TREE SPECIES CLASSIFICATION USING AERIAL PHOTOGRAPH AND HIGH-SPATIAL RESOLUTION REMOTELY SENSED DATA IN THE SATOYAMA (SECONDARY FOREST) OF JAPAN

*Yuka Watanabe [1], Takuhiko Murakami [2], Shota Mochizuki [3], Ayaka Kotoda [3]and Tomohiko Kamitani [4]
[1] Graduate student, Graduate School of Science & Technology, Niigata University,
8050 Ikarashi 2nocho, Nishi-ku, Niigata, 950-2181, Japan; Tel: + 81-25-262-6627;
E-mail: f11e076b@mail.cc.niigata-u.ac.jp

[2] Associate Professor, Graduate School of Science & Technology, Niigata University,
8050 Ikarashi 2nocho, Nishi-ku, Niigata, 950-2181, Japan; Tel: + 81-25-262-6627;
E-mail: muratac@agr.niigata-u.ac.jp

[3] Graduate student, Graduate School of Science & Technology, Niigata University,
8050 Ikarashi 2nocho, Nishi-ku, Niigata, 950-2181, Japan; Tel: + 81-25-262-6627;

[4] Professor, Graduate School of Science & Technology, Niigata University,
8050 Ikarashi 2nocho, Nishi-ku, Niigata, 950-2181, Japan; Tel: + 81-25-262-6625;
E-mail: crenata@agr.niigata-u.ac.jp

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ABSTRUCT: SATOYAMA is traditional secondary forest in the rural area of Japan and recently paid attention to as a place where the use of sustainable natural resource works out. Therefore utilization and management of SATOYAMA has been active. However, the change of species composition or oak wilt disease due to underuse of SATOYAMA has become a serious problem in Japan. It is a concern regarding the reduction of food resources for wildlife caused by such changes in SATOYAMA. Therefore, distribution information on nut tree species is acquired, the amount of nut species is an indicator of the relative importance of secondary forest. The purpose of this study was to classify tree species in secondary broad-leaved forest using remote sensing technique, aerial photograph and satellite image. Study area is secondary forest around Takigashira wetland which is located in Niigata prefecture, Japan. Aerial photographs were acquired on 01 May 2009, and 06 November 2008, and 04 November 2009. The aerial photograph acquired on 04 November is a color infrared photo and others are natural color. After pre-processing, the tree species classification was carried out on each of five images, single date images and multitemporal composite images, and then we compared their classification accuracy. The classification classes are beech, oak, and painted maple. For the satellite image, GeoEye-1 acquired on 18 May 2010, the classification classes are a beech and non-beech only. Object based image analysis was applied to all classification carried out in this study. Classification accuracy on aerial photograph is the highest in a single image acquired on 01 May 2009 in comparison with combined or single photograph. In Satellite image, as for the classification of the beech, all objects for the verification were classified into the correct class, beech.

1. INTRODUCTION

Recently, the utilization of natural resources that considers sustainable development and ecosystem is required in worldwide. SATOYAMA is the mixed area of farmland and secondary forest in the rural area of Japan that people have managed since pre industry. The continuous human activity such as logging for woody fuel has maintained SATOYAMA. Moreover, various wildlife species that adopted and depended on such a secondary environment inhabit in SATOYAMA region. For this reason, SATOYAMA is paid attention to as a place which expected to the use of sustainable natural resource works out and the trend of utilization and management in SATOYAMA has been active. "SATOYAMA INITIATIVE" advocated by United Nations University Institute of Advanced Studies (UNU-IAS) and Ministry of the environment in Japan is typical example.

However, the change of species composition or oak wilt disease due to underuse of SATOYAMA has become a serious problem in Japan. Especially, it is a concern regarding the reduction of food resources for wildlife caused by such changes in SATOYAMA (Yamazaki, 2009). Wildlife like Asiatic-Black bear (*Ursus thibetanus*) live in SATOYAMA of Japan often use beech, nuts and chestnuts as food resources (Hashimoto, 1997). However, the possibility that the change in distribution of food resources is thought by the problem above mentioned. Therefore, it is important that the approach to acquire distribution information on nut tree species and estimation the amount of nut species which is an indicator of the relative importance of secondary forest.

Tree classification in wide area has been carried out using satellite images of medium resolution such like LANDSAT comparatively at early time as the subject of the forest management in the forest industry (Setojima, 2006). Tree species classification in the forest composed by various tree species as Japan was assumed that a seasonal change (green shoots, fall foliage, leaf abscission etc.) in the tree became an important parameter, and was tried the analysis that used the multi-temporal satellite images (Awaya and Tanaka 1999). The availability that multi-seasonal satellite image for tree classification in wide area was confirmed (Setojima, 2006), and then the tree species classification has been carried out based on the change in the leaf color by using multi-temporal aerial photograph (Setojima, 2001; Setojima, 2002). In addition, the high resolution satellite imagery is rapidly widespread in recent years. Satellites such as IKONOS, WorldView-2, QuickBird and GeoEye-1 can be observed by the spatial resolution 1.0 m-pixel or less. It becomes possible to observe individual tree crown in the forest region by the height of resolution that is the maximum characteristics of the high resolution satellite and the application of the living thing damage that occurs locally to the monitoring is expected (Hirata, 2009).

The objective of this study was to attempt tree species classification using multi-temporal aerial photograph and high-spatial resolution remotely sensed data. Our target tree species were Japanese beech (*Fagus crenata*) and Japanese oak (*both Quercus serrata and Quercus crispula*) which generaly compose Japanese secondary forest. Detecting and mapping these species was important for the management of SATOYAMA.

2. STUDY AREA

The study area is around Takigashira wetland, located in eastern Niigata prefecture, Japan (37.55N, 139.51E). The Takigashira is artificial wetland that is an unusual in Japan. This area was a small village until the 1970s. After a village disappeared, wasteland such as reed grass or shrub was maintained and it became the artificial wetland. The secondary deciduous broad-leaved forest consisted of mainly beech and oak and other species that painted maple, Japanese big-leaf magnolia (*Magnolia hypoleuca*) and horse chestnut (*Aesculus turbinata*) has extended now, and it is the valuable habitat of wild animals.

3. DATA

3.1 Aerial Photograph

Aerial photographs of this study were acquired with a RC-30 aerial camera system (Leica Geosystem .inc). The aerial photograph is scanned to digital data with 0.1-m spatial resolution and three layers that Red, Green and Blue were used for each analysis. These aerial photographs were acquired on 1 May 2009, 6 November 2008, and 4 November 2009. The image acquired on 4 November has two types of photographs which processed into true-ortho photo with natural color and color infra-red (CIR) photo. The images acquired on 1 May 2009, 6 November 2008, and 4 November 2009 (color infra-red) were used for tree classification. The image acquired on November 2009 (natural color) was used as the reference of geometric collection. The image acquired on 1 May 2009 was captured on a quest to capture green-up of beech, while the image acquired on 6 November 2008 captured fall foliage across the study area. Herein, these images are referred to as 0501, 1106, 1104(NC), and 1104(NIR).

3.2 Satellite image

Satellite images were acquired on 18 May 2010 by GeoEye-1(GeoEye.inc). The images were panchromatic image with a spatial resolution of 0.5m and multispectral one with a spatial resolution of 2.0m. Multispectral data have four bands: blue, green, red, and near infra-red. These images were processed to pan-sharpen image with spatial resolution 0.5m. Then, geometric collection and calibration of topographic effect were conducted in pan-sharpen image. This pre-processed image was used for tree species classification.

3.3 Tree Location Data

Tree location data was prepared based on field survey. Field surveys were carried out several times from October to November, 2010 with the purpose of obtaining a sample data for using tree species classification. The survey is conducted by comparing the image printed with trees appeared near the forest road in Takigashira wetland and trees are identified.

4. METHOD

4.1 Digital data correction

In this study, four pre-processing steps were employed. First, geometric correction of aerial photographs and satellite image was carried out using LPS (Leica Photogrammetry Suite) of ERDAS IMAGINE9.3.2 (Erdas .inc). In addition, for the processed aerial photographs, geometric correction was carried out again using rubber sheeting to superpose individual tree that each image. Second, for the satellite image, topographic effect was corrected using the Minnaert method in this study. Third, the imagery was extracted only the area with which it has overlapped correctly, in order that the exact compensation by the geometric correction of rubber sheeting was not completed. For the satellite image, image was also carried out subset image to reduce the data volume, because high resolution imagery has large volume of data which require time for each processing. When the range of subset image was selected, the field survey point was included in both aerial photograph and satellite image. Fourth, for the purpose of single image and the combination of two or more image to classify, the composite imageries were produced. For the aerial photograph, two images that 0501 image and 1106 image were combined, and three images that 0501 image and 1106 image and 1104(NIR) image were combined. As a result, two composite imageries were produced, 0501+1106 and 0501+1106+1104(NIR). While the satellite image, the near-infrared band was pulled out from the image that consisted of four bands and the satellite image that consisted of three bands was output in order to examine the result of classification the image composited of only visible bands.

4.2 Tree species classification

The object-based image classification was adapted to the tree species classification in this study. The object-based classification is a technique for classifying the object that divides the image into sets of similar pixels, and is treated as a minimum unit for classification. In the high resolution satellite data and the aerial photograph, the tree crown of a single tree is composed of many pixels, and also even the shadow that exists in the tree crown of a single tree can be captured. In the pixel-based classification that classifies one pixel as a minimum unit, such a shadow described above cannot be captured as a part of single tree crown. Thus, only a digital number of each pixel is considered in pixel-based classification. On the other hand, the statistic of the mean value and standard deviation, etc. exists in each object because the object in the object-based classification is a set of the pixel (Bents *et al.*, 2004; Murakami, 2010). In addition, the shape of the object and the index concerning the texture exist, and the object can be classified in consideration of the difference of these statistics. That is why we employed object based classification for high resolution satellite image and aerial photograph. In the tree classification process, eCognition Proffesional4.0 (Definiens .inc) was used. Mask processing had been done to all the use images for improving spectral separability before the tree species classification started. The mask targeted road, cryptomeria, Japanese big-leaf magnolia, and horse chestnut that were able to be confirmed clearly by inspection.

We prepared five image data sets of aerial photograph for tree species classification: 0501, 1106, 1104 (NIR), 0501+1106, and 0501+1106+1104 (NIR). In the case of satellite image, the tree species is classified into two kinds of the pan-sharpen image in which normal pan-sharpen image and without near infrared band, respectively. First of all, the segmentation was performed to each image one by one. In the segmentation process, we set parameters of scale parameter, shape factor, and compactness so that single tree crown was extracted as much as possible. Next, the classification class was decided as three classes that beech, oak, and painted maple in the aerial photograph. Only two classes that beech and non-beech were focused in the satellite image. It cannot decide where painted maple and oak are located from the satellite image with low resolution compared with the aerial photograph unlike the beech from which the feature is plainly seen. Therefore, it was thought that it was difficult to acquire a pure sample, and the focus only to the classification of the beech. After that, the sample was acquired based on the classification class that set it. The sample separately acquired the training sample and the validation sample based on the location information of the tree obtained by the field survey. The acquisition place of the sample selected it from the same point in all images as possible. The Nearest Neighbor method was applied for the tree species classification. This is one of the classification methods of the allocation to the class to which the distance is the shortest when the object is classified based on the feature space defined with the selected training sample. In the Nearest Neighbor method, multiple features within each object can be selected. Mean value of the sample object, Standard deviation, and Ratio were selected in this study. Then, the combination of the most effective amount of characteristics for the classification was selected. The accuracy assessment went by comparing validation object and the classification image were compared, and confirming into which class the object for the validation had been classified. The result was summarized in an error matrix, and user’s and producer’s accuracy, overall accuracy, and Kappa coefficient were determined.

5. RESULTS AND DISCUSSION

5.1 Aerial photograph

Each classification image is shown in Figre.1. Table1 shows overall accuracy and Kappa coefficient for each combination of aerial photograph. First, we will consider the classification result of a single each image. In the classification of a single image, overall accuracy was 0.949 and the Kappa coefficient became 0.887 that obtained the highest accuracy by 0501 image. In the 1106 and 1104(NIR) classification image, both of overall accuracy were about 0.6, Kappa coefficient was 0.443 in 1106 image and was 0.262 in 1104(NIR) image. Thus, classification accuracy of 1104(NIR) image was the lowest in this classification by using single image. Then, the occurrence misclassification of each class is examined. In the class of beech, the misclassification was hardly seen in 0501 classification image, and high producer's accuracy obtained, 0.980. In the 1106 and 1104(NIR) classification image, the misclassification mainly into oak class was seen, and producer's accuracy became 0.747 in 1106 image and 0.802 in 1104(NIR) image, respectively. As for oak class, a lot of misclassifications into the beech class were seen. In especially 1104(NIR) classification image, half the number of the validation sample was misclassified into the beech class. It is lower accuracy of 0.485 in 1104(NIR) than the accuracy of 0.7 over in 0501 and 1106 when focused on producer's accuracy. In the class of painted maple, although all the verification objects were correctly classified in 0501classification image, one object was not correctly classified in 1106 and 1104(NIR).

Next, the result of classifying the image that composite each time is examined. In 0501+1106 images and 0501+1106+1104(NIR), overall accuracy was 0.872 and 0.736, and the Kappa coefficient was 0.750 and 0.483, respectively. When the producer's accuracy and the user's accuracy were compared, the accuracy of the image that combined three imageries (0501+1106+1104) was lower than that of the image that combined two imageries (0501+1106) in all classes. Although the incorrect classification to oak class in beech class was the same tendency as the single image classification, producer's accuracy was 0.8 over in both combination images. The incorrect classification to beech class in oak class was also the same tendency, and producer's accuracy was 0.7 or more in both combination images. Especially producer's accuracy of 0501+1106 classification image was a slightly high compared with 0501 that accuracy was the best accuracy for a single image. As for painted maple, there was no validation sample correctly classified as well as the case of a single image of 1106 and 1104(NIR).

In a single image of 0501, all of classification accuracy that producer's accuracy, user's accuracy, overall accuracy and Kappa coefficient except producer's accuracy of oak were the highest of five images. Although the only producer's accuracy of oak in 0501+1106 was higher than that of 0501, it was a little difference. The low accuracy in 1106 and 1104 (NIR) influenced the classification accuracy of composite image.

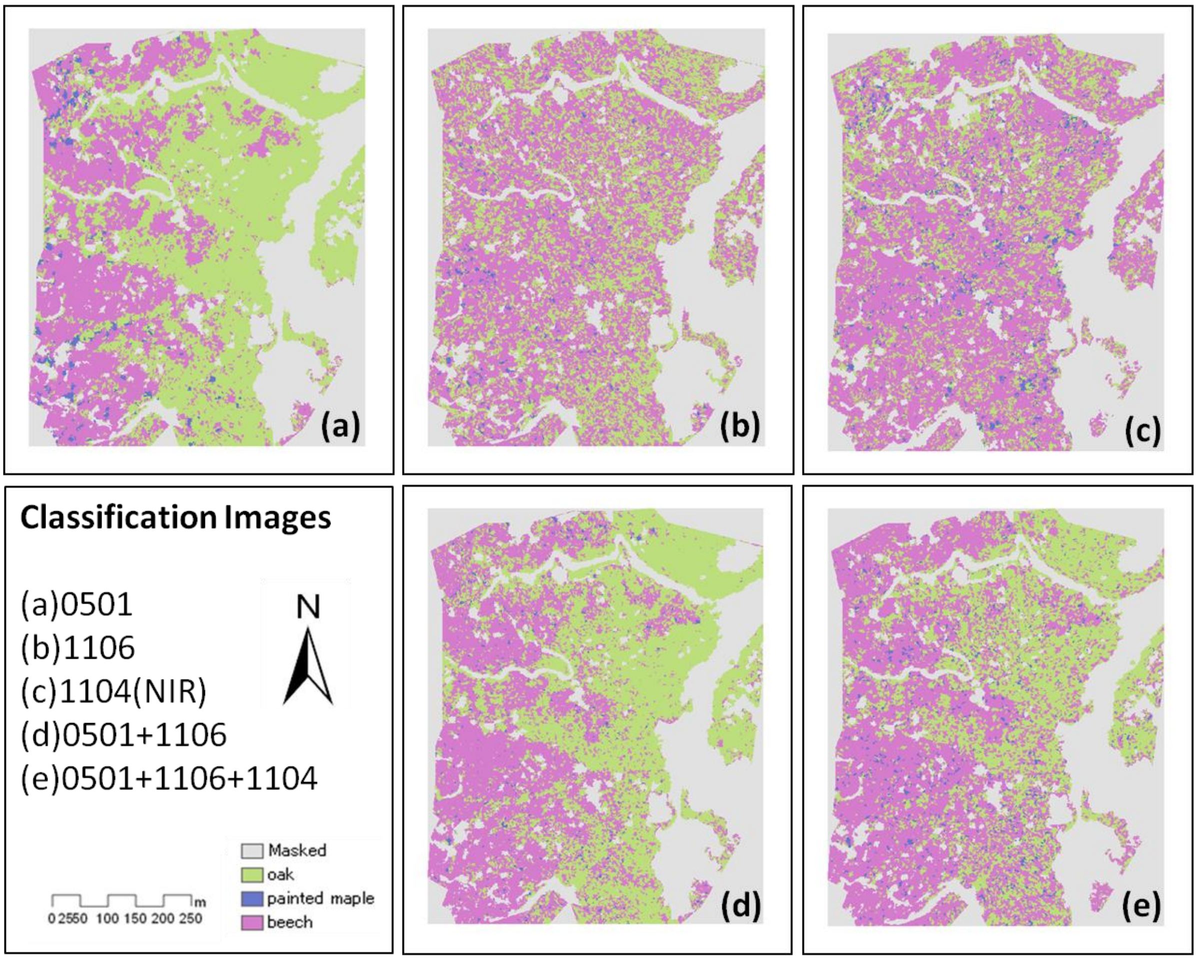

Fig.1 Each of classification image

As the reason which 0501 imagery was the best accuracy, the clearly difference of three classes (i.e., beech, oak, and painted maple) in the aerial photograph was confirmed. A vivid pea green in the beech and oak look like a white mist, painted maple look like a blurred yellow. It is thought that these catch the appearance of open leaf in beech, unopened leaf in oak and flowering in painted maple, respectively. On the other hand, the fall foliage was seen in all of three classes, and various tones are presented in one class in 1106 and 1104(NIR) image. Moreover, we could not see the apparent difference between three classes. Thus, because of the uniformity of each class is not clearly seen, it was thought that classification accuracy became low in autumn image.

Table.1 Overall accuracy and Kappa coefficient at each combination of aerial photograph

	Overall Accuracy	Kappa coefficient
0501	0.949	0.887
1106	0.699	0.443
1104(NIR)	0.616	0.262
0501+1106	0.872	0.750
0501+1106+1104(NIR)	0.736	0.483

5.2 Satellite image

In the classification of the satellite image, two classes of beech and non-beech were classified in the image with and without NIR. In the pan-sharpen image with NIR, because all of the validation sample were classified into the beech correctly, the beech class was detected with high accuracy. While in the classification of pan-sharpen image without NIR, about 1/3 of the test samples was misclassified. Thus, it was confirmed that extraction of beech accuracy in the image without NIR lowered compared to the image with NIR. The image with near infra-red correctly expressed the actual distribution of beech. When the color composition compared between false color and true color, the discrimination of beech is higher in false color.

A lot of misclassifications were generated in the image without near infra-red band. However, in the aerial photograph of similar condition that only visible and image was acquired on May as satellite image, the best classification accuracy was achieved. This is thought that difference at only acquisition time gap influenced, acquisition date was 01 May in aerial photograph and 18 May in satellite image.

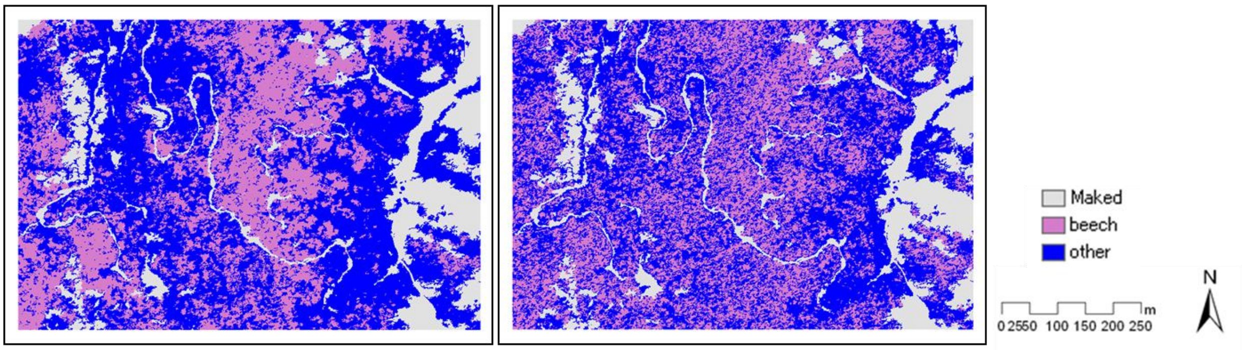

Fig.2 Classification image of satellite image
(Left: with near infra-red band, Right: without near infra-red band)

6. CONCLUSIONS

In the classification of aerial photograph, 0501, 1106, 1104(NIR), 0501+1106, and 0501+1106+1104(NIR) were classified. As a result, 0501 represented the highest accuracy in the imageries. The difference of the phenology like an open leaf of beech, flowering of painted maple was seen between aerial photographs. The aerial photograph in 0501 was a scene which caught the phonological features.

For the satellite image, detection of beech was examined in pan-sharpen image with and without near infra-red band.

The beech could be extracted in the pan-sharpen image with near infra-red band acquired May by high accuracy. From these, it can be said that the image acquired on May is effective for extraction of beech or oak. However, though the satellite image without near infra-red was similar condition (only visible and acquisition on May) as aerial photograph 0501 image that achieves the best accuracy, a lot of misclassification had been generated. Thus, it is thought that the difference on the image acquisition day influenced the extraction of the beech. In fact, when we can use the data of near infra-red, it is probably highly accurate and the extraction of the beech is possible even if it shifts at the best acquisition time. However, it is thought that it is necessary to examine the acquisition time in detail to classify it only by information on the visible.

Because the change is seen by the region and the age as for the phenology, we cannot clearly expect appropriate acquisition time. Though if the image that phenology the different between each class and united tones in each class as 0501 image used in this study are acquired, classification of beech or oak is highly accurate and possible. In the future work, we will try to the tree species classification that increases the number of classification classes (i.e. Japanese big-leaf magnolia, horse chestnut) and more wide range.

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