊。