How is SWIR useful to discrimination and a classification of forest types?

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Abstract: This study confirmed the usefulness of short-wavelength infrared (SWIR) in the discrimination and classification of evergreen forest types. A forested area near Hisayama and Sasaguri in Fukuoka Prefecture, Japan, served as the study area. Warm-temperate forest vegetation dominates the study site vegetation. Coniferous plantation forest, natural broad-leaved forest, and bamboo forest were analyzed using LANDSAT5/TM and SPOT4/HRVIR remote sensing data. Samples were extracted for the three forest types, and reflectance factors were compared for each band. Kappa coefficients of various band combinations were also compared by classification accuracy. For the LANDSAT5/TM data observed in April, October, and November, Bands 5 and 7 showed significant differences between bamboo, broad-leaved, and coniferous forests. The same significant difference was not recognized in the visible or near-infrared regions. Classification accuracy, determined by supervised classification, indicated distinct improvements in band combinations with SWIR, as compared to those without SWIR. Similar results were found for both LANDSAT5/TM and SPOT4/HRVIR data. This study identified obvious advantages in using SWIR data in forest-type discrimination and classification.
Keywords: SWIR, LANDSAT5/TM, SPOT4/HRVIR, evergreen forest, bamboo forest

1. Introduction

There are advantages to using short-wavelength infrared (SWIR) for forest monitoring. Atmospheric effects are less in the SWIR region, and SWIR can also be used to detect soil or canopy water contents. Spaceborne sensors, such as LANDSAT/TM, LANDSAT7/ETM+, SPOT4 /HRVIR, SPOT5/HRG, and TERRA/ASTER, cover the SWIR wavelengths. SPOT2/HRV and IKONOS, however, are limited to visible and near-infrared wavelengths. Despite the higher spatial resolution of SPOT2/HRV, research has shown that LANDSAT/TM produces classifications that are more accurate in forested areas [1, 2]. These results are largely due to the LANDSAT/TM Band 5 (the SWIR band).

Evergreen forests have less seasonal change in canopy reflectance than deciduous forests. Using multi-temporal SPOT2/HRV data, Murakami (2000) determined seasonal changes in reflectance factors for various forest types in northern Kyushu, Japan. Because evergreen forest dominates in that region, the range of reflectance factor change was relatively low. Although SPOT2/HRV covers the visible and near-infrared (NIR), the combination of different observation dates can be useful in discriminating forest types. However, the effectiveness of using a single scene (especially a single scene with SWIR data) has not previously been evaluated in this area. If adding SWIR makes a single scene as effective as scene combinations, single-scene imagery with SWIR will improve forest monitoring, since single scenes are easier to acquire than multiple scenes.

This study examined how SWIR addition affected the discrimination and classification of forest types. Using LANDSAT5/TM and SPOT4/HRVIR data, the reflectance factor for each forest type in the SWIR and non-SWIR bands was compared. Supervised classification was also applied to band combinations with and without SWIR, and classification accuracies were compared.

2. Study Area

The study area is a forested area located near Hisayama (3,743 ha) and Sasaguri, (3,890 ha) in Fukuoka Prefecture, Japan. The area includes the Kyushu University Forest (482 ha). Hisayama has 2,412 ha of forest, and Sasaguri has 2,313 ha. Coniferous plantation forest makes up 74 % of the forest area in Hisayama and 80 % in Sasaguri. The area ranges in altitude from 20 to 670 m asl. The natural vegetation is warm-temperate evergreen broad-leaved forest.

This study focused on three forest types for classification: natural broad-leaved forest, coniferous plantation forest, and bamboo forest. The natural broad-leaved forest has the following tall species, identified from ongoing plot research in the university forest: *Cinnamomum camphora*, *Neolitsea sericea*, *Machilus thunbergii*, *Castanopsis sieboldii*, *Quercus serrata*, *Quercus glauca*, *Quercus acuta*, *Quercus salicina*, *Myrica rubra*, *Symplocos prunifolia*, and *Carpinus laxiflora*. Except for *Quercus serrata* and *Carpinus laxiflora*, the dominant broad-leaved trees are evergreen species. *Cryptomeria japonica* and *Chamaecyparis obutusa* dominate nearly all of the coniferous plantation forest. The bamboo forest is composed mainly of *Phyllostachys pubescens* (*Phyllostachys heterocycala*), but also contains some *Phyllostachys bambusoides*.

3. Methods

Data and pre-processing

Table 1 lists the LANDSAT5/TM and SPOT4/ HRVIR observation dates used in this study. Aerial photographs obtained in July 1995 were used to acquire classification training data and for verification. A Digital Map 50-m grid, published by the Geographical Survey Institute of Japan, was used for the digital elevation model (DEM). A Digital Map 25000 (map image), produced by the Geographical Survey Institute, was used for geometric registration.

All analyses were executed on ERDAS IMAGINE Version 8.6. All imagery data were geometrically registered on a Universal Transverse Mercator projection, zone 52, using ground-control points on the Digital Map 25000. The LANDSAT or SPOT model of ERDAS IMAGINE, one of the specific rectification modules, was applied to correct topographic distortion from the central projection and oblique viewing. Aerial photographs were orthorectified using ERDAS IMAGINE OrthoBASE. All images were atmospherically corrected and converted into reflectance factors using ATCOR2.

Supervised classification

As mentioned above, natural broad-leaved, coniferous plantation, and bamboo forest types were chosen for supervised classification. Training data for the three forest classes were collected by dividing the slope aspect from 45 to 224 degrees and from 225 to 44 degrees. The acquired training data were executed on the orthorectified aerial photographs. A total of six initial classes were set (three forest-type classes and two slope-aspect classes). Images in which a cloud or cloud shadow covered the training area were excluded in advance. The maximum likelihood method was used for supervised classification. After classification, the slope aspect classes were merged, creating a classified image with three classes. Training data for accuracy assessment were prepared independently. Both training data sets for each forest type were determined on dense forests with canopy closure.

Table 1. Data set used for this study.

Sensor	Observation Date	Path-Row
LANDSAT5/TM	24 Apr. 1997	113-37
LANDSAT5/TM	17 Oct. 1997	113-37
LANDSAT5/TM	7 Nov. 1997	113-37
SPOT4/HRVIR	17 Sep. 2001	313-283

Accuracy assessment

Kappa analysis [4] was applied to evaluate error matrices derived from the supervised classification. In this study, Kappa coefficients were calculated as a measure of classification accuracy. Using z-tests, the Kappa statistic and its variance were used to statistically compare the classification accuracies among forest types [4].

4. Results

Comparison of reflectance factors

Figure 1 shows the reflectance factor for each forest type. ANOVA post hoc tests of Band 4 data from April, and Band 5 data from April, October, and November, indicated significant differences among the three forest types. Band 4 data from October and November, however, showed no difference between bamboo and broad-leaved forests. The reflectance factor order for each forest type differed between the April Band 4 data and all the Band 5 data. For all Band 5 scenes, bamboo showed the highest reflectance, followed by the broad-leaved forest, and then the coniferous plantation forest. Band 7 indicated the same results as Band 5.

Comparison of classification accuracy (with SWIR vs. without SWIR)

Figure 2 shows classification accuracy comparisons

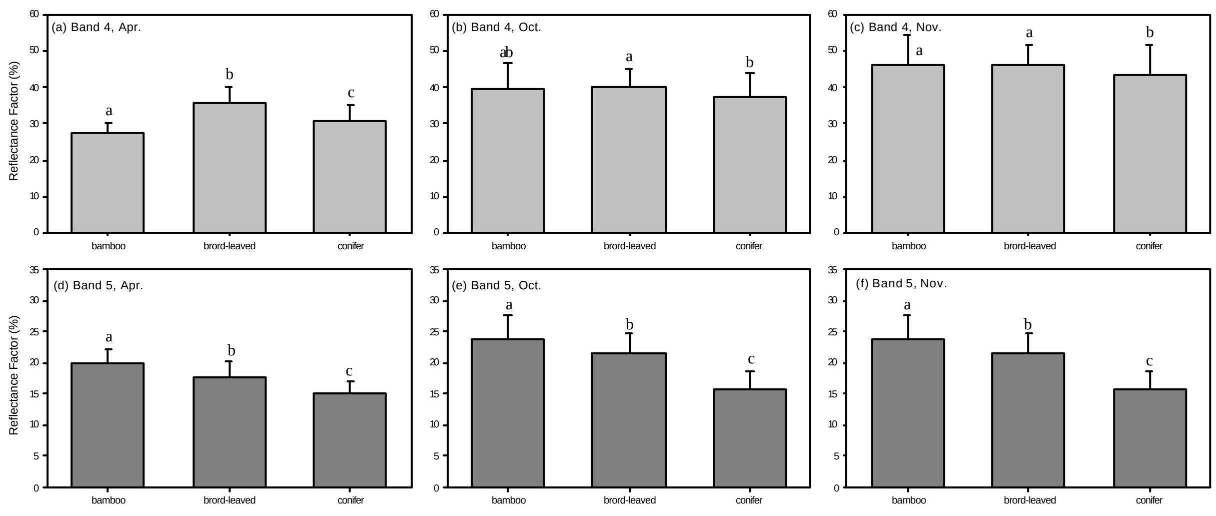

Fig. 1. The reflectance factor of each forest type by band and observation date. Error bars show the standard deviation. The upper figures show Band 4 and lower figures show Band 5. The characters indicate ANOVA post hoc test groupings.

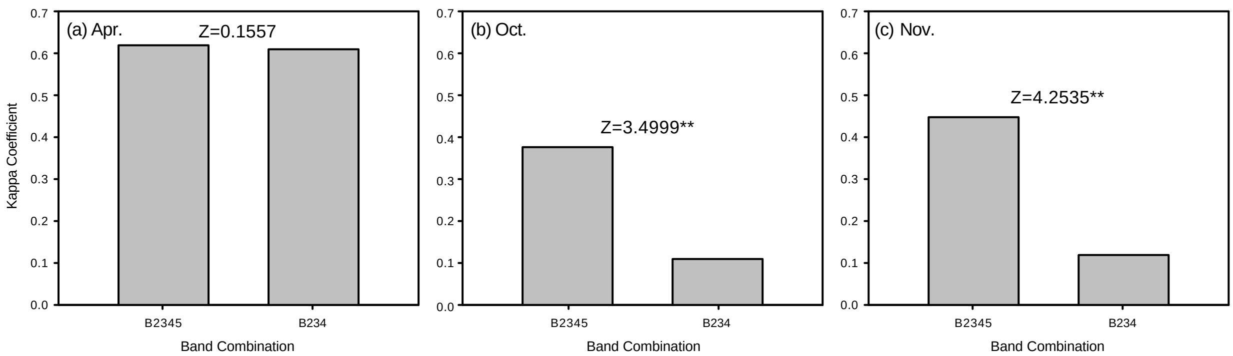

Fig. 2. Classification accuracy measured by different band combinations of LANDSAT5/TM. Combinations are Bands 2, 3, 4, and 5 and Bands 2, 3, and 4. (a) 24 April 1997 data, (b) 17 October 1997 data, (c) 7 November 1997 data.

of LANDSAT5/TM band combinations. The classification accuracy of a Band 2, 3, 4, and 5 combination was compared with that of a Band 2, 3, and 4 combination, for each scene. No significant difference was found for these band combinations using the April data. However, for the October and November data, the Band 2, 3, 4, and 5 combination was significantly more accurate than the Band 2, 3, and 4 combination. At this time of year, the addition of SWIR improved the classification accuracy.

Comparison of classification accuracy measured by different SPOT4/HRVIR band combinations is shown in Figure 3. The Kappa coefficients of the full band and the combination of Bands 1, 2, and 3 were 0.844 and 0.609, respectively. The full band showed significantly higher classification accuracy than the combination of Bands 1, 2, and 3.

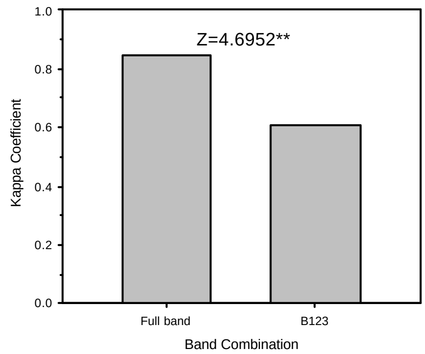

Fig. 3. Classification accuracy measured by different band combinations of SPOT4/HRVIR. Band combinations are the full band and Bands 1, 2, and 3.

5. Discussion

Use of SWIR revealed significant differences among the three forest types (Fig. 1). This feature was not seen in other bands. Moreover, the addition of SWIR improved classification accuracy significantly (Figs. 2 and 3). This result suggests that SWIR is very important in the discrimination and classification of evergreen forest types.

This research has practical applications. For example, in recent years Japan has faced the problem of increasing bamboo forest. The results of this study confirm that SWIR can be used to extract bamboo from other forest types in remotely sensed images. Although LANDSAT5/TM, SPOT4/HRVIR, SPOT5/HRG, and Terra/ASTER are suitable sensors, LANDSAT5/TM has the most substantial data archive. As archival data provide information on past forest conditions, LANDSAT5/TM data could be used for temporal change analysis of bamboo forest expansion.

Atmospheric effects are weaker in the SWIR. The SWIR can also detect soil or canopy water contents and is effective in extracting cut areas. Given the usefulness of SWIR in forest-type discrimination and classification, SWIR has an important role to play in the remote sensing analysis of forests. SWIR is indispensable to forest remote sensing, and optical sensors for environmental monitoring should be equipped with this band.

Acknowledgements

The LANDSAT/TM data used in this study were provided by NASA/National Space Development Agency (NASDA). The SPOT/HRV data used in this study were provided by SPOT IMAGE/National Space Development Agency (NASDA).

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