

# **A Study on Index of Vegetation Surface Roughness using Multiangular Observation**

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**Abstracts:** A satellite remote sensing is useful for vegetation monitoring. But it has some problem. One of these, it is difficult to find a difference of vegetation surface roughness using satellite remote sensing. Each vegetation type has unique surface roughness, for example needle leaves forest, broad leaves forest and grassland. Difference of vegetation surface roughness can be detected by satellite multiangular observation. In this study, objective is to propose index of vegetation surface roughness using BRF property. General vegetation indices are calculated from nadir data of satellite data. A proposed index is calculated from two different observation zenith angle data. Two different zenith data can provide BRF (Bi-directional Reflectance Factor) property of satellite observation data. A proposed index was able to detect different value on where NDVI shows similar high value areas of rice field and forest. This index is useful for vegetation monitoring.

**Keywords:** Vegetation Index, Multiangular Observation

## **1. Introduction**

A satellite remote sensing is useful for global land use and land cover monitoring. And vegetation monitoring is one of important those monitoring. In case of vegetation monitoring, vegetation indices are used. Therefore vegetation indices are suggested. However these indices have problem. One of these, it is difficult to find a difference of vegetation surface roughness. Each vegetation type has unique surface roughness, for example needle leaves forest, broad leaves forest and grassland. Difference of vegetation surface roughness can be detected by satellite multiangular observation. In this study, objective is to propose index of vegetation surface roughness using BRF property.

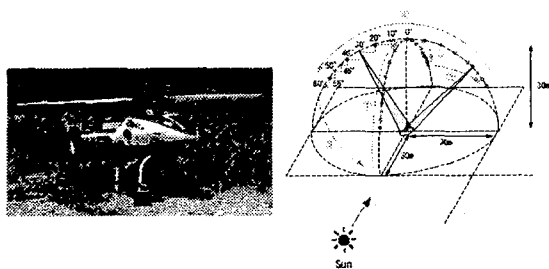
## **2. Method**

Each vegetation type has unique surface roughness. And each surface roughness has each BRF property. It is need to understand BRF property of each vegetation type.

Filed experiment is needed for understanding BRF property of each vegetation type. BRF model is able to apply to field experiment data. However there is not BRF model that all BRF property of each vegetation type can apply. BRF model is needed for all BRF property of each vegetation type can apply. BRF model is able to show BRF property that satellite sensor can measure. From BRF property on satellite data, new vegetation index is proposed.

### **2.1. Filed Experiments**

Filed experiment is needed for understanding BRF property of each vegetation type. In this study, much kind of vegetation field experiment data was collected by field experiment using RC Helicopter system (see Fig. 1). Field experiment sites are shown in Table. 1. Fig.2 shows an example of nadir image in field experiment site. These are spectrum data of each site. And these are multiangular reflectance of each site (see Fig. 3).



(A) RC Helicopter system (B) Flight patter

Fig. 1 Summary of observation method

Table. 1 Field Experiment sites

Place	Object
Mongolia	Grassland, Area where desertification is advancing
Alizona (USA)	Dead Grassland
New Mexico (USA)	Area where desertification is advancing
Kansas (USA)	Grassland
Montana (USA)	Plain, Broadleaf ,Coniferous forest
British Columbia (Canada)	Coniferous forest
Oregon (USA)	Coniferous forest
Lake Saroma(Hokkaido)	Floating ice
Mandal-govi (Mongolia)	Grassland, Area where desertification is advancing
miri (Malaysia)	Tropical rain Forest, Oil Palm Forest
Kochi (Japan)	Landslide
Ishigakijima (Japan)	Mangrove Forest
Australia	Pasture land
Morioka (Japan)	Beech Forest

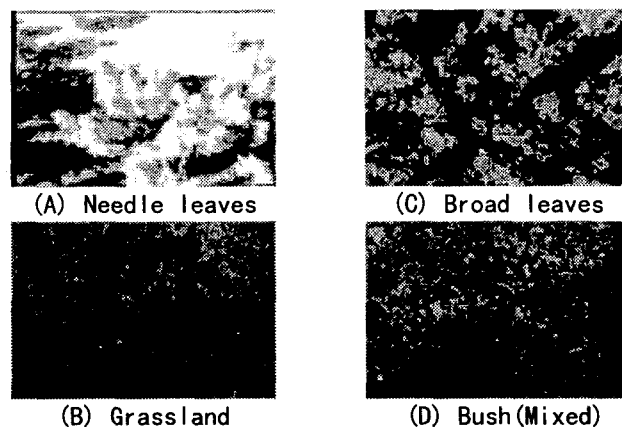


Fig. 2 Nadir Image in field Experiment site (Montana)

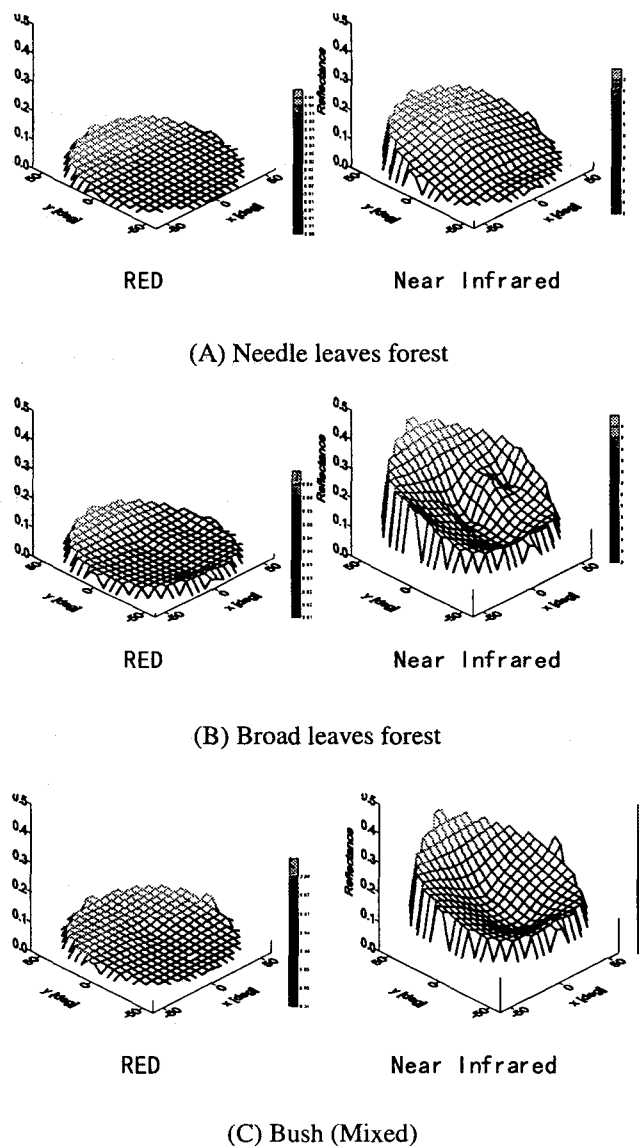


Fig. 3 Field observations data (Montana site)

## 2.2. BRF Model

BRF model is needed for all BRF property of each

vegetation type can apply. In this study, applying model is cylinder model (see Fig. 4 and Fig. 5).

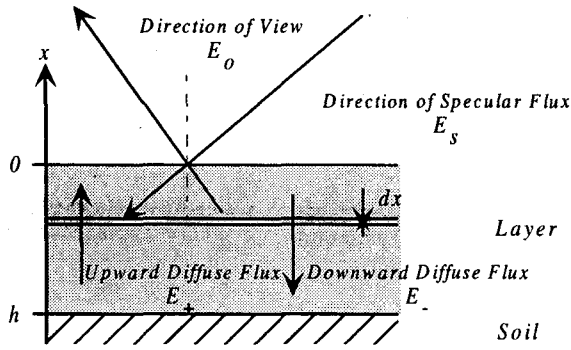


Fig. 4 coordinate system of Layer model

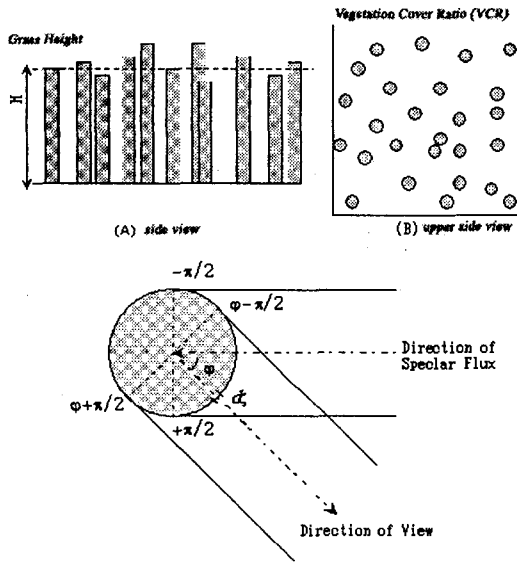


Fig. 5 Cylinder Model

This model is shown following liner equation.

$$R_B(\theta_s, S) = f(VCR, N, H, R_s, \theta_s, R_g, \tau, S) \quad \text{eq.1}$$

- $R_B$  : Multi angular Reflectance
- $VCR$  : Vegetation Cover Ratio
- $N$  : Number of Grass
- $H$  : Grass Height
- $R_s$  : Reflectance of Soil
- $\theta_s$  : Solar Zenith angle
- $R_g$  : Reflectance of target (nadir)
- $\tau$  : Transmittance
- $S$  : Sensor geometry

This model was developed for applying BRF property of grassland. So it is needed to confirm that cylinder model is possible to apply BRF property of other vegetation type. Ex.2 is proposed cylinder model for applying to BRF property of forest. Change points are input parameter.

$$R_B(\theta_s, S) = f(VCR, N, H, R_s, \theta_s, R_g, \tau, S) \quad \text{eq.2}$$

- $R_B$  : Multi angular Reflectance
- $VCR$  : Vegetation canopy cover ratio
- $N$  : Number of Tree
- $H$  : Tree Height
- $R_s$  : Reflectance of Soil
- $\theta_s$  : Solar Zenith angle
- $R_g$  : Reflectance of target (nadir)
- $\tau$  : Transmittance
- $S$  : Sensor geometry

In sensor geometry, sensor azimuth angle are  $\pm 90$  deg. and sensor zenith angle are  $0 \sim +40$  deg. These parameters were decided from Satellite observation condition. Fig. 6 shows Simulation Results using Cylinder Model and Filed Observation data and field experiment data. In this simulation, input parameter are shown Table. 2. Simulation is good applying field experiment data.

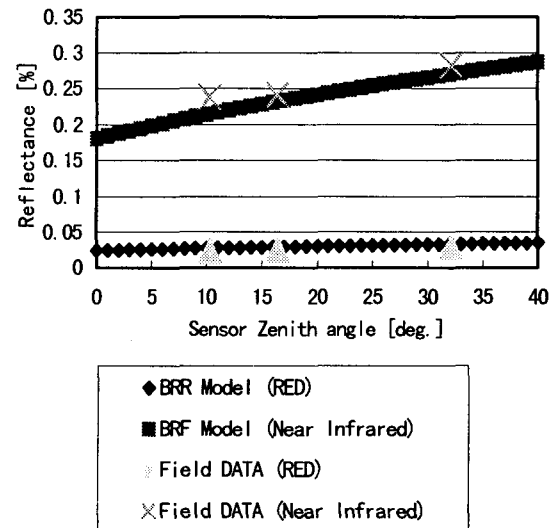


Fig. 6 Simulation Results using Cylinder Model and Filed Observation data

. So cylinder model is useful for applying BRF property of other vegetation type (ex. Forest). Each Field data could not compare with each other. Because Solar zenith angle, sensor zenith angle and etc are different of each other. Under satellite geometry, simulation data using BRF model can compare. Cylinder model is useful for that simulation model. Fig. 7 shows simulation results using cylinder model under satellite geometry. From Fig. 7, reflectance is approximate by sensor zenith angle.

Table. 3 are calculated results of liner regression equation are of vegetation shown fig.7.  $R^2$  Error is excellent. Under satellite geometry, BRF property is able to show linear expression. And each vegetation type has different liner regression equation is. Especially, slope of near-infrared liner regression equation is different of each vegetation type.

Table. 2 Input parameter

Vegetation canopy cover ratio	26.59 %
Number of Tree	3
Tree Height	21 M
Reflectance of soil (RED)	0.09
Reflectance of soil (Near infrared)	0.10
Solar Zenith Angle	57.13 deg.
Reflectance (RED)	0.02
Reflectance (Near infrared)	0.15
Transmittance	0.00

Table. 3 Linear regression equation

	Red	$R^2$ Error
Needle leaves forest	$y=0.0002x+0.0207$	0.9977
Broad leaves forest	$y=0.0003x+0.0245$	0.9957
Bush	$y=0.0003x+0.0515$	0.9977
	nir	
Needle leaves forest	$y=0.0023x+0.2436$	0.9944
Broad leaves forest	$y=0.0026x+0.1869$	0.9927
Bush	$y=0.0016x+0.2576$	0.9942

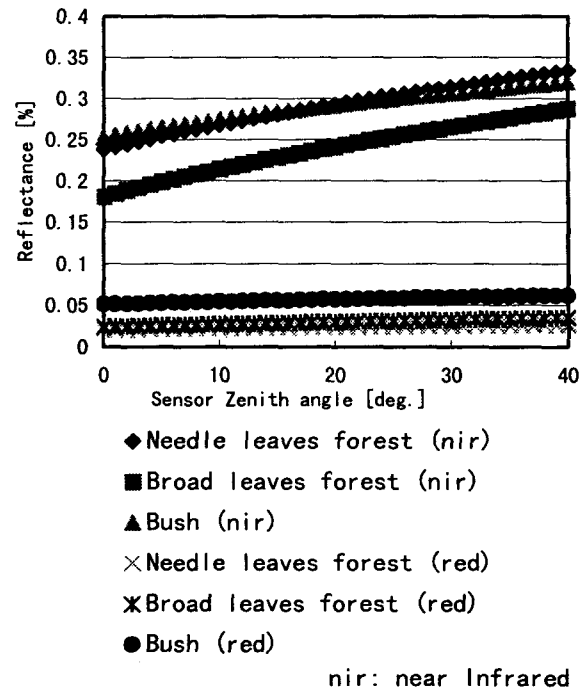


Fig. 7 Simulation Results

### 2.3. Proposal Vegetation Index

Fig. 8 shows outline of BRF property in satellite data. BRF property is shown liner regression equation. Each vegetation type has liner regression equation of BRF property. And BRF property of each wavelength is difference. Especially, BRF property of near infrared is different slope of linear regression equation. Using these characters, the difference of BRF for each vegetation type is able to make two areas (see fig. 9).

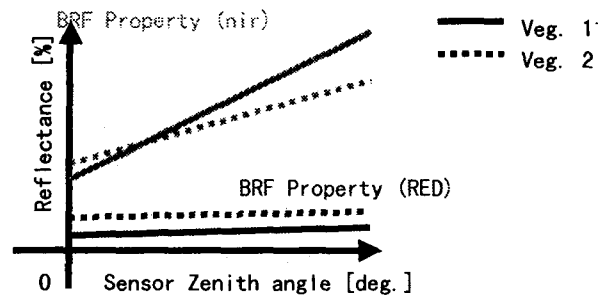


Fig. 8 Outline of BRF property of satellite observation data

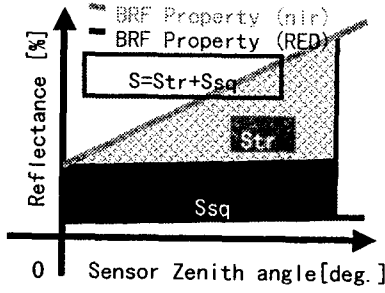


fig. 9 Area from BRF Property

Part of  $S_{sq}$  has relationship with Vegetation cover ratio. Because difference of near-infrared band reflectance and red band reflectance are used for calculate NDVI. Part of  $S_{tr}$  has relationship with BRF. BRF has relationship with vegetation surface and vegetation cover ratio. Difference of each vegetation surface roughness is able to show following equation.

$$\text{Ratio of difference of surface roughness} = \frac{S_{tr}}{S_{sq}} \quad \text{eq.3}$$

$S_{tr}$  and  $S_{sq}$  are calculated as the following equation,

$$S_{tr} = \frac{1}{2}(\theta_o - \theta_n) \times \{N_o - (N_n - R_n + R_o)\} \quad \text{eq.4}$$

$$= \frac{1}{2}(\theta_o - \theta_n) \times \{(N_o - N_n) + R_n - R_o\}$$

$$S_{sq} = (\theta_o - \theta_n) \times (N_n - R_n) \quad \text{eq.5}$$

$\theta_o$ : Sensor zenith angle of off nadir

$\theta_n$ : Sensor zenith angle of nadir

$N_o$ : Near Infrared Reflectance data of off nadir

$N_n$ : Near Infrared Reflectance data of off nadir

$R_o$ : Red Reflectance data of off nadir

$R_n$ : Red Reflectance data of off nadir

Eq.3 is calculated as following equation from eq.4 and eq.5.

$$\begin{aligned} \frac{S}{S_{sq}} &= \frac{S_{tr} + S_{sq}}{S_{sq}} = 1 + \frac{S_{tr}}{S_{sq}} \\ &= 1 + \frac{\frac{1}{2}(\theta_o - \theta_n) \times \{(N_o - N_n) + R_n - R_o\}}{(\theta_o - \theta_n) \times (N_n - R_n)} \\ &= \frac{1}{2} \times \frac{2 \times (N_n - R_n) + \{(N_o - N_n) + R_n - R_o\}}{(N_n - R_n)} \\ &= \frac{1}{2} \times \left( 1 + \frac{N_o - R_o}{N_n - R_n} \right) \end{aligned}$$

eq.6

A clause to change in eq.6 is only following clause,

$$\frac{N_o - R_o}{N_n - R_n}$$

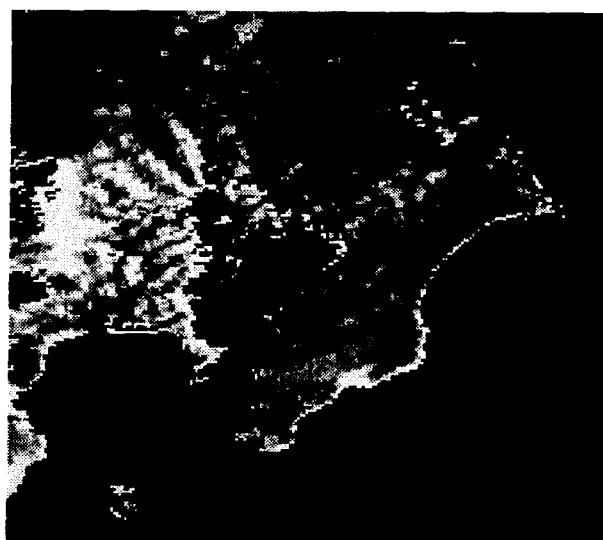
In this study, this clause is proposed propose index of vegetation surface roughness (BSI : Bi-directional Reflectance Structure Index). Eq.7 is BSI.

$$BSI = \frac{N_o - R_o}{N_n - R_n} \quad \text{eq.7}$$

### 3. Results

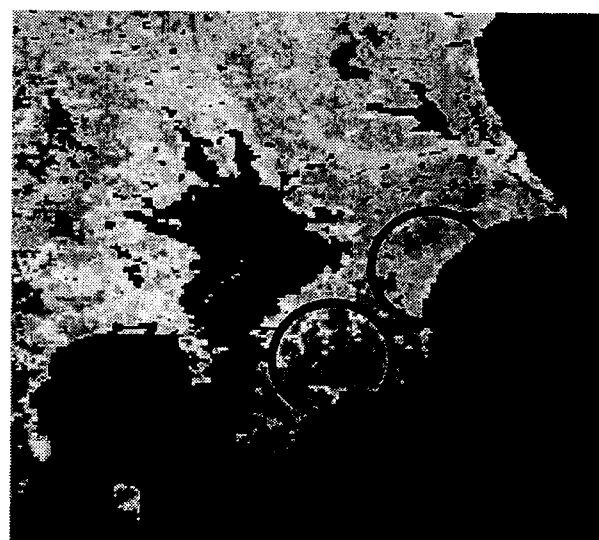
fig. 10 shows calculated BSI using NOAA AVHRR DATA around Chiba Pref. In Japan fig. 11 shows NDVI image. BSI image is different distribution of value of NDVI value.

fig. 12 shows Land cover map. Inside red circle filed in fig. 12 is Agriculture Field. Inside blue circle filed in fig. 12 is Broad leaves forest. NDVI image shows that both field is similar high value. But BSI image shows that Agriculture field is lower value, and Broad leaves forest is higher value. BSI is able to apply different vegetation character of NDVI. Between forest and agriculture field is different of surface roughness. BSI is able to apply difference of vegetation surface roughness.



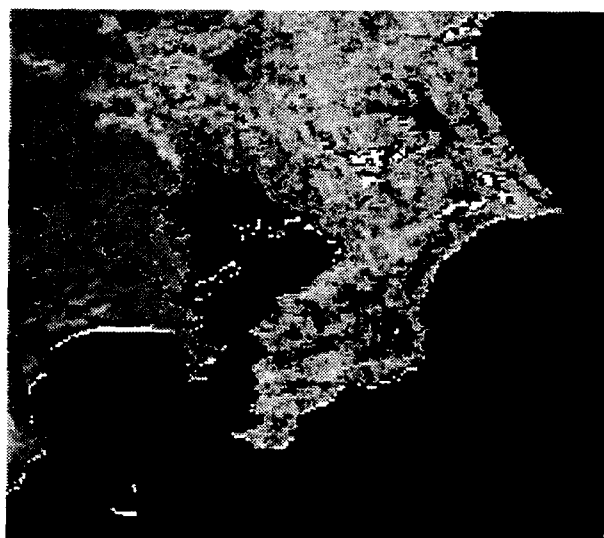
0 1.0 2.0

fig. 10 BSI image



■ Broad leaves forest ■ Mixed forest  
■ Agriculture field

fig. 12 Land Cover Image



0 1.0

fig. 11 NDVI Image

#### 4. Conclusion

New Vegetation Index of vegetation surface roughness (BSI) is proposed using BRDF property. BSI shows the difference of Vegetation 3D Structure.

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