# Forest Type Classification Using Data Fusion of Multispectral and Panchromatic High-Resolution Satellite Imageries

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***Abstract*— This paper proposes fusion analysis of high-resolution multispectral and panchromatic satellite imageries for forest type classification.**

**We have shown the performance of forest type classification using panchromatic and multispectral high-resolution QuickBird satellite imageries separately. With texture features obtained from a panchromatic imagery, forest was classified into two types, such as coniferous and broad-leaved forests. On the other hand, with spectral features obtained from a multispectral imagery, forest was classified into six types, such as three coniferous, one broad-leaved and two mixed forests. These results showed that both texture and spectral features are effective for classification of forest types.**

**In this paper, we apply the object-based classification using the common segments obtained from a pansharpen imagery to fusion and single imagery analysis in order to compare the difference only between texture and spectral features. The mean value of each texture and spectral feature from a segment is adopted in the supervised classification, the standard nearest neighbor method, using radiometrically corrected satellite imageries. We selected the contrast as texture feature, and normalized band values and differences between normalized band values as spectral features. From the comparison of the result with ones obtained from a single imagery analysis, we demonstrated that data fusion analysis exceeds a single imagery analysis in accuracy.**

***Keywords-forest type classification; fusion analysis; high-resolution satellite imagery; multispctral imagery; panchromatic imagery.***

## I. INTRODUCTION

Precise and functional information about forest conditions is necessary to improve the performance of forest, such as the prevention of floods and landslides, sequestration of carbon dioxide, which is one of greenhouse gases, and offering comfortable environment.

In conventional survey of a forest area, photographic interpretation has been widely applied to classify a forest type, estimate a crown size and a stand number. Other airborne systems of LIDAR and hyperspectral sensor also show their usefulness for forest observation [1][2]. Even though airborne observation enables us precise survey, the cost performance for spacious area is worse than satellite imagery. Most conventional studies based on satellite imagery rely on spectral feature, because the spatial resolution is not enough to make use of texture information [3][4]. Recently, a high-resolution satellite imagery, which provides both texture and spectral information of forest, is available, and several studies show its effectiveness [5].

We have reported the performance of forest type classification using panchromatic and multispectral high-resolution QuickBird satellite imageries separately. With texture features obtained from a panchromatic imagery, forest was classified into two types, such as coniferous and broad-leaved forests [6]. Here, texture features, such as homogeneity, contrast and entropy, which were proposed by Haralick, were applied [7]. On the other hand, with spectral features obtained from a multispectral imagery, forest was classified into six types, such as three coniferous forests, one broad-leaved forest and two mixed forests [8]. Here, mixed forest types were defined by the ratio of coniferous and broad-leaved trees. These results showed that both texture and spectral features are effective for classification of forest types.

In this paper, we evaluate the effectiveness of data fusion of multispectral and panchromatic high-resolution satellite imageries in forest type classification. We apply data fusion analysis to forest type classification of cedar, cypress, larch, mixed forests, and broad-leaved tree, and compare the result with ones obtained from a single imagery analysis.

## II. STUDY SITE AND SATELLITE IMAGERIES

### A. Study Site

The study area is located within the Takayama city on the southwestern slopes of the Norikura Mountains in the Japan Alps, approximately on 1400 m above sea level around 137°25′22″ E in longitude and 36°08′44″ N in latitude as shown in Figure 1. The mean annual temperature is 7.2˚C and the annual precipitation is 1911 mm. The site is covered by snow from late November to mid April and the maximum snow depth is about 150 cm. In the study site, secondary deciduous broadleaf trees are dominated. Artificially planted coniferous forest such as Japanese cedar, Japanese cypress, and Japanese larch are growing on a gentle slope. Mixed forests with deciduous trees and red pine cover the ridge areas.

### *B. Satellite Imageries*

Panchromatic and multispectral imageries of QuickBird satellite are obtained simultaneously on Oct. 3rd, 2002, with 0% of cloud coverage, and about 21 degrees in zenith angle. A type of the imagery is "standard imagery" which is applied radiometric sensor and geometric corrections.

A panchromatic imagery with 0.6m of spatial resolution shows differences in textures due to the shape of a tree crown and a planted interval as shown in Figure 2.

On the other hand, a multispectral imagery with 2.4m of spatial resolution shows not textural but spectral differences as shown in Figure 2.

## III. METHOD

Figure 3 shows the flow of fusion analysis using the panchromatic and the multispectral satellite imageries in this study. First, texture and spectral features are calculated using radiometrically corrected imageries. Next, segments used in the object-based classification are generated using the pansharpen imagery. Then, the object-based classification using the standard nearest neighbor is applied as a fusion analysis.

For the analysis using a single imagery, the input to the object-based classification is either texture or spectral features.

### *A. Radiometric Correction*

The intensity of a mountainous region in satellite imagery is affected by topography and a kind of surface object such as a tree kind.

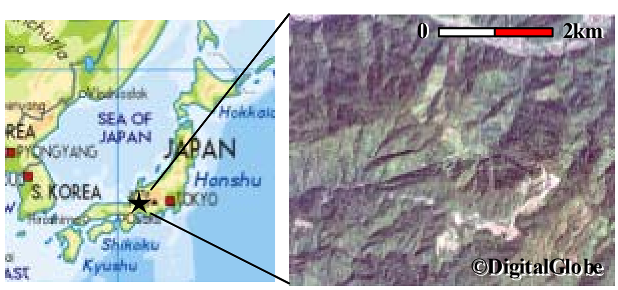
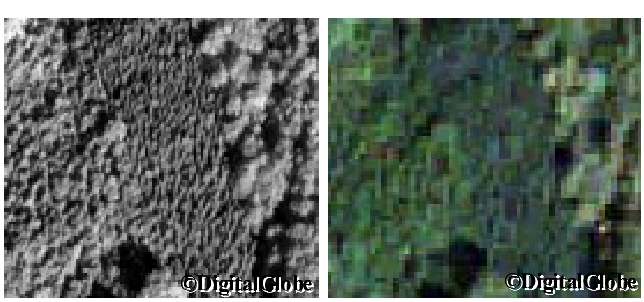



Figure 1 Location of Study Area.




(a) Panchromatic imagery. (b) Multispectral imagery.

Figure 2 Panchromatic and Multispectral Satellite Imageries.

For the panchromatic imagery, we calibrate topographic effect and generate texture-oriented imagery by dividing a pixel value by mean value of a 13 pixels by 13 pixels as shown in Figure 4.

For the multispectral imagery, we first transform the pixel value of $(x, y)$ with band number $n$ from the radiance, $L(x, y, n)$, to the reflectance, $R(x, y, n)$, as below,

$$R(x, y, n) = \alpha(n) \cdot L(x, y, n) + \beta(n). \quad (1)$$

Here, $\alpha(n)$ and $\beta(n)$ are calculated using the reflectance, $R_{reference}(n)$, at ground reference point, $(i, j)$ in the imagery, as below,

$$R_{reference}(n) = \alpha(n) \cdot L(i, j, n) + \beta(n). \quad (2)$$

In this study, the reference points are asphalt in a road, soil in a playground, and water in a pond. Next, we normalize the intensity of spectral data as below,

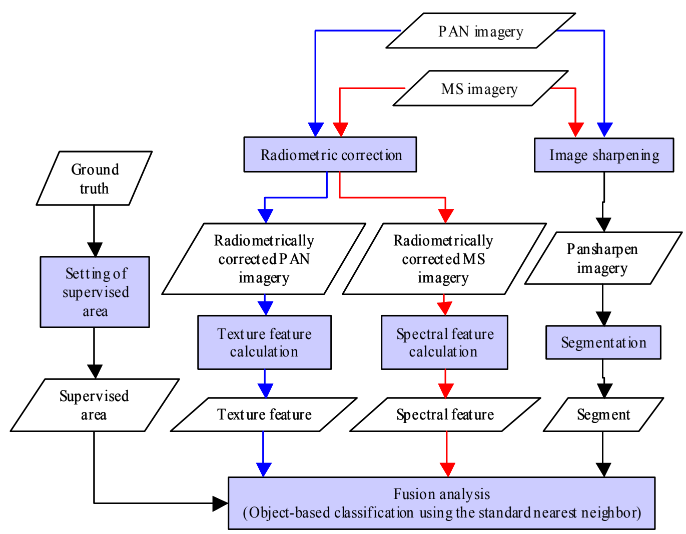
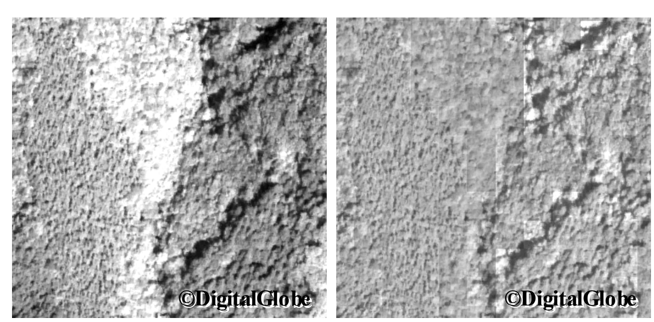



Figure 3 The Flow of Fusion Analysis.
(PAN: Panchromatic, MS:Multispectral)




(a) Original imagery. (b) Radiometrically corrected imagery.

Figure 4 Radiometric Correction of Panchromatic Imagery.

$$R_{norm}(x,y,n) = R(x,y,n) \Big/ \sqrt{\sum_m R^2(x,y,m)} . \qquad (3)$$

Figure 5 shows the normalized spectral data of forest types, such as cedar, cypress, larch, mixed forests, and broad-leaved tree. The value of Band4 is indistinct, while Band1, Band2, and Band3 show the spectral differences.

### B. *Texture and Spectral Features*

Figure 6 shows the texture and spectral features of forest types. We apply the texture features using co-occurrence matrix [7], which has been known effective to identify a forest type [9]. Figure 6 indicates homogeneity, contrast, and entropy as the texture features, which have been demonstrated effective in forest type classification [1], and the order of texture feature values of each forest type is almost same. As spectral features, we used normalized band values as shown in Figure 5, and differences between bands as shown in Figure 6. The spectral features identify coniferous trees, while those of mixed forest and broad-leaved tree are overlapped.

### C. *Object-Based Classificatiion*

The object-based classification is adopted in this study. The segmentation, which is based on the distance and the difference between pixels in the pansharpen imagery, is applied to the classification as shown in Figure 7. The supervised classification, the standard nearest neighbor method [10], is applied using the averaged feature value of each segment. In this study, the common segments obtained from the pansharpen imagery are used in fusion and single imagery analysis in order to compare the difference between texture and spectral features.

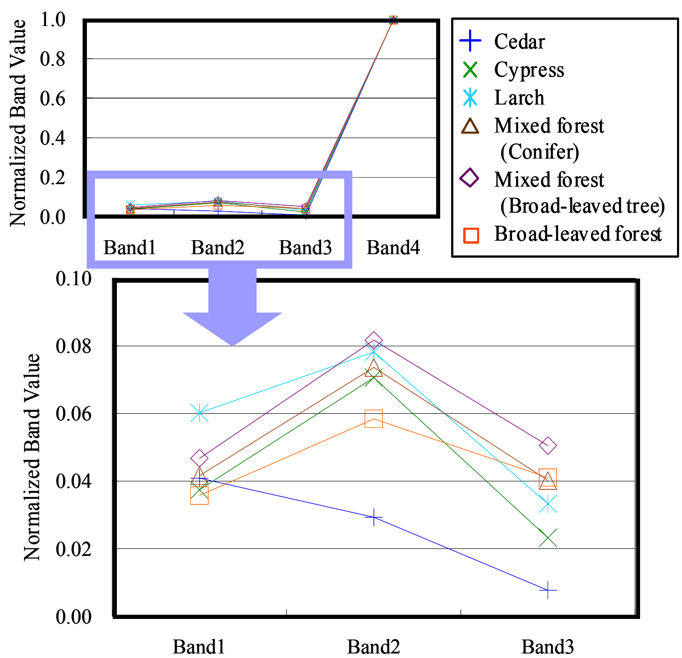



Figure 5 Normalized Spectral Data of Forest Types.

## IV. Results and Discussion

TABLE I shows the accuracy of forest type classification using a fusion analysis, and a single imagery analysis.

### A. *Panchromatic Imagery*

First, each texture feature and combinations of them were examined. The analysis using only the contrast showed the best result of all. This is why the correlations between these three texture features are very high, the coefficient was about 0.9, and the separability of forest types was highest of all. Here, the separability was calculated by the equation below.

$$separability = stdev(classes) / mean(classes) . \qquad (4)$$

Here, *mean* and *stdev* are calculated using texture feature of all forest types, *classes*.

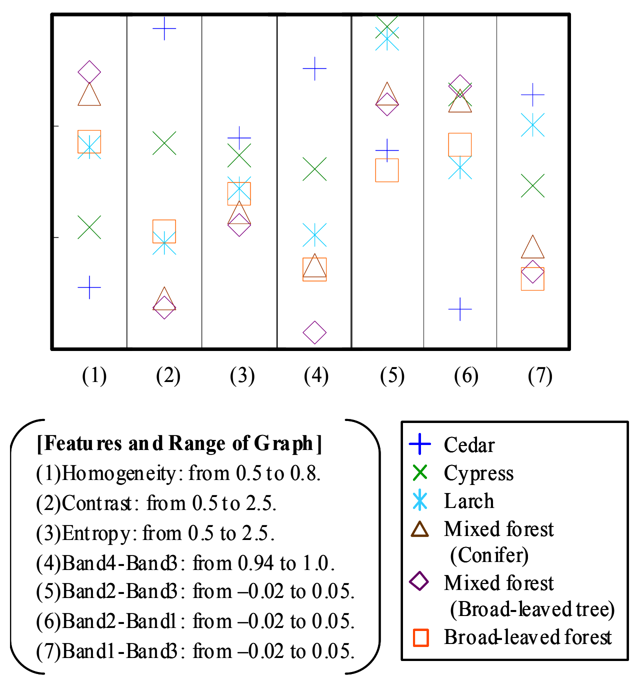



Figure 6 Texture and Spectral Features of Forest Types.

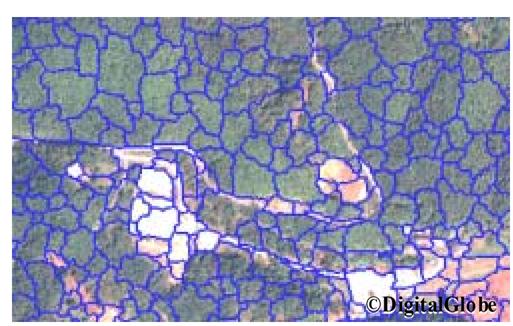



Figure 7 Segmentation of Satellite Imagery.

The misclassified within conifers, between mixed forests, conifers, and broad-leaved forest reduce the accuracy as shown in TABLE I

*B. Multispectral Imagery*

Most of the forest types were classified more accurately using multispectral imagery than panchromatic one as shown in TABLE I The result indicates that the separability of spectral features is higher than that of texture features, which is shown in the fundamental investigation of texture and spectral features in section III. B.

*C. Fusion of Multispectral and Panchromatic Imageries*

The accuracy of all conifers and mixed forest, which includes more conifer than broad-leaved tree in the coverage, is higher using fusion of panchromatic and multispectral imageries than ones using a single imagery. The result shows the effectiveness of fusion analysis. Figure 8 shows the pansharpen and the classified imageries by fusion analysis.

## V. CONCLUSION

In this paper, we evaluated the effectiveness of data fusion using multispectral and panchromatic high-resolution satellite imageries in forest type classification. We apply data fusion analysis to forest type classification of cedar, cypress, larch, mixed forests, and broad-leaved forest, and compare the result with ones obtained from a single image analysis. We demonstrated that data fusion exceeds a single image analysis in accuracy.

As a future work, we are going to apply more features such as variance of texture and spectral features in each segment in order to reduce the misclassification of mixed forest.


## ACKNOWLEDGMENTS

The authors wish to thank Mr. Yoshitaka Kuwata and Mr. Hiroyuki Arai for their suggestion to this paper, and Mr. Kurumado for his support of ground survey.


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TABLE I ACCURACY OF CLASSIFICATION.

| | Cedar | Cypress | Larch | Mixed forest (Conifer) | Mixed forest (Broad-leaved tree) | Broad-leaved forest |
|---|---|---|---|---|---|---|
| Fusion Analysis [a] | 84% | 84% | 90% | 67% | 35% | 78% |
| Multispectral Imagery Analysis [b] | 81% | 75% | 86% | 58% | 51% | 78% |
| Panchromatic Imagery Analysis [c] | 68% | 16% | 10% | 10% | 54% | 13% |

[a] Spectral Features, such as Band1, Band2, Band3, Band4, Band4-Band3, Band2-Band3, Band2-Band1, Band1-Band3, and Texture Features, such as Contrast are used.

[b] Spectral Features, such as Band1, Band2, Band3, Band4, Band4-Band3, Band2-Band3, Band2-Band1, Band1-Band3, are used. [c] Texture Features, such as Contrast, is used.

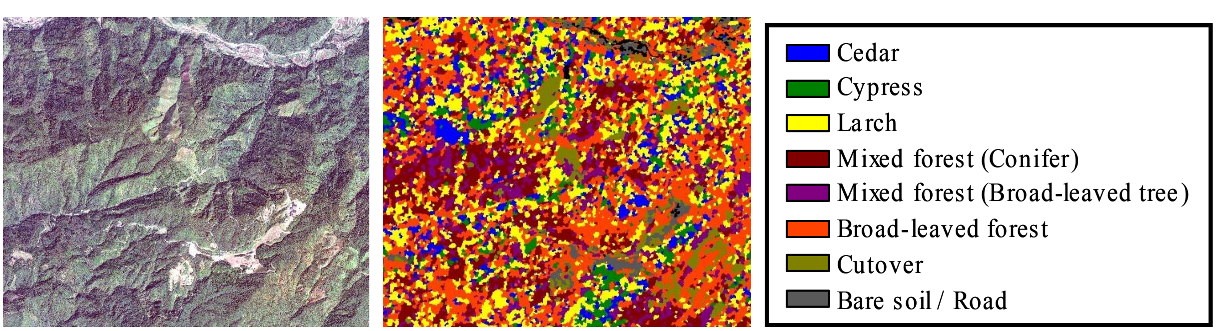


Figure 8 Pansharpen Imagery and Classified Imagery by Fusion Analysis.