RULE-BASED CLASSIFICATION OF ALOS/ AVNIR-2 AND PRISM DATA FOR BAMBOO DISTRIBUTION MAPPING

Atsuko NONOMURA [a] Seiya Hozumi[a] and Takuro MASUDA[a]

[a] Engineering faculty, Kagawa University, Hayashicho 2217-20, Takamatsu, Japan nonomura@eng,kagawa-u.ac.jp

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ABSTRACT:

Previously bamboo forests were utilized and maintained to obtain several kinds of product, however, recently the demand has been decreased, so the bamboo forests are not utilized so much, and it is disorderedly expanding in many rural area, in Japan. It has caused serious damage to the ecosystem that expanding bamboo forests are destroying other species. Since the distribution is rapidly expanding, it is very difficult to map the current bamboo distribution with conventional way, such as manually interpretation of aerial photo and satellite data because of required efforts. In this study, we developed a hierarchical algorithm to map bamboo distribution using ALOS /AVNIR-2 and PRISM data. As the first step, land cover is largely classified into vegetated area and non-vegetated area using NDVI. The vegetated area is classified into paddy field and forest area with height of objects, which is derived with surface height calculated with PRISM data and elevation data. Finally, bamboo area is differentiated with discriminant function by using reflectance data estimated from ALOS/AVNIR-2 and PRISM data. By following these rules, finally, landcover is classified into five categories including bamboo forest.

1. INTRODUCTION

Previously, bamboo forest was actively utilized to yield bamboo product as one of the precious natural resources in rural areas. However, recently, demand of the product has decreased and the number of agricultural engagers has decreased in parallel with increase of import from other countries. Besides aging of rural community, as a result, secondary forests and rural native forests have been degraded due to lack of maintenance of bamboo forest.

One of the serious influences is disordered invasion of bamboo. In order to properly maintain ecological balance in the secondary forests, it needs to control the outgrowth. The growth rate is much faster than other species both vertically and horizontally, so it completely occupies habitats of other species and it tends to cause irreverent changes. However, the growth rate is too fast and the number of the bamboo forest is too many, to clearly identify the current distribution.

There are several approaches to map land cover; some are operational or conventional methods, and some are currently developed methods by integrating new technologies.

One of the conventional approaches is field survey. A particular advantage of field survey is that comprehensive descriptions of plant species can be provided for selected areas. However, it is not appropriate method for regional mapping because of required time and effort. The burden work can be reduced by extrapolation from aerial photographs through visual interpretation aided by stereo viewing. Experienced filed surveyors can interpret these photographs and delineate the distribution from limited filed work provided that extrapolations are restricted to an area of a few kilometers. However, the interpretations depend on their experience and it is sometimes lack of objectivity. In addition, photographs are rarely taken frequently enough to estimate a dynamics and the amount of data is one of the limitations. Moreover, manual work takes a lot of time and effort, so it is almost impossible to interpret the distribution within a wide area.

With the limitation of field survey and aerial photograph, alternative information needs to be available for subjective and effective mapping. Earth observation data from satellite sensors provide the alternative. Earth observation data acquired in a single over flight cover a swath that is vastly wider than that of aerial photographs. In addition to the visible data, near infrared and shortwave infrared wavelength data are also recorded with high radiometric quality, which generally have a greater dynamic range and more suited to subjectively land cover mapping. Since sensors onboard satellites are constantly operated with the same condition, spatial resolution and viewing direction is consistent. Land cover and land use classification is one of the main topics of satellite data analysis. Despite the advantages of satellite data, earth observation satellite data have not been routinely adopted yet for mapping and monitoring changes in habitat and vegetation types in several Japanese local governments in Japan. One of the main causes is resolution of data. User's expected resolution tends to be higher than that of available data. In order to extract the necessary information from coarser spatial resolution data, several algorithms of mixed pixel analysis have been developed (Faraklioti and Petrou, 2000; Busetto et al., 2008). At the same time, sensor has also been developed and high resolution data has been gradually available with reasonable price, for example ALOS (Advanced Land Observing Satellite) data; AVNIR-2 (Advanced Visible and Near Infrared Radiometer type 2)with 10m resolution, PRISM (Panchromatic Remote-sensing Instrument for Stereo Mapping) with 2.5m resolution (JAXA, 2007) .

However, the factors of limitation are not only spatial resolution, but also spectral resolution. Some land cover types are hardly recognized with spectral information derived from satellite data. In order to improve the limitation, other kinds of quantified attribute are also used. LiDAR altimetry is one of the breakthrough approaches (Chen et al., 2004; Bork and Su, 2007) . It measures shape and height of the objects precisely. However, it is difficult to use it operationally because of cost.

Another limitation of operational satellite use is that classification algorithm, such as supervised or unsupervised classification (Lillesand and Kiffer, 1999), is sometimes implicitly composed of several statistical procedures, so it is difficult to evaluate the accuracy. The estimated results always include some error, therefore recognizing the errors and analyzing the cause of the error is indispensable to use it operationally.

Therefore in this paper, we proposed a simple and explicit method for regionally mapping land cover including bamboo forest by using satellite data onboard ALOS (Advanced Land Observing Satellite). In order to compensate the spectral resolution, estimated height data with ALOS/PRISM data is used after analyzing the ability of classification.

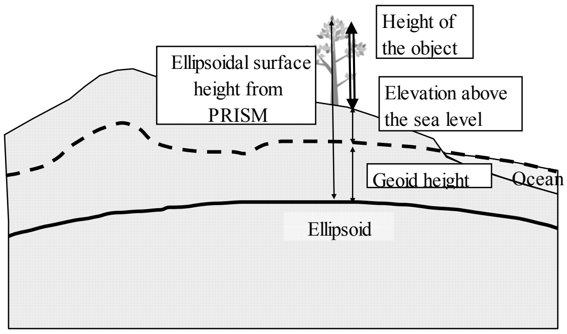

Figure 1 Model of estimated height of objects

Table 1 ALOS/AVNIR-2 and PRISM data

sensor	AVNIR-2	PRISM
the number of band	4	1
wave length	0.42-0.50μm 0.52-0.60μm 0.61-0.69μm 0.76-0.89μm	0.52-0.77μm
spatial resoluton (nadir)	10m	2.5m
swath wide	70km	35km

2. DATA

Simultaneously observed ALOS/AVNIR-2 and PRISM data on 18th August in 2007 were used for land cover classification (Table 1). AVNIR-2 sensor is composed of four bands with 10m resolution; three bands in visible and one band in near infrared. PRISM data is obtained as panchromatic data with 2.5m resolution. Each data was convert from digital number to radiance data, and finally it was converted into reflectance data by using Equation 1 (Chander and Markham, 2003).

$$R = \frac{\pi \cdot L}{E \cos\theta} \quad \cdots\cdots \quad (1)$$

R: spectral reflectance, L: spectral reflected radiance,
E: spectral solar irradiance, θ: zenith angle

Some land cover types are hardly recognized with spectral information derived from satellite data, so additional use of other data than spectral data might be effective for classifying the land cover types. In this study, estimated height of object is also used to compensate spectral information for land cover classification. The height data was estimated by using digital surface model (DSM), which is ellipsoidal height of the object and digital elevation model (DEM) and estimated geoid height (Figure 1) by using Equation 2 (NRC, 2009).

Object height = ellipsoidal surface height from PRISM
- (geoid height + elevation above the sea level) ….(2)

As a DSM data, ALOS/PRISM 3-D surface height measurement is used. As a DEM data, 10m-DEM derived from 1:25,000 topographical map offered by the Geospatial Information Authority of Japan (GSI) is used.

As a model area, about 5km x 5km square was selected in southern part of Takamatsu city (Figure 2), which is one of places where some local people have suffered from disorderly expanding bamboo forest. The expanding speed is too fast to precisely identify the distribution.

3. METHOD

Five types of land cover categories including bamboo forest are set in this study; bamboo forest, other forest than bamboo forest, paddy, city, water body. The proposed algorithm is for

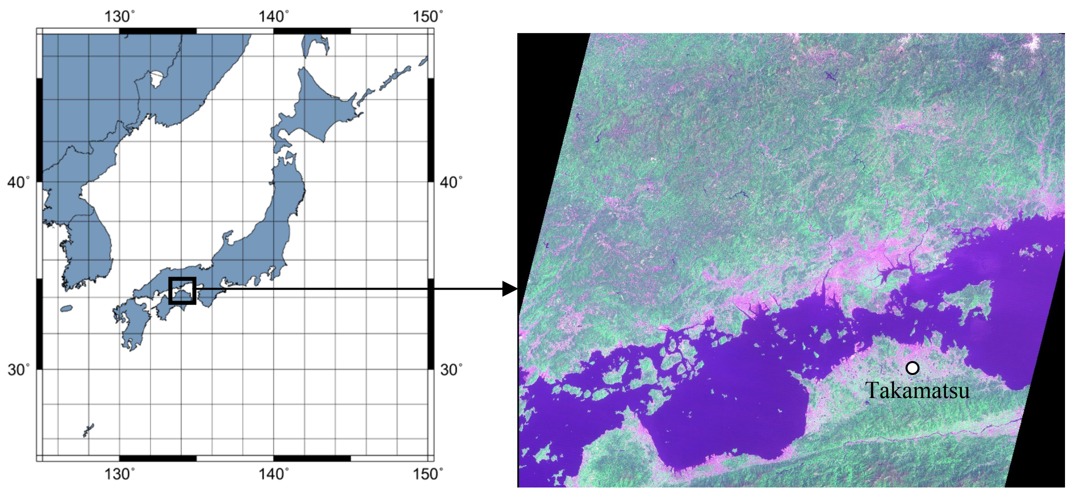

Figure 2 Location of the study area, Takamatsu city

classifying the land cover step-by-step (Figure 3). Thresholds of classification are decided based on the distribution of data sampled at 50 points in each land cover types. At the sampling point, the land cover was identified through field observation and aerial photo observation. Table 2 shows the summarized data.

At first, the land cover is classified into two types; non-vegetated area and vegetated area by using NDVI (Normalized Vegetation Difference Index) calculated from Equation 3.

$$NDVI = \frac{NIR - R}{NIR + R} \cdots\cdots \quad (3)$$

NIR: reflectance of near infrared domain
R: reflectance in visible red domain

Non-vegetated area is classified into city and water body with near infrared reflectance. Vegetated area is classified into two types, paddy and forest, and then the forest is classified into bamboo forest or other forest than bamboo forest.

3.1 Classification of land cover into non-vegetated and vegetated area

At first, land cover was classified into vegetated area and non-vegetated area by using NDVI. The NDVI of vegetated area is higher than non-vegetated area. Although within the vegetated area, each class shows the almost same value, the NDVI value of the paddy area shows larger deviation than other two categories of vegetated area, so the average (ave) is slightly lower. Therefore, a threshold for classifying the vegetated area and non-vegetated area is decided by using average and standard deviation (σ) of paddy data; ave-2σ of NDVI of paddy. Larger NDVI than the threshold means it is classified into vegetated area, and lower NDVI than the threshold means it is classified into non-vegetated area.

3.2 Classification of non-vegetated area into city and water body

Non-vegetated area is classified into water body and city. At the water body, the reflection of infrared is particularly low. The threshold was decided by the same rule as classification of non-vegetated and vegetated area, ave-2σ of near infrared reflection of water body. Larger near infrared reflectance than the threshold means it is classified into city, and lower near infrared reflectance than the threshold means it is classified into water body.

3.3 Classification of vegetated area into paddy and forest

Since the reflectance value of each band and NDVI is similar within the vegetated area, it is difficult to classify land cover types by using only the spectral information. While, the height

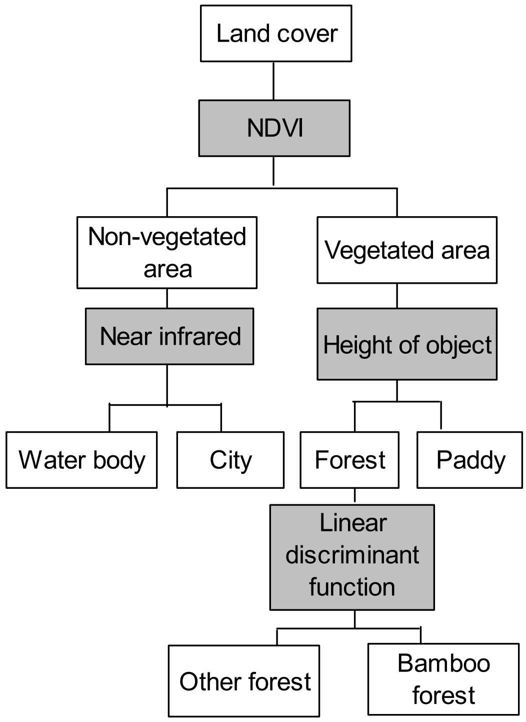

Figure 3 Flow of classification

Table 2. Summarized sampling data of AVNIR-2 and PRISM

landcover	AVNIR-2（spectral reflectance） band 1	band 2	band 3	band 4
water body	0.088±0.005	0.065±0.013	0.033±0.006	0.018±0.004
city	0.140±0.031	0.125±0.040	0.105±0.040	0.091±0.029
paddy	0.085±0.001	0.065±0.002	0.034±0.002	0.135±0.017
bamboo forest	0.084±0.002	0.064±0.003	0.033±0.002	0.140±0.012
other forest	0.083±0.002	0.058±0.003	0.031±0.002	0.126±0.013

landcover	PRISM（reflectance）	NDVI	height（m）
water body	0.061±0.010	-0.299±0.106	-
city	0.186±0.059	-0.064±0.075	12.778±3.933
paddy	0.086±0.004	0.592±0.073	7.906±4.914
bamboo forest	0.087±0.004	0.615±0.031	18.870±6.483
other forest	0.079±0.005	0.607±0.041	16.524±5.498

※ average±standard deviation

value of paddy is lower than that of forest (both bamboo forest and other forest than bamboo) although the paddy filed shows higher value than height of general rice crop. The overestimated height is caused by large standard deviation (4-6m). It corresponds with previously reported accuracy, 5-6m in Takaku and Tadono (2009).

Generally, there is more than 5-6m height difference between bamboo and rice crop, so in this study the threshold is decided by considering the relative relationship between paddy and forest. The average height of paddy is 7.9m and the average height of forest is 16.5-18.9m. Since the standard deviation is larger than spectral data, the thresholds is calculated by averaging ave-σ of forest and ave+σ of paddy; 12m.

3.4. Classification of forest into bamboo forest and other forest than bamboo forest

Finally, forest is classified into bamboo forest and other forest than bamboo forest by linear discriminant analysis. The discriminant function (Equation 4) is derived by using reflectance of AVNIR-2 data PRISM data.

$$F = -2.24\times Band1 + 0.98\times Band2 + 3.52\times Band3 + 0.04\times Band4 + 0.15\times PRISM - 0.33 \qquad \ldots\ldots\ldots(4)$$

The equation was applied to vegetated area in all the study area. $F \geqq 0$ means bamboo forest and $F<0$ means other forest than bamboo.

Above mentioned rules are hierarchically applied to the satellite data and land cover was classified into five categories (Figure 4).

4. EVALUATION OF THE CLASSIFICATION

The classified land cover, especially bamboo distributions were validated in some area, which is bounded by a black square in Figure 4 and it is zoomed up in Figure 5. Field observation was performed 3rd June 2010. The black dot circle indicates the bamboo forest within the each photo.

At point 1 and 2, the distribution of bamboo forest is actually identified and it is clearly estimated with our proposed algorithm. Near the top of the mountain, point 3 and point 4 is estimated as the bamboo forests, respectively. However, actually bamboo forests are not found there, but deciduous forests are distributed.

At point 5, the bamboo forest is distributed there. Currently, this is not residential area, but evidence of block wall and bamboo forest over the flat area on the slope imply that previously people lived there and produce bamboo products.

At the skirt of the slope, there are agricultural fields and at the back of the agricultural field, there are several bamboo forests, (for example bamboo forest indicated with dot circle in the photo taken at point 6). Many of them are not classified into bamboo but paddy. Therefore the classification of vegetated area into forest and paddy should be improved more to distinguish forest from paddy in the vegetated area.

On the slope, relatively large size of the bamboo forest distribution is estimated clearly (at point 7 and 8). Near the boundary between bamboo forest and other forest (at point 7), bamboo and other trees are found together. However, since the height of the bamboo is mostly higher than other trees, it is considered that bamboo trees tend to be dominant at the canopy.

In the residential area, even small size of bamboo, the distribution is able to be clearly estimated (at point 10 and 11).

Over the mountainous slopes, the distribution is able to be es-

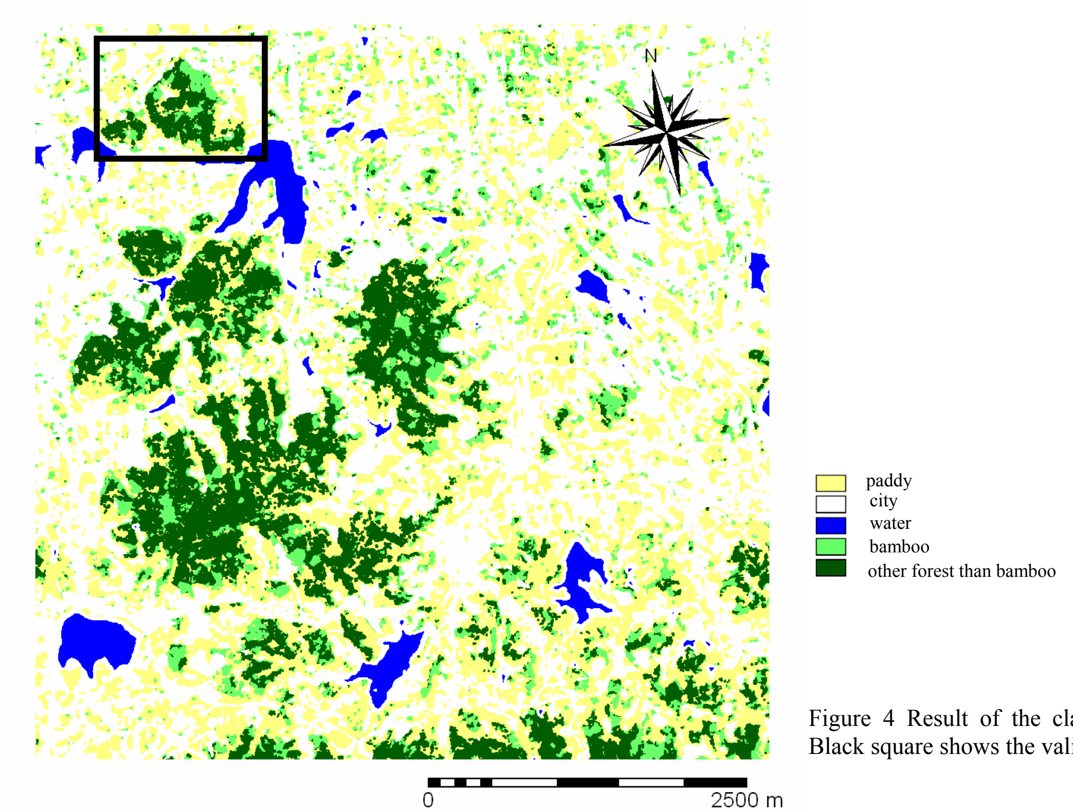

Figure 4 Result of the classification. Black square shows the validation site.

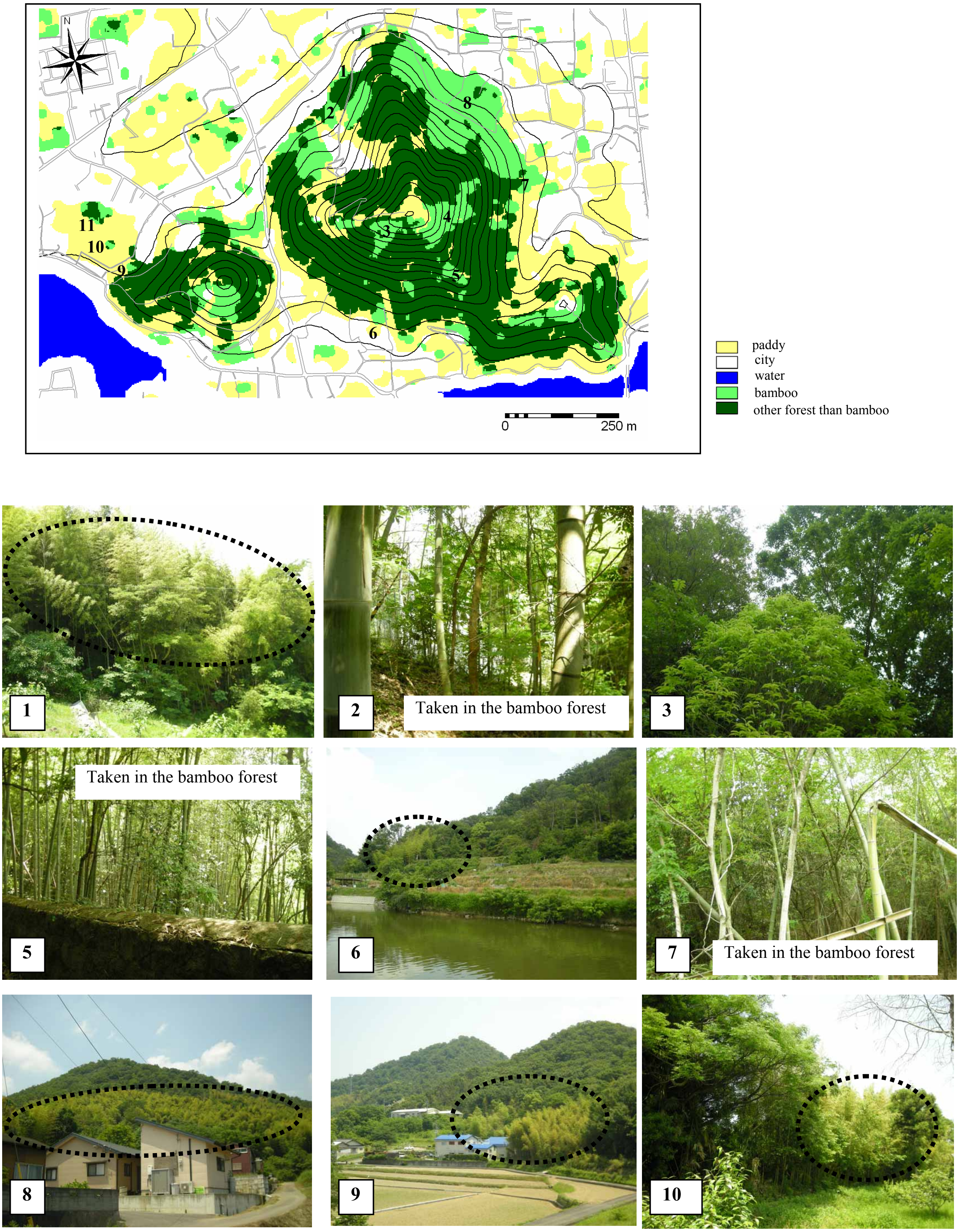

Figure 5 Extracted classified map (above) and field data at each point of the map. Each dot circle indicates bamboo forest

timated at point 1, 2, 5, 7, 8, 9. At point 3 and 4, other trees are misclassified as bamboo. These two points are located relatively steep slopes. It might imply that topographic conditions affect the accuracy of the classification.

The relationship between the accuracy and several local characteristics are discussed. Although the validated points are only eleven points, non-differentiable bamboo is summarized here;

1) Other forests distributed over steep slopes are classified into bamboo forest. Although the relationship between the accuracy and topographic conditions is not still investigated yet in this study, it should be indispensable for improving the accuracy.
2) Some bamboo forests located near paddy are classified into paddy. The threshold for classifying vegetated area into forest and paddy need to be improved.

5. CONCLUSION

In this study, land cover classification method is proposed by using ALOS/AVNIR-2 and PRISM data. Vegetated area is classified into three types; paddy, bamboo forest, and other forest than bamboo forest. It is difficult to differentiate these three categories by using only spectral data because the spectral reflectance shows similar characteristics. Therefore, ALOS/PRISM 3-D surface height measurement is used and height of object is subtracted elevation data from DSM.

Accuracy evaluation shows that misclassification is caused in classifying vegetation into paddy and forest. Topographic conditions also seem to affect the classification accuracy of forest into bamboo forest and other forest.

As a next step, after validating the classification more, we will apply this algorithm to other areas.

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