Comparison of Minnaert Constants Based on Multi-Temporal SPOT/HRV Data for Three Forest Types

Takuhiko MURAKAMI*

(Received July 9, 2007)

Summary

The Minnaert constant of the Minnaert topographic correction method is based on a specific surface; however, few studies have examined how the Minnaert constant may vary with the observed scene. This study compared Minnaert constants derived from remote sensing data from three different forest types. A Minnaert constant for each forest type was computed using data for similar topographical conditions (*i.e.*, slope angle and slope azimuth), and significant difference tests were performed. Minnaert constants from random sample data stratified only by topographical conditions without specifying a forest type were also obtained and had similar values. The study focused on a forested area in the Sangun mountainous region near Fukuoka, Japan. Data were obtained from seven scenes observed by the SPOT/HRV satellite in 1997. No significant differences were found among the Minnaert constants for the three forest types from the sample data with similar topographic conditions. The random topographic data also indicated no significant differences in the Minnaert constants for all scenes and bands. These results suggest that even if the sample set were changed, a stable Minnaert constant could be acquired by stratifying data based on topographical conditions.

Bull.Facul.Agric.Niigata Univ., 60:83-90, 2007

Key words : Minnaert constant, Minnaert topographic correction, Multi-temporal remote sensing data, SPOT/HRV, Topographic effect

Almost all forests in Japan are located on sloping ground in rugged terrain. Shade caused by such topographic relief can create serious obstacles to the analysis of remote sensing data (Leprieur *et al.*, 1988; Civco, 1989). Since the early 1980s, various forest remote sensing studies have attempted to address this "topographic effect" problem (*e.g.*, Holben and Justice, 1980; Smith *et al.*, 1980). Two correction methods are available to offset topographic effects: a non-geometric technique that uses band ratios and a geometric technique based on solar, surface, and sensor positions. The present study focused on the geometric technique.

Smith et al. (1980) introduced geometric correction methods for topographic effects. The Lambert model and model correction methods that they presented continue to be cited by many researchers and a number of verification studies have been conducted (*e.g.*, Teillet *et al.*, 1982; Chiou *et al.*, 1992; Meyer *et al.*, 1993; Murakami *et al.*, 1998; Riaño *et al.*, 2003; Vincini and Frazzi, 2003; Soenen *et al.*, 2005). The Lambert model assumes the land surface has perfect scatter in which the bidirectional reflectance factor is independent of incidence and exitance angles. This model is very simple, dividing an observed radiation value by the cosine of a solar incidence angle. Actual land surfaces, however, seldom result in even scattering in all directions, and some researchers have noted the limitations of the Lambert model (Teillet *et al.*, 1982; Chiou *et al.*, 1992; Meyer *et al.*, 1993; Murakami *et al.*, 1998).

Another model correction method uses the Minnaert constant (Smith *et al.*, 1980). The value of the Minnaert constant is determined by landcover characteristics and relates to surface roughness (Minnaert, 1941; Smith *et al.*, 1980). Although some additional correction models incorporate the solar incidence angle (Teillet *et al.*, 1982; Kawata *et al.*, 1988; Richter, 1997; Gu and Gillespie, 1998), these models have not been widely used, mainly because of the complicated parameter preparation required. The Minnaert correction method is both easy to apply and theoretically linked with the Lambert model. Therefore, the Minnaert method is an appropriate correction model for topographic effects.

Murakami (2002) studied seasonal variation in the Minnaert constant for three forest types (bamboo, broadleaf, and coniferous plantation forest) using multi-temporal SPOT/HRV (High Resolution Visible sensor) data and discussed similarities and differences based on band variation. That study, however, lacked adequate comparison of the Minnaert constant among forest types, and any change in the constant with forest type remained unclear. Because just one Minnaert constant is generally used for an entire image, it is desirable that Minnaert constants for various forest types do not differ significantly. Therefore, it is important to compare the Minnaert constant among forest types.

The present study compared Minnaert constants for different forest types using multi-temporal remote sensing data. Minnaert constants for each forest type were derived from sample data with similar topographic conditions; significance tests were used to examine the results. Minnaert constants were also derived from sample data randomly stratified using only topographic conditions (slope angle and

Faculty of Agriculture, Niigata University
*Corresponding author: muratac@agr.niigata-u.ac.jp

slope azimuth), without specifying forest type.

MATERIALS AND METHODS

Study area

Two study sites were selected in a forested area of the Sangun mountainous region near Fukuoka, Japan (**Fig. 1**). Elevations in this area range from 30 to 930 m above sea level, and the natural vegetation is warm-temperate evergreen broadleaf forest. Secondary natural broadleaf forest presently dominates the area. Other landcover includes coniferous plantation forests composed mainly of Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obutusa*) and bamboo forests.

Table 1. Satellite image data list

Observation Date	Day of the Year	Pointing Angle (deg.)
17 January 1997	17	R 7.3
5 March 1997	64	R 13.8
26 April 1997	116	R 14.1
17 June 1997	168	R 14.1
23 July 1997	204	R 0.8
25 Octorber 1997	298	R 15.2
5 December 1997	339	L 5.9

Data and preprocessing

Seven SPOT/HRV images were analyzed (**Table 1**). All SPOT/HRV data were observed in 1997. SPOT/HRV has three spectral bands: band 1 (visible green, 500-590 nm), band 2 (visible red, 610-680 nm), and band 3 (near-infrared, 790-890 nm). The spatial resolution of SPOT/HRV is 20 m.

A 50-m grid digital map published by the Geographical Survey Institute of Japan was used for the digital elevation model (DEM). This DEM was applied for the geometric registration (including ortho-rectification) of satellite data and for the calculation of the solar incidence angle and sensor exitance angle in each pixel. A 1:25000 digital map produced by the Geographical Survey Institute was used for geometric registration.

ERDAS IMAGINE software Version 8.7 (Leica Geosystems Geospatial Imaging, Norcross, GA, USA) was used for preprocessing the satellite data. All data were geometrically registered on a Universal Transverse Mercator projection, zone 52. The resampling method was nearest-neighbor. The SPOT model of ERDAS IMAGINE, one of the specific rectification modules, was applied to correct topographic distortion resulting from the central projection and oblique viewing. Atmospheric correction was not conducted to avoid the error caused by this correction process and because only relative variation information was required.

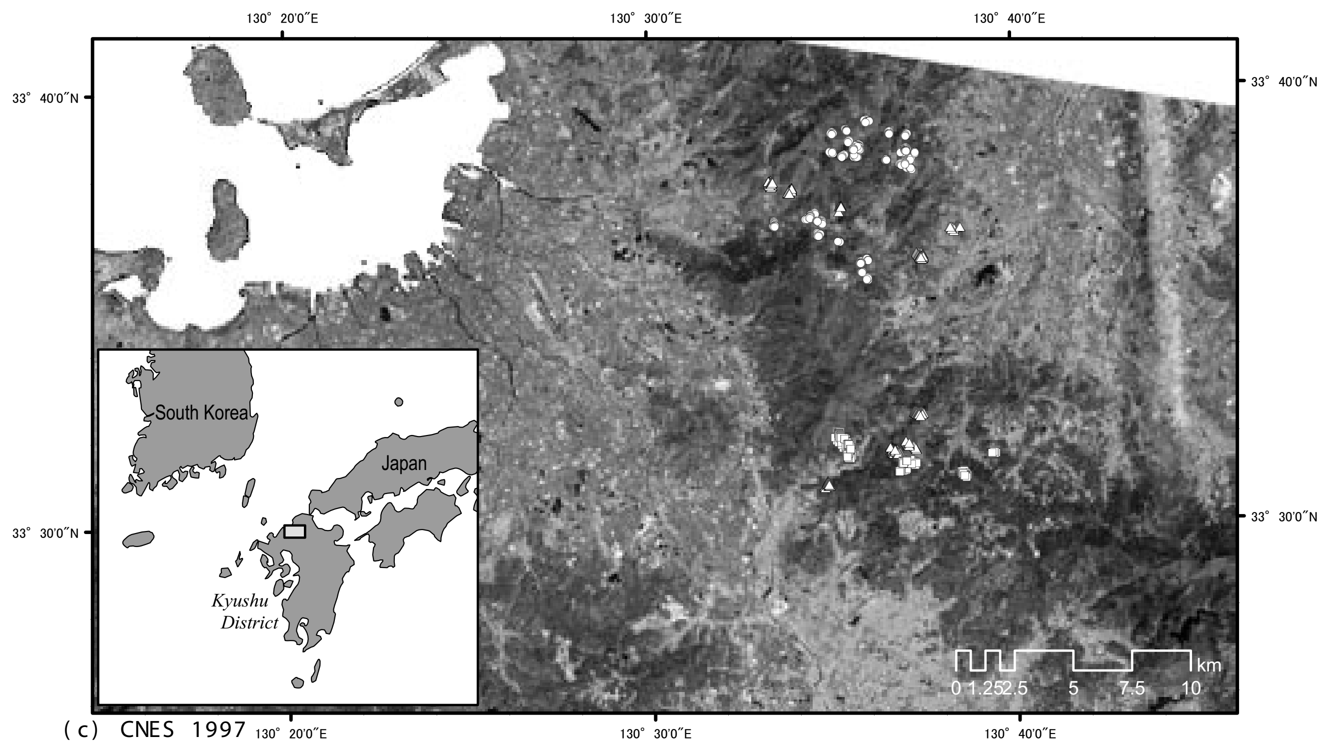

Fig. 1. Study area. Data sampling points for each forest type are displayed as open circle: bamboo stand, open triangle: broadleaf forest, and open square: conifer plantation.

Table 2. The solar and sensor positions at the time of the satellite observations

Observation date	Solar zenith angle (deg.)	Solar azimuth (deg.)	Sensor zenith angle (deg.)	Sensor azimuth (deg.)
17 January 1997	57.72	157.29	8.26	101.12
5 March 1997	44.68	148.48	15.64	101.75
26 April 1997	26.04	136.18	15.98	101.78
17 June 1997	19.46	116.72	15.98	101.78
23 July 1997	21.17	124.94	0.90	100.52
25 Octorber 1997	47.76	160.35	17.23	101.89
5 December 1997	55.63	164.66	6.67	280.99

Minnaert constants

The Minnaert correction method is one of the most common topographic correction methods (Smith *et al.*, 1980). This model is based on an empirical formula originally proposed by Minnaert (1941). Smith et al. (1980) adopted the Minnaert constant to correct topographic effects and further research has confirmed its effectiveness (Teillet *et al.*, 1982; Chiou *et al.*, 1992; Meyer *et al.*, 1993). The Minnaert method is expressed by the following formula:

$$D_c = \frac{D_o \cdot \cos\ \varepsilon}{(\cos i \cdot \cos \varepsilon)^k} \quad (1)$$

where D_c is the corrected data value, D_o is the original data value, i is the solar incidence angle, ε is the sensor exitance angle, and k is the Minnaert constant.

The solar incidence angle is defined as the position of the Sun with respect to the surface normal. Parameters related to topographic conditions (slope angle and slope azimuth) and solar position (solar zenith angle and solar azimuth) are required for determining the solar incidence angle as follows:

$$\cos i = \cos\theta \times \cos e + \sin\theta \times \sin e \times \cos(\phi - A) \quad (2)$$

where e is the slope angle, ϕ is the slope azimuth, θ is the solar zenith angle, and A is the solar azimuth. The sensor exitance angle is similarly defined as the angle between the surface normal and the sensor position. Solar position is often replaced by sensor position for the above-mentioned solar incidence angle calculation. The sensor exitance angle is defined as:

$$\cos\varepsilon = \cos\gamma \times \cos e + \sin\gamma \times \sin e \times \cos(\phi - \psi) \quad (3)$$

where γ is the sensor zenith angle and ψ is the sensor azimuth. For the oblique viewing of SPOT/HRV, the sensor exitance angle may vary with the scene. **Table 2** shows the four required parameters for the solar incidence angle.

After logarithmic transformation of Equation 1, as follows, the Minnaert constant is determined as the slope of linear regression:

$$\mathrm{In}(D_o \cdot \cos\varepsilon) = k \cdot \mathrm{In}(\cos i \cdot \cos\varepsilon) + \mathrm{In}(D_c) \quad (4)$$

The correction of topographic effects can be achieved by using Equation 1, where parameter k is the slope from Equation 4. In this analysis, D_o is the digital number that was converted to radiance. The radiance conversion factors were derived from a header file attached to the SPOT/HRV data.

Data sampling methods

Smith et al. (1980) suggested that the Minnaert constant is inherent to a landcover type, meaning that the landcover type must be spatially explicit prior to calculating the Minnaert constant. Therefore, a previously classified remotely sensed image or specific GIS data for a given area must already exist. However, if such data pre-exist, there is little need for correction of topographic effects. For cases with no prior data available, it is desirable to examine the difference of Minnaert constants among forest types and validate the consistency of Minnaert constants derived without specifying forest type. Thus, in the present study, sample data were extracted using the following procedures, and the resulting Minnaert constants were statistically compared.

I. The sample points for each forest type were established by comparing a vegetation map published by the Environment Agency of Japan with satellite data. Comparisons accounted for any changes that may have occurred between the date of the map (1988) and the satellite data observation year (1997). Furthermore, because distinguishing forest types based only on a single SPOT/HRV image was difficult, two or more images were combined to improve the visual interpretation. Combining scenes allowed for effective discrimination of the three forest types. The combination of band 3 in April (day of year [DOY] 116) and June (DOY 168) resulted in the very accurate identification of broadleaf, coniferous, and bamboo forests. After ensuring that there were no clouds or cloud shadows over the sampling point for each scene, the sampling point was established. This method was used to create the primary dataset.

II. The Minnaert constant tends to be affected by sampling bias because, as noted above, the constant is derived from regression analysis. To avoid topographic bias in the sample data, Murakami (2002) used stratified random sampling to extract sample data based on a combination of topographical features (slope angle and slope azimuth). In this study, the sampling design was adjusted so that only data related to the combination of slope angle and slope azimuth would be extracted for each forest type.

III. The first objective of this study was to compare Minnaert constants among forest types; the data were author-controlled so that the sampling conditions of the three

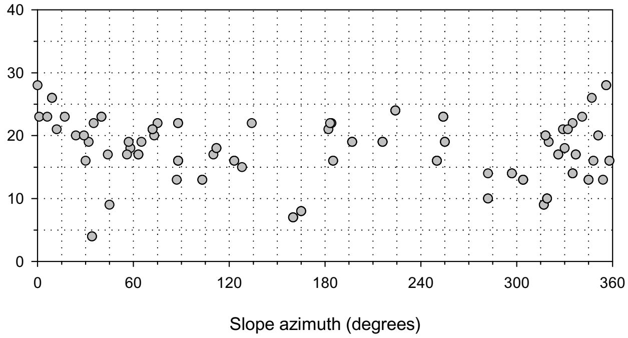

Fig. 2. Scattergram between slope azimuth and slope angle for the analysis of Sample I.

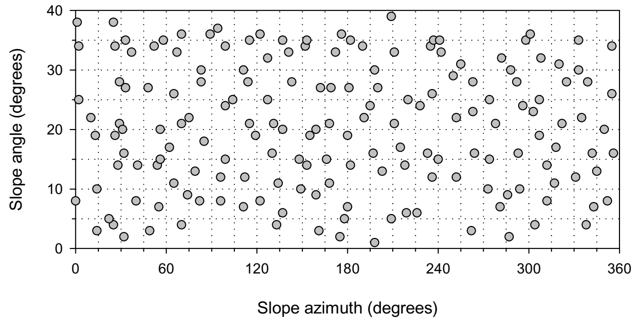

Fig. 4. Scattergram between slope azimuth and slope angle for the analysis of Sample II.

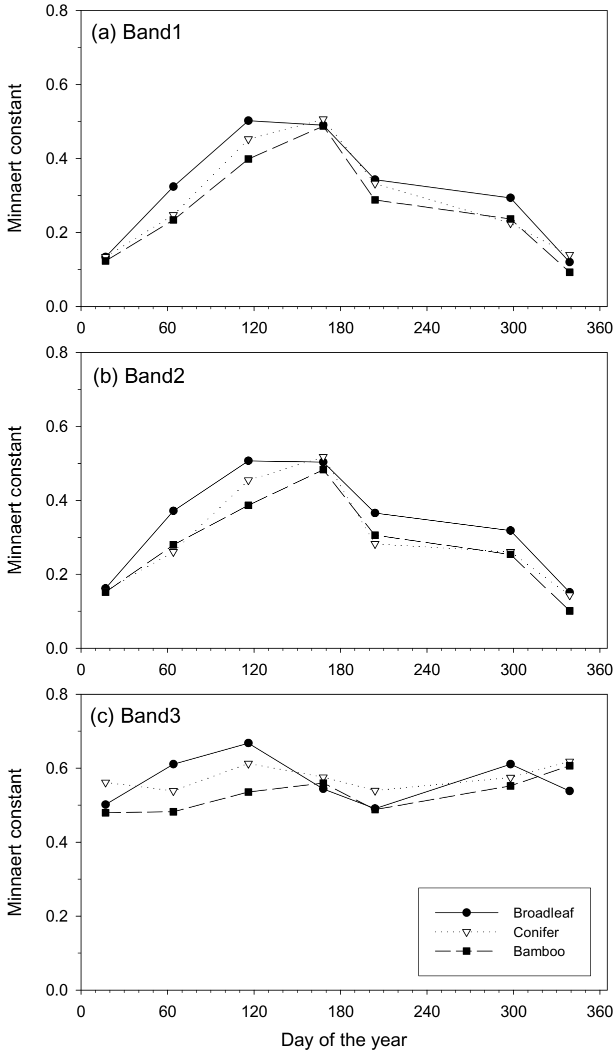

Fig. 3. The Minnaert constants for three forest types derived from same topographical features. (a) Band 1, (b) Band 2 and (c) Band 3.

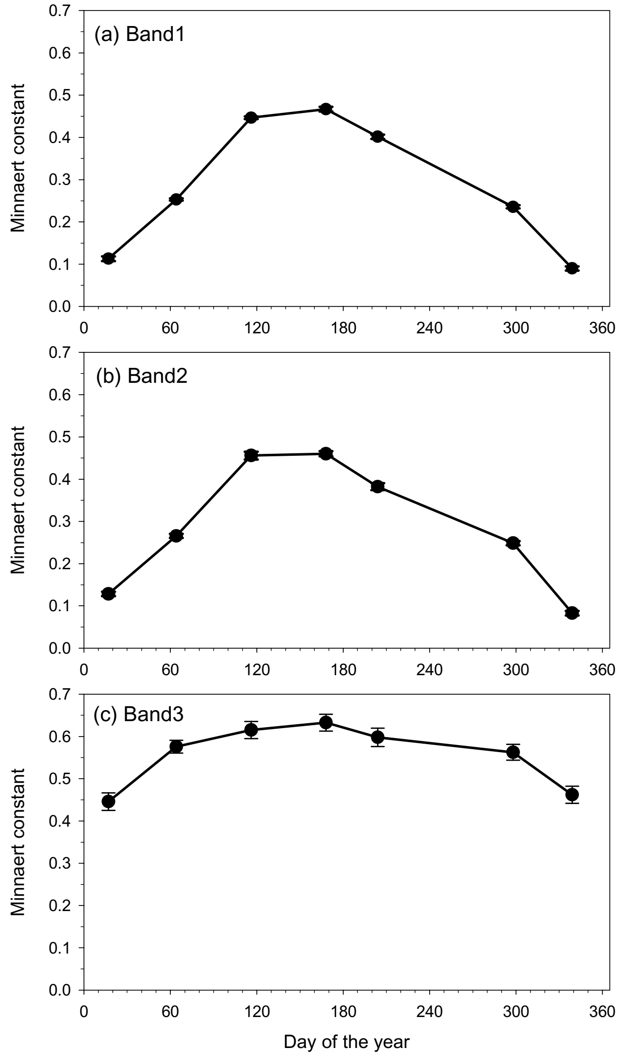

Fig. 5. The Minnaert constants derived from stratified random sampling, Sample II. Error bars represent standard deviations. (a) Band 1, (b) Band 2 and (c) Band 3.

Table 3. Significant probability of the parallelism test. The results for Minnaert constants obtained from Sample I

	Day of the Year						
	17	64	116	168	204	298	339
Band 1	0.000**	0.000**	0.000**	0.120	0.532	0.062	0.000**
Band 2	0.000**	0.000**	0.004**	0.029*	0.000**	0.056	0.000**
Band 3	0.121	0.190	0.000**	0.010**	0.331	0.429	0.112

**significant at the 0.01 level, *significant at the 0.05 level.

Table 4. Significant probability of the parallelism test. The results for Minnaert constants obtained from Sample II

	Day of the Year						
	17	64	116	168	204	298	339
Band 1	0.9357	0.999	0.999	0.9373	0.999	0.999	0.9886
Band 2	0.9484	0.9991	0.9813	0.9852	0.999	0.9979	0.9744
Band 3	0.6205	0.9441	0.9616	0.996	0.9983	0.9156	0.8144

forest types would be standardized. Accordingly, the extracted data for the three forest types had the same combinations of slope angle and slope azimuth. The sample set obtained using this method was called Sample I.

IV. Other data were extracted without specifying forest type, although the data had to represent one of the three target forest types. This dataset, which consisted of topographic data (slope angle and slope azimuth from the DEM) and satellite data (the digital number [DN] in each band), was extracted from a forest-covered mountainous area. Stratified random sampling based on topographical conditions was then conducted. Stratification criteria included slope angle and slope azimuth. For stratification, classes were established at combinations of 5° intervals (0-40°) for slope angle and 15° intervals for slope azimuth; classes expressed similar topographic units. One sample (the set of topographic and satellite data) was randomly extracted per topographic class. It was assumed that topographic bias was eliminated through this sampling method. To validate the stability of the Minnaert constant, these operations were repeated 10 times. Ten Minnaert constants were calculated per scene and per band and were compared using statistical tests. The sample dataset compiled using this process was referred to as Sample II.

Statistical test

Because a Minnaert constant is estimated from the slope of a regression line, comparing Minnaert constants means comparing the slopes of regression lines. A test of parallelism of covariance analysis (ANCOVA) was used to compare the slopes of the regression lines. In this analysis, a test of significant difference in the Minnaert constants was carried out using a test of parallelism. The statistical analysis software R 1.9.1 (http://www.r-project.org/) was used for this test.

RESULTS

Fig. 2 shows a scattergram of Sample I. For slope angle, the points concentrated between 10 and 30°. Relatively few samples, however, had a slope azimuth of 150-270°. Although extracted data did not scatter equally for all topographic features, the main purpose here was obtaining the same topographical features for the three forest types. Thus, the following analysis comparing the Minnaert constants among forest types could be carried out using Sample I.

Fig. 3 shows the results of Sample I analysis. **Fig. 3a** focuses on band 1, which had a convex-shaped overall change pattern. The broadleaf forest had the largest value throughout the year. When the Minnaert constants for each forest type were compared for each scene, a difference exceeding 0.1 was only found on DOY 116 (0.103). Differences for the other scenes ranged from 0.090-0.011. The minimum difference occurred on DOY 17. As illustrated in **Fig. 3b**, the seasonal variation pattern for band 2 was similar to that for band 1. The largest difference, 0.120, occurred on DOY 116, and the next greatest difference was on DOY 64 (0.110). Other scenes had differences of less than 0.1. Band 3 differed slightly from bands 1 and 2 in that its seasonal variation pattern varied within a certain range rather than forming a clear peak **(Fig. 3c)**. Moreover, although the broadleaf forest had the highest value for bands 1 and 2, no clear ranking of forest types was found for band 3. The maximum difference in band 3 was 0.132 (DOY 116), followed by 0.129 (DOY 64). The minimum difference was 0.032 (DOY 168). In general, differences in the Minnaert constants for band 3 were larger than those for bands 1 and 2.

Table 3 shows the results of significance tests on Minnaert constants by forest type for each scene. The values in this table indicate significance probability. For band 1, no significant difference was recognized in the Minnaert constants of the three forest types on DOY 168, 204, and 298. For band 2, only DOY 298 had no significant difference. Band

3 had the most scenes without significant difference. Five of the seven scenes had no significant difference in Minnaert constants among the three forest types.

Fig. 4 shows the scattergram of one set of SPOT/HRV-derived sample data. Almost all topographic conditions were represented by uniform amounts of data. Thus, for the stratification of topographic conditions, data were randomly sampled, and Minnaert constants were calculated.

Fig. 5 illustrates seasonal variations in Minnaert constants for each band, as shown by means and standard deviations (SD). Variation in the Minnaert constant was small for band 1 (± 0.003-0.006 SD). The variation for band 2 was similar to that for band 1 (± 0.005-0.009 SD). Band 3 had standard deviations larger than those for bands 1 and 2 (± 0.015-0.022 SD). Table 3 summarizes the significance test results. The values in this table show the probability of Minnaert constant similarity. All dates and bands indicated no significant differences. The SPOT/HRV dataset (Sample II) showed that the Minnaert constants obtained from samples stratified using topographic conditions were stable.

DISCUSSION

Seasonal variation of the Minnaert constant was examined as an aspect of the comparison of Minnaert constants among the three forest types. Minnaert constants for each forest type based on data with the same topographical conditions showed no significant difference for some scenes or bands (**Fig. 3** and **Table 3**). Furthermore, Minnaert constants derived only from topographic conditions without forest-type specification presented no significant difference in all bands and all scenes (**Fig. 5** and **Table 4**). While not directly confirming that Minnaert constants are similar regardless of forest type, combined with the results from the Sample I of this study, these results suggest that a stable Minnaert constant can be obtained taking only topographic conditions into consideration. Obtaining Minnaert constants for each forest type is difficult, and applying more than one constant to a scene is impractical. Therefore, the indication that Minnaert constants can be determined without considering forest type is important.

In comparison with Sample II (**Fig. 5**), which was stratified only by topographical conditions without specifying forest types, Sample I (**Fig. 3**), based on topographic conditions alone, had larger variation in the value of Minnaert constants. This difference probably reflects deviations caused by the geographical features. Moreover, in Sample I (**Fig. 3**), seasonal variations in the Minnaert constants were somewhat irregular, while those for Sample II (**Fig. 5**) showed a smooth curve; deviation caused by topographical conditions may also be reflected in these results. In Sample II (**Fig. 5**), no significant difference was recognized even after changing the dataset combination used to calculate the Minnaert constant. This result suggests the importance of stratification based on topographical conditions.

Previous studies have calculated Minnaert constants from single scenes (Smith *et al*., 1980; Teillet *et al*., 1982; Colby, 1991; Meyer *et al*., 1993; Gu and Gillespie 1998; Tokola *et al*., 2001; Riaño *et al*., 2003; Mitri and Gitas; 2004) or a few separate scenes (Holben and Justice, 1980, 1981; Civco, 1989; Vincini and Frazzi, 2003). Moreover, it is unknown how much these studies considered biases caused by topographic conditions. As demonstrated in this study, it is necessary to include topographic conditions when calculating the Minnaert constant (**Figs. 2** and **4**). Taking all topographic conditions into consideration (*i.e.*, the slope azimuth and slope angle) is both logical and important because the Minnaert constant depends on regression analysis. As the analysis results of this study show, a highly stable solution results if almost all topographic conditions are considered.

In all bands, the seasonal variation pattern of the Minnaert constant showed a convex form. This pattern may be associated with the DOY or the solar zenith angle. Future research should examine data from an additional year to determine whether a model can be made using the DOY or the solar zenith angle. Although such modeling may differ by sensor, this technique would present a great convenience in that a Minnaert constant could be estimated to a certain extent based on the image acquisition time. For example, such an estimated value may be used when strict topographic correction is not required.

At present, the applicability of our results is limited. In the study area in the northern part of the Kyushu District, Japan, warm temperate forests composed mainly of evergreen species dominate. In more northern regions and at higher elevations where deciduous forests dominate, it is unknown whether a stable Minnaert constant can be achieved. Unlike evergreen forests, deciduous forest experience dramatic changes in spectral reflectance characteristics due to leaf color change and drop. Future research should apply the same approach to other areas to examine the stability of the Minnaert constant.

Furthermore, this study only examined SPOT/HRV-derived data. Additional analysis should use similar middle-resolution satellite data such as those obtained by LANDSAT/TM and Terra/ASTER. Studies of high-resolution satellite data, in contrast, should first examine whether application of the Minnaert method is possible, because there remain many unknowns associated with this data type. As shown by Sample II in the present study, sampling without specifying a forest type can be effective. One advantage of this approach is that it only requires image data and a DEM, not prior or additional information. This method is thus simple and easy to use as an initial analysis. In addition, this study demonstrated the stability of the Minnaert constant through significance tests and indirectly clarified whether the Minnaert constant varies with forest type. If established methods to acquire the Minnaert constant existed for any sensor or area, topographic effect correction processes would progress greatly.

ACKNOWLEDGMENTS

The SPOT/HRV data used in this study were provided by the National Space Development Agency of Japan (Japan Aerospace Exploration Agency).

REFERENCES

Chiou, C. R., V. L. Thomas and R. M. Hoffer. 1992. Comparison of four techniques for topographic normalization of Landsat TM data. *ASPRS/ACSM/RT 92-Technical Papers*, **4**: 184-196.

Civco, D. L. 1989. Topographic normalization of Landsat Thematic Mapper digital imagery. *Photogramm. Eng. Remote Sens.*, **55**: 1303-1309.

Colby, J. D. 1991. Topographic normalization in rugged terrain. *Photogram. Eng. Remote Sens.*, **57**: 531-537.

Gu, D. and A. Gillespie. 1998. Topographic normalization of Landsat TM images of forest based on subpixel sun-canopy-sensor geometry. *Remote Sens. Environ.*, **64**: 166-175.

Holben, B., and C. Justice. 1980. The topographic effect on spectral response from nadir-pointing sensors, *Photogramm. Eng. Remote Sens.*, **46**: 1191-1200.

Holben, B. and C. Justice. 1981. An examination of spectral band ratioing to reduce the topographic effect on remotely sensed data. *Int. J. Remote Sens.*, **2**: 115-133.

Kawata, Y., S. Ueno and T. Kusaka. 1988. Radiometric correction for atmospheric and topographic effects on Landsat MSS images. *Int. J. Remote Sens.*, **9**: 729-748.

Leprieur, C. E., J. M. Durand and J. L. Peyron. 1988. Influence of topography on forest reflectance using Landsat Thematic Mapper and digital terrain data. *Photogramm. Eng. Remote Sens.*, **54**: 491-496.

Meyer, P., K. I. Itten, T. Kellenberger, S. Sandmeier and R. Sandmeier. 1993. Radiometric corrections of topographically induced effects on Landsat TM data in an alpine environment. *ISPRS J. Photogramm. Remote Sens.*, **48**: 17-28.

Minnaert, M. 1941. The reciprocity principle in lunar photometry. *The Astrophy. J.*, **93**: 403-410.

Mitri, G. H. and I. Z. Gitas. 2004. A performance evaluation of a burned area object-based classification model when applied to topographically and non-topographically corrected TM imagery. *Int. J. Remote Sens.*, **25**: 2863-2870.

Murakami, T. 2002. Minnaert constant of several forest types from SPOT/HRV data. *J. Jap. Soc. Photogramm. Remote Sens.*, **41**: 47-55 (in Japanese with English abstract).

Murakami, T., H. Fujii and M. Imada. 1998. Comparison of correction methods for topographic effects on Landsat TM data. *Bull. Kyushu Univ. Forest*, **78**: 13-28 (in Japanese with English abstract).

Riaño, D., E. Chuvieco, J. Salas and I. Aguado. 2003. Assessment of different topographic corrections in Landsat-TM data for mapping vegetation types. *IEEE Trans. Geosci. Remote Sens.*, **41**: 1056-1061.

Richter, R. 1997. Correction of atmospheric and topographic effects for high spatial resolution satellite imagery. *Int. J. Remote Sens.*, **18**: 1099-1111.

Smith, J.A., T. L. Lin and K. J. Ranson. 1980. The Lambertian assumption and Landsat data. *Photogram. Eng. Remote Sens.*, **46**: 1183-1189.

Soenen, S. A., D. R. Peddle and C. A. Coburn. 2005. SCS+C: A modified sun-canopy-sensor topographic correction in forested terrain. *IEEE Trans. Geosci. Remote Sensing*, **43**: 2148-2159.

Teillet, P. M., B. Guindon and D. G. Goodenough. 1982. On the slope-aspect correction of multispectral scanner data. *Can. J. Remote Sens.*, **8**: 84-106.

Tokola, T., J. Sarkeala and M. Van Der Linden. 2001. Use of topographic correction in Landsat TM-based forest interpretation in Nepal. *Int. J. Remote Sens.*, **22**: 551-563.

Vincini, M. and E. Frazzi. 2003. Multitemporal evaluation of topographic normalization methods on deciduous forest TM data. *IEEE Trans. Geosci. Remote Sens.*, **41**: 2586-2590.

多時期 SPOT/HRV データによる３つの森林タイプから得られた Minnaert 定数の比較

村上　拓彦*

（平成19年７月９日受付）

要　約

Minnaert 地形効果補正法における Minnaert 定数は特定の地表面に固有のものであると言われているが、この Minnaert 定数が観測シーンに応じてどの程度変動するのか検討された例はほとんどない。本研究では、リモートセンシングデータに対し異なる３つの森林タイプから得られた Minnaert 定数を比較している。各森林タイプの Minnaert 定数を同一の地形条件（傾斜角と斜面方位角）のところから計算し、有意差検定を行った。森林タイプを特定せずに地形条件のみで層化した層化無作為抽出法でも類似の Minnaert 定数が得られた。対象地は福岡県の三郡山地周辺である。使用した画像データは、1997年中に観測された SPOT/HRV データ７シーンである。地形条件が同一のサンプルを用いて３つの森林タイプで Minnaert 定数を比較したところ、いずれも有意差は認められなかった。森林タイプを特定しない無作為抽出のデータにおいても、全てのシーン、バンドにおいて Minnaert 定数に有意差は認められなかった。本論で得られた結果から、たとえサンプルが変わっても、地形条件に基づいて層化されたデータからは安定した Minnaert 定数が得られることが示唆された。

新大農研報, 60:83-90, 2007

キーワード：Minnaert 定数、Minnaert 地形効果補正法、多時期リモートセンシングデータ、SPOT/HRV、地形効果

新潟大学農学部

* 代表著者：muratac@agr.niigata-u.ac.jp