Correction of Landcover Mis-classification Caused by the Similarity of Spectral Characteristics Using SAR Image

Agus SUHARYANTO*1, Chikashi DEGUCHI*2, Satoru SUGIO*2, Masato KUNITAKE*3

Abstract

In the landcover classification using optical multi-spectral scanning data some mis-classifications of landcover categories occur due to the similarity of spectral characteristics. A method has been developed to correct the mis-classification of Open Land category into High Density category classified from Satellite Pour l’Observation de la Terre High Resolution Vidicon (SPOT-HRV) image by using roughness information derived from Japan Earth Resources Satellite 1 Synthetic Aperture Radar (JERS-1 SAR) image. Twenty four core clusters were made based on a clustering algorithm as supervised data. After labeling them to 8 landcover categories, HRV image was classified by Nearest Neighbor Classification (NNC) and Maximum Likelihood Classification (MLC) methods. The occurrence of mis-classification is detected by comparing the classified image with color aerial photograph and investigated using error matrix.

In the correction procedure, the pixel position of the High Density category of HRV is transformed into a position of SAR image using Affine transformation. The pixel positions of both images are in the Universal Transverse Mercator (UTM) coordinate system. The SAR pixels surrounding this transformed pixel position play an important part in the correction method and is termed SAR neighbor pixels.

Each digital value of SAR neighbor pixels is logarithmically transformed to classify the pixel to be rough or flat. When the logarithmically transformed value of the SAR neighbor pixels is greater than 59, the pixel is decided to be urbanized pixel. The proportion of the numbers of SAR pixels determined to be urbanized within SAR neighbor pixels is calculated and defined as an urbanized ratio. The mis-classification of HRV image is estimated based on the urbanized ratio. The HRV pixels classified to High Density category are changed to Open Land when the urbanized ratio is less than 0.05.

By comparing the landcover images before and after correction with the information interpreted from aerial photograph, it is seen that the category accuracy of Open Land category classified by NNC and MLC were increased to 92.1% from 66.9% and to 94.6% from 74.5%, respectively. Approximately 80% of Open Land pixels mis-classified into High Density of HRV can be corrected. The results show that the method proposed is useful.
for correcting the mis-classification between High Density and Open Land caused by similarity of spectral characteristics.

1. Introduction

1.1. Past studies

In the classification of satellite remote sensing multi-scanning system data, mis-classification often occurs in the landcover classification based on spectral characteristics of the pixel unit. The occurrence of this mis-classification may relate to the training data selection, lack of agreement between target of landcover categories and the characteristics of image and classification method used.

In supervised classification methods, several approaches have been tried to overcome this problem so as to increase the accuracy of classification result. They include improving the design to select the training data\(^1\), polishing of training data such as number, size and location of training data\(^2,3,4\), by dividing the training class into small part\(^5,6\) and purifying the training data\(^7,8\). Purifying training sample for classifying high resolution satellite data classified using MLC has success result to increase the classification accuracy\(^7\).

In unsupervised classification methods, mis-classification is apt to occur in labeling the clusters to the landcover categories target. Although classification accuracy is evaluated in this labeling process, mis-classification may still occur. In this process, the probability of mis-classification occurrence may be higher than the supervised classification methods. For example, as high-densely urbanized area contains shadows, it is difficult to separate it from dark brown open land. It can be said that this kind of mis-classification is inevitable in the landcover classification based only spectral characteristics of pixel unit. From this observation, spatial information is required to decrease this kind of mis-classification. Techniques to increase the accuracy of multi-spectral data analysis have been done by reconstruction of multispatial data\(^9,10\). The enhancement image and restoration image are more useful than the texture feature for increasing the classification accuracy\(^10\).

Landcover classification using the multi-temporal SAR images evaluated by the classification result from optical sensor is also effective to increase the classification accuracy\(^11,12\). Classification of multi-seasonal SAR digital data was improved in the classification accuracy among paddy field, farm land and grassland but could not be improved in urban area\(^13\). Both of these papers reported that it is necessary to combine SAR data with optical data to increase the classification accuracy of SAR image.

From the logarithmic transformation of CCT digital values of SAR image, the backscattering coefficient of the earth surface can be calculated\(^13\). This coefficient corresponds to the roughness of earth surface. Usually, urbanized area contains artificial objects and also natural objects which mainly have rough characteristics and open land has flat characteristics. On the other hand, the different look angles of SAR affect the tone on the image and this was considered as cardinal effect\(^14\). The paper reported that the linear feature oriented perpendicular to the radar beam yield very strong radar return. Although cardinal effect from plural SAR images with different looking angles are required to classify the artificial object with direction and linear features such as buildings, classification of the open land without linear feature (park and air field), can be classified without the cardinal effect\(^14\).

1.2. Characteristics of method proposed

The method proposed aims to correct the mis-classification of open land (Open Land) into high-densely urbanized area (High Density) of SPOT-
HRV classified by a kind of unsupervised classification method, in which the supervised data is made by a clustering algorithm. This correction is required when the number of High Density category pixels is used as one of predictor variables to estimate the percentage of impervious area in the urbanized area.

In the method the ratio of the high density area, which is calculated in \( n \times n \) pixels of SAR image and termed urbanized ratio, plays the role of external reference for correcting the mis-classification of HRV image as described later in detail. In a sense this correction method is a kind of Contextual Classification. The urbanized ratio, a kind of spatial information is used taking account of the geometrical error between HRV and SAR images and the mis-classification of SAR image due to the cardinal effect.

In this correction method, it is necessary that SAR image corresponds to HRV image as exactly as possible. However, it is very difficult to relate the position of HRV image to corresponding pixel of SAR image exactly, because both images have geometrical error. This geometrical error and correspondence will be investigated in detail in section 4.2.

The digital values of the SAR data are logarithmically transformed to facilitate the correction process. To evaluate the mis-classification of High Density pixel of HRV, the positions of HRV pixels are transformed to a position of SAR image by Affine transformation. The SAR pixels surrounding the transformed position are termed SAR neighbor pixels. The logarithmically transformed values of SAR neighbor pixels will be evaluated one by one to know whether it is an urbanized pixel or not. From the numbers of the pixels estimated as urbanized, the urbanized ratios of SAR neighbor pixels are calculated. This ratio will be used to investigate whether the High Density of HRV image has been mis-classified or not.

The effectiveness of this correction method is evaluated by comparing the error matrices. These matrices are extracted from the comparison between classification results of HRV before and after correction and the information interpreted from aerial photograph. The reduction in mis-classification will be confirmed from the pixel numbers before and after correction and the pixel numbers of aerial photograph image in section 4.3.

### 2. Classification

#### 2.1. Study area and satellite images used

The study area is a part of Miyazaki city, which is located in Kyushu island, Japan. This study area is about 6 \( \times \) 5 square kilometers and the Oyodo river flows through this area. The corner points of this area are shown in Table 1. The pixel numbers of the study area are 305 \( \times \) 248 for HRV image and 442 \( \times \) 313 for SAR image. The landcover in the study area is almost all commercial-residential land and other kinds include forest, open land and water. In this study HRV with ground resolution of 20 m \( \times \) 20 m, JERS-1 SAR at L-band (1.275 GHz, wavelength 23.5 cm, Bandwidth 15 MHz) with the ground resolution of 18 m \( \times \) 18 m are used.

From the CCTs (Computer Compatible Tapes) of HRV and SAR, the grey maps of Miyazaki city are taken out. Band 3 of HRV image is used to print out the grey map. From each grey map, three Ground Control Points (GCPs) are selected. The images are transformed to UTM coordinate system by using Affine transformation and GCPs. Then the images of study area are taken out. The natural color composite of HRV and SAR images of the study area are used.

<table>
<thead>
<tr>
<th>Corner points</th>
<th>Latitude (N)</th>
<th>Longitude (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31°57'00&quot;</td>
<td>131°24'00&quot;</td>
</tr>
<tr>
<td>2</td>
<td>31°54'00&quot;</td>
<td>131°24'00&quot;</td>
</tr>
<tr>
<td>3</td>
<td>31°54'00&quot;</td>
<td>131°26'30&quot;</td>
</tr>
<tr>
<td>4</td>
<td>31°57'00&quot;</td>
<td>131°26'30&quot;</td>
</tr>
</tbody>
</table>
area are shown in Plate 1 and Plate 2. Color aerial photograph (scale 1:12500) is used to investigate the occurrence of mis-classification and to check the correction result. Contents of these data are shown in Table 2.

The SAR image is related with the HRV image by Affine coordinates transformation with the parameters obtained from the above GCPs\(^{17}\). To evaluate the geometrical errors, twenty points selected from topographic map with scale 1:2500 are used. As the points are required to be clear and stable points\(^{17,18}\), the location of bridges, breakwater, airport and harbor areas are taken.

### 2.2. Landcover classification

The landcover was classified by two methods i.e.

<table>
<thead>
<tr>
<th>No.</th>
<th>Categories</th>
<th>Cover Types</th>
<th>No. of Core clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water 1 (W1)</td>
<td>Sea, Lake, Shadow</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Water 2 (W2)</td>
<td>Water front, Tide area, Shadow</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Forest (F)</td>
<td>Silhouettes, Tree, Broad leafed tree, Bamboo groove</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Open Land (OL)</td>
<td>Sport ground, Bare field (white and brown group)</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Shrub &amp; Brush (SB)</td>
<td>Grass, Mixed range land</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>High Density (H)</td>
<td>Town areas with crowded manmade facilities</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>Medium Density (M)</td>
<td>Between High and Low densities</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Low Density (L)</td>
<td>Town area with many natural areas</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2. Satellite and aerial photograph data.

<table>
<thead>
<tr>
<th>Data</th>
<th>Sensor</th>
<th>Date</th>
<th>Path-Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOT</td>
<td>HRV</td>
<td>09.01.1991</td>
<td>316-286</td>
</tr>
<tr>
<td>JERS-1</td>
<td>SAR</td>
<td>19.06.1992</td>
<td>78-247</td>
</tr>
<tr>
<td>Aerial Ph.</td>
<td></td>
<td>27.12.1991</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Landcover Classification Categories.

**Fig. 1. Spectral characteristic of High Density and Open Land categories.**

NNC\(^{19}\) and MLC\(^{19}\). About 300 pixels were taken out from the 305×248 pixels of HRV image observed in January 1991 by systematic sampling method as training data\(^{17}\). By using Ward clustering algorithm, 25 core clusters were made and one core cluster was rejected. The landcover classification target was decided as shown in Table 3. The character map with 24 classes is printed out. By comparing this map with aerial photograph and topographic map, the 24 core clusters were categorized and labeled to the 8 landcover categories target. In this process the mis-classification may occur due to the similarity of spectral characteristics. The correspondence of 24 core clusters and the landcover categories is shown in the right part of the Table 3. These core clusters are used as the supervisors for each category.

Fig. 1 shows the spectral characteristics of 3 core clusters of High Density and 4 core clusters of Open Land categories of HRV image in January 1991. From this figure it can be seen that the spectral characteristics of both categories are similar. Plate 3 shows the landcover classification result classified by NNC. Areas P and Q are used to investigate the occurrence of mis-classification.

**2.3. Mis-classification**

To know whether mis-classification has occurred or not, the landcover classifications of HRV image classified by NNC and MLC are compared with aerial photograph. In order to investigate the mis-
classifications, 8 test areas corresponding to the categories of landcover were selected out side of areas P and Q. Each test area consisted of a series of 15×15 pixels block. From these test areas, category accuracy, percent omission error and percent commission error were calculated. Table 4 and Table 5 show the error matrices of the classification results for NNC and MLC, respectively. The whole classification accuracy is calculated by using PCC (Probability Correct Classification) method.

\[
PCC(\%) = \frac{\sum P_i(\%)}{C}
\]

where \( P_i \) is the accuracy of \( i \) category and \( C \) is the number of categories. Table 4 and Table 5 show that the omission errors of Open Land to High Density is the highest of 25.9% and 20.9% for NNC and MLC, respectively. The omission errors between other categories are almost negligible, except for the detection approximately 6%-7% omission error of High Density to Water 2. These errors show that the mis-classifications of Open Land to High Density categories in the classification results of HRV image need to be corrected. This mis-classification can be seen at the river front of area Q in Plate 3.

3. Correction Method of Mis-Classification

3.1. Characteristics of SAR data

One of the characteristics of SAR data is that it can be used to distinguish between flat and rough areas. By logarithmic transformation, the backscattering coefficient of SAR image can be calculated. The values of backscattering coefficient have relation with the kind of landcovers. For example the backscattering coefficient is low on flat areas and high on rough areas. Urbanized area and open land are examples of rough and flat areas, respectively.

Generally, the backscattering coefficient is calculated by the equation \( CF + 20 \log_{10}(SAR\ CCTs) \). This CF is called conversion factor, and has different values depending on the observation condition. The correction method proposed is based on the backscattering coefficient. However, CF was omitted for convenience and \( 20 \log_{10}(SAR\ CCTs) \) is used to classify landcover and called roughness information in this correction method.

It is necessary to evaluate SAR neighbor pixels whether the pixel are rough, namely urbanized, or flat based on the above roughness information. For this evaluation, threshold method is applied and the value of this threshold is termed SAR threshold value.

In order to evaluate the classification ability based on the roughness information, High Density, Low Density, Open Land and Forest and Agriculture land are categorized for the landcover classification from SAR image. About 40×40 of SAR CCT digital values of every category are taken out as sample data for the evaluation of the SAR threshold value. These sample areas are indicated by

<table>
<thead>
<tr>
<th>Table 4. Accuracy error matrix (%) from NNC</th>
</tr>
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<tbody>
<tr>
<td><strong>Classified results</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>W1</td>
</tr>
<tr>
<td>W2</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>OL</td>
</tr>
<tr>
<td>SB</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>L</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5. Accuracy error matrix (%) from MLC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classified results</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>W1</td>
</tr>
<tr>
<td>W2</td>
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<tr>
<td>F</td>
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<tr>
<td>OL</td>
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<tr>
<td>SB</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td>M</td>
</tr>
<tr>
<td>L</td>
</tr>
</tbody>
</table>
squares A, B, C, D, and E, respectively in the Plate 2. High Density and Open Land for SAR image correspond with High Density and Open Land for HRV image in the Table 3, respectively. High Density category samples are taken out from the central city and Open Land category samples are taken out from the ground park.

Fig. 2 shows the relative distribution curves of $20\log_{10}(\text{SAR CCTs})$ obtained from these samples. This figure shows that it is difficult to classify the High Density and Low Density, but High Density can be distinguished from Open Land and the other categories as whole by a certain value of threshold. The classification error of SAR High Density due to cardinal effect remains. However, this error is not taken into account in this study, because the classification results of High Density category are used to correct mis-classification of HRV not as a pixel unit but as spatial information described later. The SAR threshold value between High Density category and the other categories especially Open Land category will be decided to minimize the probabilities of mis-classification between them. If the SAR roughness information, $20\log_{10}(\text{SAR CCTs})$ is greater than the SAR threshold value, the pixel can be classified to SAR High Density pixel.

In this figure, curves of Forest, Low Density and Open Land categories are similar. But according to the error matrices shown in Table 4 and Table 5, it is known that there is few mis-classification among these categories in HRV image and this mis-classification is not considered in this correction method.

3.2. Procedure of correction

As mentioned before, the correction object is the pixel of HRV which is classified to High Density category. If the relation between HRV and SAR images can be established exactly or line-column error is equal to 0, SAR CCTs digital values on the same position play a correction role. However, the relation can not be established exactly in reality, because this transformation contains geometrical (line-column) error. This is a reason why the SAR neighbor pixels are considered in the correction method proposed. It is assumed that $\pm n$ pixels of line-column errors occur between HRV and SAR images transformation in the correction method.

Fig. 3 represents the transformed pixel and the SAR neighbor pixels. The pixel of HRV classified to High Density is transformed to a position in the SAR image. This transformed pixel is the center of SAR neighbor pixels with mesh size of $n \times n$. If all
Correction of Landcover Mis-classification Caused by the Similarity of Spectral Characteristics Using SAR Image

logarithmically transformed values of the SAR neighbor pixels is greater than SAR threshold value then urbanized ratio will be equal to 1. It can be considered that the HRV pixel is adequately classified to High Density. But if not all of SAR neighbor pixels is greater than SAR threshold value then the urbanized ratio is less than 1. The urbanized ratio \((R)\) is calculated by the equation as follow;

\[
R = \frac{(m_1w_1/k_1)+(m_2w_2/k_2)+......+(m_nw_n/k_n)}{W},
\]

where \(m_1, m_2, ..., m_n\) are pixel numbers greater than the SAR threshold value in the line-column error equal to \(\pm 1, \pm 2, ..., \pm n\), \(w_1, w_2, ..., w_n\) are weights and \(k_1, k_2, ..., k_n\) are pixel numbers in the line-column error equal to \(\pm 1, \pm 2, ..., \pm n\), calculating by \((2n+1)^2-(2(n-1)+1)^2\) and \(W\) is total weight, calculating by \(w_1+w_2+...w_n\). In the urbanized ratio calculation, weight is given to each pixel of the SAR neighbor pixels according to the value and distribution curves of line-column errors. By selecting the threshold value of urbanized ratio, which is termed threshold of urbanized ratio, the HRV pixel classified to High Density can be evaluated to High Density or Open Land categories. If \(R\) is less than or equal to threshold of urbanized ratio, then the possibility of misclassified of HRV pixel classified to High Density is high. In this case, the pixel will be corrected to Open Land category. The threshold of urbanized ratio will be investigated in section 4.2.

After SAR threshold value described in section 3.1 is decided, the threshold of urbanized ratio are decided and line-column error is evaluated, the mis-classification between High Density and Open Land categories is corrected with flow diagram shown in Fig. 4. The process is described as follows;

1. Read the landcover classification map classified from HRV image.
2. When a pixel classified is High Density, transform the position of the pixel to a pixel of SAR image. The Affine transformation is used in this transformation.
3. Read SAR neighbor pixels.
4. Check whether the SAR neighbor pixels are High Density pixel or not by SAR threshold value.
5. Calculate the urbanized ratio \((R)\).
6. When the urbanized ratio is less than or equal to the threshold of urbanized ratio, the High Density pixel of HRV is corrected to Open Land category.
7. After the correction process is finished, the new
cluster map which is corrected by the use of SAR roughness information is printed out.

4. Results and Discussion

4.1. SAR threshold value

The SAR threshold value has been selected under the condition that the probability of mis-classification between Open Land and High Density categories should be smallest or approximately equal. From the calculation results, the SAR threshold value is evaluated to be equal to 59. Consequently the pixels greater than the roughness information of 59 is classified to High Density pixel, although some mis-classification remains, especially between High Density and Low Density category as shown in Fig. 2.

4.2. Geometrical error

The relation between HRV and SAR images is better found by exactly relating pixel to pixel. But as described earlier both images have geometrical error or line-column errors. The geometrical error is estimated from twenty GCPs. Fig. 5 shows the line-column error of HRV and SAR images. The standard deviation of line-column error are ±1.08, ±0.86, ±1.17 and ±1.56 for line and column error of HRV and SAR, respectively. Fig. 6 shows the results of normal distribution curves approximated by fitting method\(^23,24\).

Table 6 shows the probability that line-column errors may occur, which are calculated from these curves. From this table the line-column error ±n is decided to equal ±3 in this correction method. Consequently, the numbers of SAR neighbor pixels of line-column errors equal to ±1, ±2 and ±3 are 8, 16 and 24, respectively.

It can be considered that the weight of SAR neighbor pixels nearer to the transformed position namely the center of SAR neighbor pixels is higher for the calculation of urbanized ratio. According to the probability distribution of line-column error, the weight of SAR neighbor pixels of 0.68, 0.20 and 0.05 for ±1, ±2 and ±3 of line-column error\(^25,26\) are evaluated for calculating the urbanized ratio.

When the numbers of SAR neighbor pixels greater than SAR threshold value are equal to a, b and c for line-column errors of ±1, ±2 and ±3, respectively, the urbanized ratio \((R)\) is calculated as follows;

\[
R = \frac{0.68a + 0.20b + 0.05c}{24/0.93}
\]

4.3. Correction of mis-classification

The threshold of urbanized ratio from 0.25 to 0.0 with step interval of 0.05 were evaluated by trial and error. Areas P and Q of HRV images indicated in Plate 3 are used for this evaluation. The pixel numbers of areas P and Q are 85×60 and 75×139, respectively. Fig. 7 shows the relations between the pixel numbers of Open Land pixels corrected from the High Density, and the threshold of urbanized ratio. High Density and Open Land categories pixels after correction in areas P and Q are compared with High Density and
Correction of Landcover Mis-classification Caused by the Similarity of Spectral Characteristics Using SAR Image

Open Land pixels of aerial photograph. The square mesh size of 2.3 mm is used in the interpretation of aerial photograph corresponding to the pixel of HRV image.

Threshold of urbanized ratio of 0.05 is found so as to minimize the difference of pixel numbers between Open Land from the corrected images and Open Land from aerial photograph. Consequently, the High Density pixels of HRV is rectified to Open Land category when the urbanized ratio is less than or equal to 0.05 and remains as High Density of HRV when the urbanized ratio is greater than 0.05.

4.4. Correction results

Mis-classification of landcover image classified from HRV by NNC and MLC are corrected using SAR threshold values and the weights of line-column error step and the threshold of urbanized ratio decided by the earlier processes. Plate 4 shows the landcover images classified by MLC before and after correction. Table 7 and Table 8 show the pixel numbers classified by NNC and MLC before and after correction in the areas P and Q, respectively. The pixel numbers of landcover categories manually interpreted from aerial photograph are also shown in the right part of the tables. These pixel numbers are used as the true values. From these tables, it can be seen that the pixel numbers of High Density and Open Land categories after correction are nearer to the pixel numbers interpreted from aerial photograph.

In the left part of Table 9, the pixel numbers of Open Land and High Density from area P and area Q are shown and the percentages of Open Land
category corrected from High Density category and
vice versa are shown in the right part. The upper
part and the lower part show the results for area P
and area Q, respectively. These percentages are
calculated by \((p - q)/p \times 100\%\), where \(p\) is Open
Land or High Density pixel number from the uncor-
rected landcover minus Open Land or High Density
pixel numbers from aerial photograph and \(q\) is
absolute of Open Land or High Density pixel num-
bers from corrected landcover minus Open Land or
High Density pixel numbers from aerial photo-
graph. The percentage means the proportion of the
pixels corrected to the pixels to be corrected if the
pixels interpreted from aerial photograph are true
and in particular higher percentage means good
correction. These results show that the average
percentage of Open Land pixels corrected from
mis-classified High Density can be estimated appro-
ximately to be 65% and 80% for the landcovers
classified by NNC and MLC, respectively. The
percentage of mis-classified High Density pixels
corrected to Open Land can be estimated more than
approximately 68%.

### 4.5. Accuracy assessment

Correction of mis-classification is assessed by
using the pixels in the test areas which are used in
Tables 4 and 5. Table 10 shows the category accu-
racies \((P_i)\) of Open Land and High Density cate-
gories and PCC classification accuracy classified by
NNC and MLC. The values in upper and lower parts
are obtained from before and after correction
respectively. In the lower part, High Density cate-
gory is excluded from the assessment as there is no
mis-classification between High Density into Open
Land categories. From these tables it can be seen
that the category accuracy \((P_i)\) of Open Land after
correction were increased to 92.1% from 66.9% and
to 94.6% from 74.5% for NNC and MLC, respective-
ly. Consequently, the average of category accuracy
of Open Land is increased approximately 20%. The
omission error of Open Land were decreased to
7.9% from 33.1% and to 5.4% from 25.5% for NNC
and MLC, respectively. Consequently, the commis-
sion error of High Density were decreased to
1.7% from 14.3% and to 2.2% from 12.3% for NNC
and MLC, respectively. The PCC were increased to
92.2% from 89.3% and to 91.6% from 89.1% for
NNC and MLC, respectively.
Table 10. Accuracy assessment before and after correction

<table>
<thead>
<tr>
<th>Interpreted</th>
<th>Classification (NNC)</th>
<th>Classification (MLC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( P_i (%) )</td>
<td>% Omission ( P_i (%) )</td>
</tr>
<tr>
<td>OL</td>
<td>66.9</td>
<td>33.1</td>
</tr>
<tr>
<td>H</td>
<td>88.4</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>PCC= 89.3%</td>
<td>PCC= 89.1%</td>
</tr>
<tr>
<td>OL</td>
<td>92.1</td>
<td>7.9</td>
</tr>
<tr>
<td>H</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>PCC= 92.2%</td>
<td>PCC= 91.6%</td>
</tr>
</tbody>
</table>

Table 11 shows the pixel numbers of Open Land and High Density categories before and after correction. The percentage of Open Land corrected from High Density in all the 8 test areas equal to 96% and 77% for NNC and MLC, respectively. From the calculation results as shown in Table 8 and Table 11, it can be concluded that by using the method proposed and the parameters decided, the percentage of Open Land pixels corrected from mis-classified High Density is evaluated approximately 80%, which is the calculated weighted average by using the pixel numbers interpreted from aerial photograph.

From the correction results it is confirmed that roughness information obtained from JERS-1 SAR image is useful to correct the landcover mis-classification from HRV caused by the similarity of spectral characteristics.

Plate 5 and Plate 6 show the comparison between magnified images of area Q classified by NNC and MLC before and after correction, respectively. From these plates, it can be seen that the pixels corrected have tendency to be corrected in group. This may be related to not only to the value of urbanized ratio but also the characteristics of SAR image that can distinguish Open Land from other landcovers. These problems including the cardinal effect should be discussed in detail for the use of SAR image and the method proposed.

Table 11. Accuracy assessment after correction

<table>
<thead>
<tr>
<th>Sources</th>
<th>Pixel numbers</th>
<th>Percentage Corrected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>NNC</td>
<td>179</td>
<td>407</td>
</tr>
<tr>
<td>MLC</td>
<td>200</td>
<td>426</td>
</tr>
<tr>
<td>A. Photo.</td>
<td>239</td>
<td>464</td>
</tr>
</tbody>
</table>

5. Conclusions

This paper proposes a correction method of landcover mis-classification caused from the similarity of multispectral characteristics by using the roughness information derived from SAR image. The results of this study are summarized as follows.

1. By the correction method proposed, approximately 80% of Open Land pixels can be corrected from High Density pixels of HRV classified by NNC and MLC. The average of category accuracy of Open Land was increased approximately 22.6%. These results show the usefulness of roughness information derived from SAR image to correct the mis-classified Open Land into High Density categories due to the similarity of spectral characteristics.

2. The geometrical (line-column) errors to relate HRV and SAR images and to transform the position of High Density pixel of HRV to a corresponding position of SAR image by Affine transformation are estimated equal to ±3 pixels. These line-column errors were approximated to normal distribution curves. The occurrence probabilities of these line-column errors are considered as the weights and 7×7 pixels corresponding to ±3 pixels are used for calculating the urbanized ratio.

3. The roughness information calculated by \( 20 \log_{10} (\text{SAR CCTs}) \) and SAR threshold value of 59 are used to classify High Density pixels of SAR image. The cardinal effect may cause mis-classification of SAR High Density category. In...
this method, urban ratio which is a kind of spatial information is considered to decrease the mis-classification of SAR High Density category per pixel unit due to the cardinal effect.

4. To investigate the mis-classification of Open Land into High Density categories in the land-cover classified from HRV, the proportions of High Density pixel number in 7 × 7 SAR neighbor pixels are termed urbanized ratio. When the urbanized ratio is less than or equal to 0.05, High Density of HRV is determined to have been mis-classified and this pixel is corrected to Open Land category.

The problems such as the applicability of the method proposed, the relation between the urban ratio and the characteristic of Open Land pixels corrected and the cardinal effect on the mis-classification of urbanized area in SAR image and on the correction results by this method should be discussed in detail for the other images and areas.

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References

Correction of Landcover Mis-classification Caused by the Similarity of Spectral Characteristics Using SAR Image


SAR 画像を利用してした分光特性の類似性に起因する土地被覆分類の修正

アグス スハリャント・出口近士・杉尾 哲・國武昌人

要 旨
最短距離法や最尤法などの分光特性に基づく土地被覆分類では、分類項目間の分光特性が類似することに起因して誤分類が生じる。一方、JERS-1 の合成開口レーダー（SAR）画像からは地表面の粗密度に関する情報を把握できる。本論文ではこの粗密度情報を利用して、SPOT-HRV 画像の土地被覆分類において高密度市街地と空地の項目間で生じる誤分類を修正する方法を提案している。

修正対象画素が HRV 画像で高密度市街地に分類された画素とした。これらの画素の位置を UTM 座標変換により SAR 画像の画素位置に対応づけ、SAR 画像におけるこの画素位置の周囲±3 画素の範囲を SAR 周辺画素とし、HRV 画像での誤分類の判定指標である市街化率を計算する領域とした。

SAR 周辺画素の各 CCT 値を対数変換し、この値が 50 以上であれば市街化していると判断し、この値未満であれば空地や森林などの自然物と判断した。つまり、この市街地と判断された画素数の SAR 周辺画素に占める割合を市街化率とし、この指標に基づいて HRV 画像の誤分類を判定した。すなわち、この SAR 周辺画素の市街化率が 0.05 以下である場合、HRV 画像で高密度市街地に分類された画素は誤分類が生じた可能性が高いと判定して、これを空地に修正した。

空中写真からの目視判断結果を参照データとして修正前後の HRV 画像の土地被覆分類を比較した結果、空地の分類の信頼度で正式距離法で 66.9%から 92.1%に、最尤法で 74.5%から 94.6%に改善された。また、高密度市街地に誤分類された空地の約 80%が修正できたことなど、提案手法の有用性を確認している。

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Correction of Landcover Mis-classification Caused by the Similarity of Spectral Characteristics Using SAR Image


Plate 2. JERS-1 SAR image and sample areas (©MITI/NASDA, 1992).

Plate 3. Landcover classification image of SPOT-HRV by NNC.
Plate 4. Landcover images before and after correction.

Plate 5. Landcover images of area Q classified by NNC before and after correction.

Plate 6. Landcover images of area Q classified by MLC before and after correction.