Preparation of reference dataset for satellite remote sensing

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ABSTRACT**:** Recently, the surveillance of natural environment is important for the global climate change. And forest management is also important for preservation of natural environment. Generally, satellite is used for monitoring of natural environment. Therefore, the analysis of satellite data is important.

The various reference datasets are needed for the accurate analysis of satellite data. In this study, the reference datasets for satellite remote sensing will be prepared such as, GCP (ground control point) database for geometric correction, spectrum library of ground objects and field survey database for the validation.

The GCP database is used for geometric correction using transformation model. The geometric transformation model requires accurate ground coordinates of the objects and the corresponded coordinate of the satellite imagery. That is called GCP. GCP should be well identified on satellite imagery. In this study, center of intersection of road, center of bridge and corner of dike are used as the GCP. Three dimensional coordinate of GCP was measured by the VRS-RTK observation of the GPS observation. Currently, over 500 GCP were measured and the results were opened to the public through web page. The geometric correction using GCP database obtained good accuracy with less than 0.5pixel.

The analysis of satellite imagery is based on spectral reflection of the ground objects. Therefore, spectrum data is needed for the accurate analysis of satellite imagery. In this study, weekly measurements of spectral reflectance were carried out from 2010. In order to perform stable measurement, it should be measured in the darkroom. In this study, spectral radiometer which produced by OCEAN OPTICS USB4000 is used. Time series spectral library could be used to build classification algorithm.

The field survey databases are established for validation of landcover classification. Currently, 12 mountains were surveyed and the results are opened to the public through web page. At observation point, the photographs of north, south, east and west and the zenith are taken. And the surrounding vegetation is identified visually and recorded the state of landcover.

Prepared reference database can be used for any satellite image analysis. The reference dataset will grow up to make satisfy many researchers of satellite remote sensing.

KEYWORDS: satellite remote sensing, reference dataset, satellite image analysis, surveillance of natural environment

1. Background

Recently, the surveillance of natural environment is important for the global climate change. And forest management is also important for preservation of natural environment. Generally, satellite is used for monitoring of natural environment. There are many softwares for analysis of remotely sensed data. However, various reference dataset must be prepared for accurate analysis using satellite imagery.

2. Objectives

In this study, the reference datasets for satellite remote sensing will be prepared such as, GCP database for geometric correction, spectrum library of ground objects and field survey database for the validation. Moreover, landcover classification map will be generated from satellite imagery using the reference dataset. Landcover classification map is important for the monitoring of natural environment.

The target satellite was ALOS (Advanced Land Observing Satellite) which was launched on 2006 in Japan. ALOS has two sensors such as PRISM and AVNIR-2. The specification of each sensor is shown in Table 2.1 and Table 2.2.

Table 2.1: Specification of PRISM sensor

Ground Sampling Distance	2.5 m/pixel
Width of observation	35 km
Number of Bands	1
Wavelength	520 to 770 nm
Pointing Angle	-1.5 to +1.5degree
Bit Length	8bits

Table 2.2: Specification of AVNIR-2 sensor

Ground Sampling Distance	10 m/pixel
Width of observation	70 km
Number of Bands	4
Wavelength	Band 1: 420 to 500 nm Band 2: 520 to 600 nm Band 3: 610 to 690 nm Band 4: 760 to 890 nm
Pointing Angle	-44 to +44degree
Bit Length	8bits

3. GCP database

In order to measure the location using satellite imagery, geometric correction must be done. Geometric transformation model is used for the geometric correction. The geometric transformation model expresses the relation between image coordinates and ground coordinates. As a geometric transformation model, RPC (Rational Polynomial Coefficient) model (Eq.3.1) and DLT (Direct Linear Transformation) model (Eq.3.2) are usually applied. RPC model is the systematic model of PRISM sensor, which is provided by Remote Sensing Technology Center, JAPAN. DLT model is based on line sensor geometry, which is based on separated three dimensional projective transformation model.

$$\begin{cases} u = \dfrac{a_1 + a_2 X + a_2 Y + a_3 Z + \dots + a_{20} X^3}{b_1 + b_2 X + b_2 Y + b_3 Z + \dots + b_{20} X^3} \\ v = \dfrac{c_1 + c_2 X + c_2 Y + c_3 Z + \dots + c_{20} X^3}{d_1 + d_2 X + d_2 Y + d_3 Z + \dots + d_{20} X^3} \end{cases} \quad \text{Eq.(3.1)}$$

X,Y,Z :Ground coordinate *u,v*:Image_ coordinate

$a_1 \sim a_{20}, b_1 \sim b_{20}, c_1 \sim c_{20}, d_1 \sim d_{20}$:Transform_coefficients

$$\begin{cases} u = \dfrac{a_1 X + a_2 Y + a_3 Z + a_4}{b_1 X + b_2 Y + b_3 Z + 1} \\ v = \dfrac{a_5 X + a_6 Y + a_7 Z + a_8}{b_4 X + b_5 Y + b_6 Z + 1} \end{cases} \quad \text{Eq.(3.2)}$$

X,Y,Z :Ground coordinate *u,v*:Image_ coordinate

$a_1 \sim a_8$, $b_1 \sim b_6$:Transform_coefficients

The geometric transformation model requires accurate ground coordinates of the objects and the corresponded coordinate of the satellite imagery. That is called GCP (Ground Control Point).

3.1 GCP selection

GCP should be well identified on satellite imagery. In this study, center of intersection of road, center of bridge and corner of dike are used as the GCP. Figure 3.1 and Figure 3.2 shows samples of GCP on AVNIR-2 imagery.

Figure 3.1: Center of intersection of road

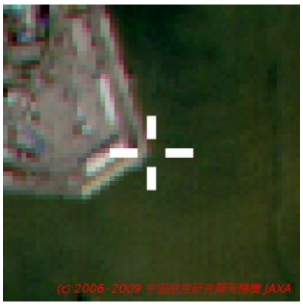

Figure 3.2: corner of dike

3.2 Observation of GCP

Three dimensional coordinate of GCP was measured by the VRS-RTK observation of the GPS observation. VRS-RTK survey can measure ground coordinates in several centimeter accuracy under good condition of GPS satellite. Moreover, it can survey in about 1 minute per point. Therefore, it is suitable for the GCP observation. Observation scenery is shown in Figure 3.3.

Figure 3.3: Observation scenery of VRS-RTK survey

Currently, over 500 GCP were observed in Shikou, Japan.

3.3 Establishment of GCP database

The GCP database was built on web system. The web system based on web GIS generated by the Geographical Survey Institute of Japan. The GCP database is opened to the public through following web site.

http://www.infra.kochi-tech.ac.jp/takalab/Information/research/GCPDB/GCPDB.html.

The item of the data field in GCP database is shown in Table 3.1. The example of GCP database is shown in Figure 3.4 and Figure 3.5.

Table 3.1: T The item of the data field of GCP database

The name of GCP point
URL of the reference GCP
The geographical coordinate system of ground coordinates
Ground coordinates
Latitude and longitude
Survey day
Observation points (Center of intersection of road, etc.)
The satellite imagery of GCP

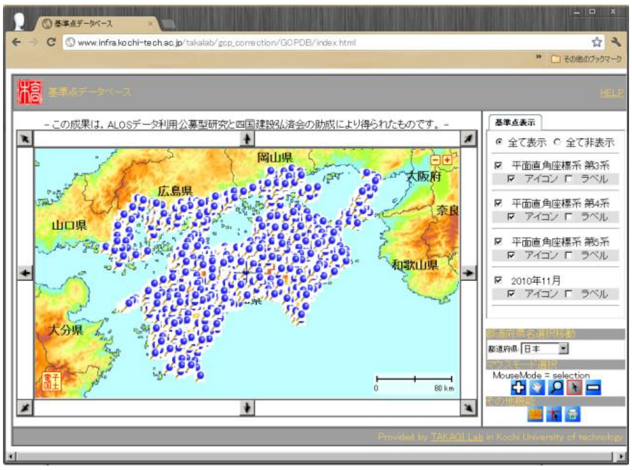

Figure 3.4: GIS web system

Figure 3.5: Offer page of GCP data

4. Spectral library of ground objects

The satellite sensor is observing reflected sunlight on the surface of the ground. When the accurate characteristics of reflectance on the ground objects are understood, the analysis of satellite imagery will be accurate. In this laboratory, measurement of spectral data is continued from 2010. In this measurement, the spectrum data of the leaves of trees are selected for vegetation monitoring. Moreover, this measurement is carried out once a week to detect seasonal change of vegetation. In this study, spectral radiometer which produced by OCEAN OPTICS USB4000 is used. The specification of spectral radiometer is shown in Table 4.1.

Table 4.1: Spec of USB4000

Measurement wavelength range	300nm to 1200nm
Wavelength resolution	0.2nm
A/D resolution	16bit

4.1 Target of measurement

Target leaves of the measurement are shown in Table 4.2. The targets are selected on the campus of Kochi University of Technology. These trees are appeared on Shikoku very widely.

Table 4.2: Measurement target

Trees name	Trees type
Japanese cedar	Evergreen needle-leaved tree
Japanese cypress	Evergreen needle-leaved tree
Zelkova	Deciduous broad-leaved tree
Sawtooth oak	Deciduous broad-leaved tree
Camphor tree	Evergreen broad-leaved tree
Oak	Evergreen broad-leaved tree
Castanopsis	Evergreen broad-leaved tree
Bamboo	-

4.2 Measurement Method

In order to perform stable measurement, it should be measured in the darkroom. Measurement scenery is shown in Figure 4.1. The halogen lamp is used for a light source. The halogen lamp is emitting the wavelength of visible light and infrared region, which is similar with sun light.

Figure 4.1: Measurement scenery

In this research, the surface of the leaf of trees is measured. And the measurement is repeated two or more times. The example of measurement data is shown in Figure 4.2. As shown in Figure 4.3, the state of a leaf is recorded using an image scanner.

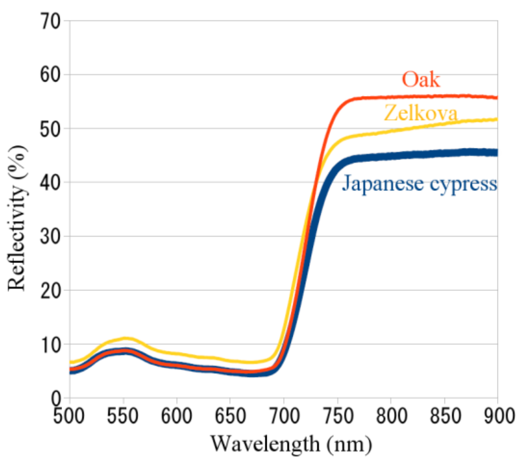

Figure 4.2: Example of measurement data

Figure 4.3: Image scan picture of leaf

From April 2010 up to now, over 50 times were measured. And, there is 100 or more measurement data of each measurement trees. Moreover, these measurement data will be opened to the public through the web site soon.

5. Field survey database

Satellite imagery analysis is expected from monitoring of natural environment. And for confirming result of analysis, exact verification data is needed. However, exact verification data is not widely established. Therefore, in order to obtain exact verification data, the field survey is performed. And exact vegetation data and position information are required in the filed survey database.

5.1 Route map creation

In order to carried out a field survey, the route map should be prepared firstly. An observation point is selected on mountain trail and typical vegetation point which is visually interpreted on the satellite imagery. Free GIS software (QGIS) is very helpful to create of the route map. The example of a route map is shown in Figure 5.1.

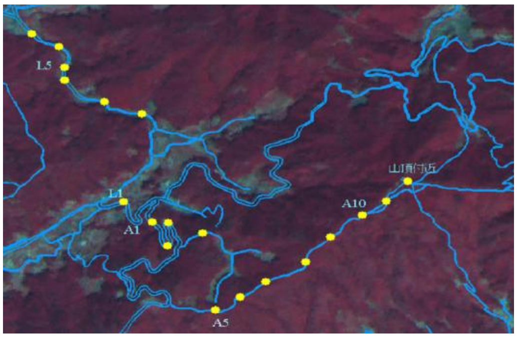

Figure 5.1: Example of route map

5.2 The method of field survey

Handy GPS is used for the navigation to observation point. At observation point, the photographs of north, south, east and west and the zenith are taken. And the surrounding vegetation is identified visually and recorded the state of landcover. The scenery of a field survey is shown in Figure 5.2.

Figure 5.2: Scenery of field survey

5.3 Establishment of Field survey database

The web system as well as GCP database was established for field survey database as follows, http://www.infra.kochi-tech.ac.jp/takalab/ForestDB/. The contents of the field survey database are shown in Table 5.1. The web page of field survey database is shown in Figure 5.3.

Table 5.1: The item of the data of field survey database

Mountain name
Observation point name
The photograph of north, south, east, west and zenith
Observation data
Vegetation data
Latitude longitude at observation point

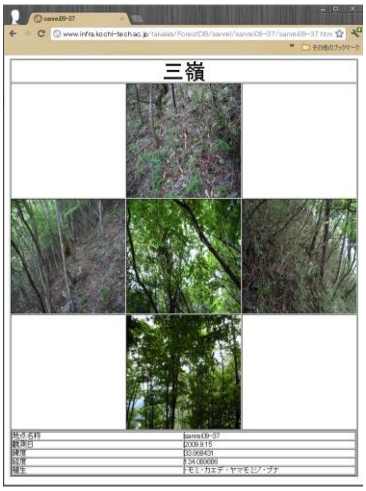

Figure 5.3: Field survey database

The mountain in north east part of Kochi Prefecture is mainly surveyed. Currently, 12 mountains and over 200 observation points were surveyed. The results of the field survey of the observation point are opened to the public through web page.

6. Example of classification using prepared reference dataset.

Landcover classification map can be generated from a satellite imagery using prepared database. As the satellite data, ALOS AVNIR-2 was used. And the receiving date of the used satellite imagery was April 7, 2009 and August 23. Test area is a part of Shikoku, Japan (Figure 6.1).

Figure 6.1: Test area

6.1 Geometric correction for satellite imagery

The geometric correction of the satellite imagery was carried out using GCP database. As shown in Figure 6.2, the image coordinates corresponded to 12 GCP are used. The geometric transformation model was applied DLT model (Eq.1.2). The accuracy of geometric correction is shown in Table 6.1.

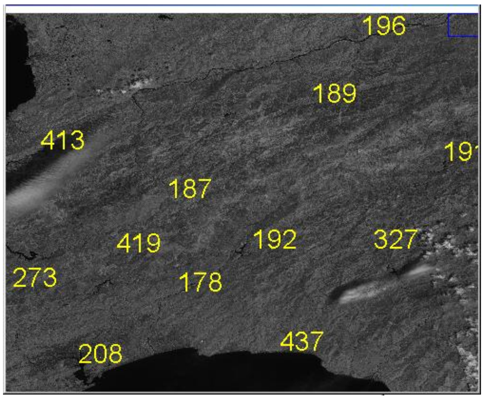

Figure 6.2: Acquisition of image coordinates

Table 6.1: Accuracy of geometric correction

Observation date	U (pixel)	V (pixel)
April 07, 2009	0.272	0.479
August 23, 2009	0.482	0.448

The result showed less than 0.5pixel accuracy. Then if will be possible to overlay both satellite imageries.

6.2 Landcover classification using satellite imagery

ALOS AVNIR-2 observes 4 spectral bands including near infra red band. Then some indexes can be suggested using band operation. In this study, the three indexes which are NDVI (Normalized Difference Vegetation Index), NDSI (Normalized Difference Soil Index) and NDWI (Normalized Difference Water Index) were applied. The each index is based on the spectral reflective characteristic of terrestrial object as shown in Figure 6.3. The formula of each index are shown in the equations 6.1 to equations 6.3. And the change of NDVI calculated from the data of the spectrum library is shown in Figure 6.4.

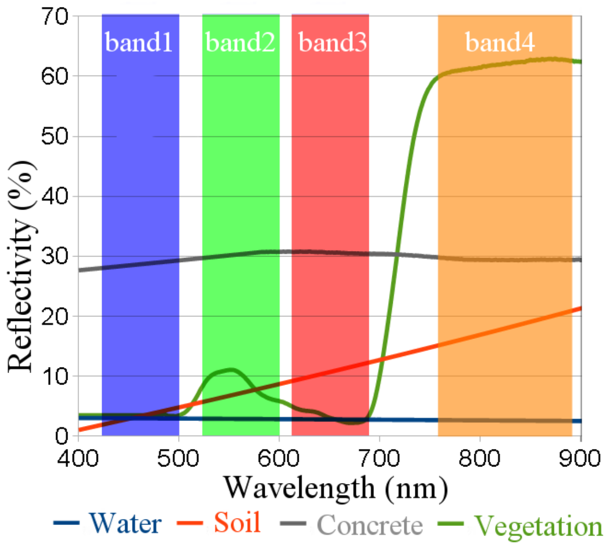

Figure 6.3: Spectrum data of terrestrial object

$$NDVI = \frac{(band4 - band3)}{(band4 + band3)} \quad \text{Eq.(6.1)}$$

$$NDSI = \frac{(band3 - band1)}{(band3 + band1)} \quad \text{Eq.(6.2)}$$

$$NDWI = \frac{(band1 - band4)}{(band1 + band4)} \quad \text{Eq.(6.3)}$$

band4: Near-infrared wavelength

band3: Red wavelength *band1*: Blue wavelength

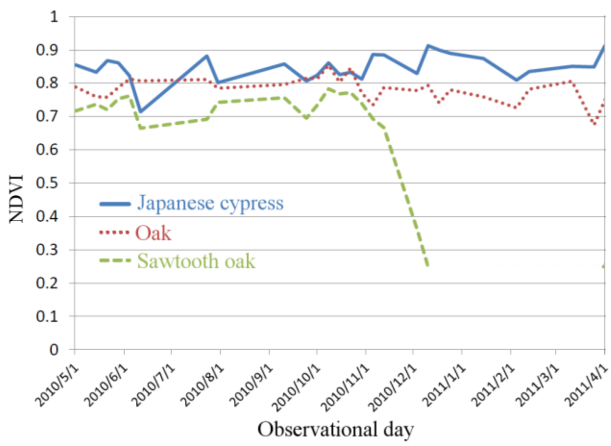

Figure 6.4: Changes in the NDVI

In the case of deciduous broad-leaved tree, NDVI is changing seasonally. Therefore, the classification of a deciduous tree is attained by comparing the April satellite imagery and the August satellite imagery. A classification algorithm is shown in Figure 6.5.

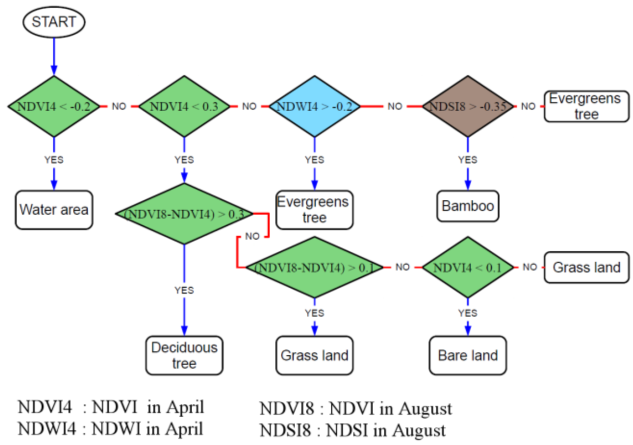

Figure 6.5: Classification algorithm

The classification algorithm was based on seasonal change of NDVI and each index. In this study AVNIR-2 imagery was classified into six categories such as evergreens tree, deciduous tree, grass land, bamboo, bare land, and water area. The classification result of a certain area is shown in Figure 6.6.

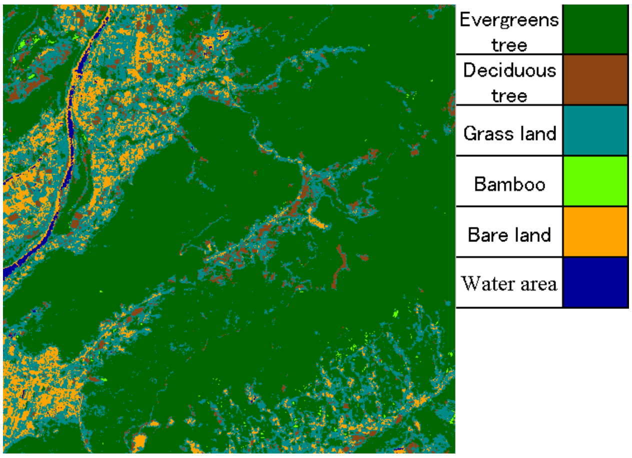

Figure 6.6: classification result

6.3 Verification of the classification result

The landcover classification map was verified using the field survey database. As verification area Akiba Mountain was selected. Landcover classification map and field survey were overlayed (Figure 6.7).

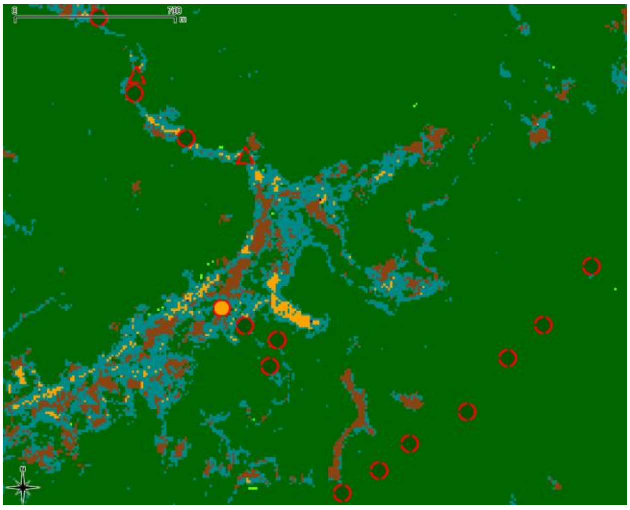

Figure 6.7: The Image for verification

The results of 16 points of field survey were compared with the result of classification. 14 points showed in agreement among 16 points.

7. Conclusions

As a reference dataset for satellite remote sensing, GCP database, a spectrum library, and a field survey database was established.

The geometric correction using GCP database obtained good accuracy with less than 0.5pixel. Time series spectral library could be used to build classification algorithm. The measurement should be continued forever. Field survey database could be used as validation of landcover classification results. The number of survey points should be increase and widely distributed on Shikoku, Japan.

Prepared reference database can be used for any satellite image analysis.

The reference dataset will grow up to make satisfy many researchers of satellite remote sensing.

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