REMOTE SENSING IMAGERY-BASED AGRICULTURAL LAND PATTERN EXTRACTION AROUND MIYAJIMANUMA WETLAND

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ABSTRCT

This research aimed to extract agricultural land use pattern around the Miyajimanuma wetland, Hokkaido, Japan. By combining the image segmentation technology - watershed transform and image classification technology- particle swarm optimization (PSO)-k-means-based minimum distance classifier, a new method for extracting the agricultural land use information based on remote sensing imagery was developed. Remote sensing image segmentation and classification provide a quick method for estimating important crop characteristics or locations of various crops in a field that appears to have similar characteristics and knowing the impact of agricultural production activities to the environment. Watershed transform algorithm was used to extract the land parcels in the catchment; PSO-k-means-based minimum distance classifier was used to do remote sensing imagery classification and classifies agricultural land into five classes including paddy, soybean field, wheat field, water body and others. Finally, the pixels in one parcel were divided into one class according to the result of classification, and thereby extracting the land use pattern. Results from the study indicated that by using this method the accuracy of classification was up to 96%, much better than the results published before. As such, the proposed method could be of interest to researchers who need more accurate information on agricultural land use.

Keywords: agricultural land use classification, remote sensing, sample pre-classification

INTRODUCTION

Agricultural land use information is required in many aspects of sustainable management of land resources and policy development, as a prerequisite for monitoring and modeling land use and environmental change, and as a basis for land-use statistics at all levels (Jansen & Di Gregorio, 2004). In the Miyajimanuma wetland, Hokkaido, Japan, agriculture is the dominate land use type. The agricultural production activities had broken the original ecological balance. Different vegetation types and their management has great effect on hydrologic process that influences the amount and quality of water entering wetlands. Affected by agricultural production activities within the catchment area, water quality deterioration and eutrophication was getting worse than before. Therefore, accurate information of the distribution and spatial extent of agricultural land use is significant for understanding the impact of environmental factors such as drainage or pest infestations to study the impact to the environment of agricultural activities.

Satellite image segmentation and classification had become main method for land use and land cover information extraction (Beekhuizen & Clarke, 2010) Various classification techniques, both parametric and non-parametric, have been developed and used in different contexts which remote sensing inclusive (Mountrakis, Im, & Ogole, 2011), and the work that aimed to improve the classification accuracy was never given up in the past years. Generally speaking, all the approaches that have been proposed for land use and land cover information extraction can be divided into three classes, that is 1) Using image classification methods. 2) Using image segmentation methods. 3) Combining methods using image classification and image segmentation. By analyzing the remote sensing data can provide critical insights into the evolving human-environment relationship.

An important problem encountered in the information extraction of remote sensing data is that classical classifiers, once they have been trained on a data set related to a specific image, seldom attain acceptable classification accuracies on different images (even if the land-cover classes present in all the images are the same) (Bruzzone & Prieto, 1999). Several factors contribute to this problem: differences in the atmospheric and light conditions at the image-acquisition dates, sensor non-linearity's, differences in soil moisture levels, etc. In addition, it has been previously determined that satellite image classification results did not improve more than 15 years (Rozenstein & Karnieli, 2011) years in spite of vigorous and creative efforts to establish new classification algorithms during this period. Therefore, it was concluded that it worth continuing research effort to improve classification algorithms in remote sensing (Rozenstein & Karnieli, 2011).

The purpose of this work was to explore an effective method for extracting the information of agriculture land use in wetland. In terms of the agriculture remote sensing, the complex situation of spectrum of different crops had decided it is much difficult to extract information of agriculture land use than any others. The proposed method is based on the land parcels extraction and training data pre-classification based MDC. In addition, parcel, the smallest plant unit in which it has similar attributes, is the basic spatial unit of land assessment and classification. The crops always keep uniform in the same parcel; therefore, it is meaningful to extract the land parcel information in the progress of agricultural land use pattern extraction. In order to reduce

the complicate of the calculating progress, the first principal component of the original satellite image was used in the land parcel extraction progress using watershed transform; a PSO-K-means based MDC was used to classify the pixels into different class in the feature space composed of the first three principal component, the PSO was used to look for the optimal initial position for K-means. Finally, the crops in the parcels were divided by a statistic progress of the result of pixels classification.

MATERIALS AND METHODS

Study area

This study focuses on the Miyajimanuma lake area, located in Bibai city in the central part of Hokkaido Island, Japan (Fig. 1). The lake is a permanent freshwater lake of 30-ha in the middle basin of a river Ishikari-gawa, surrounded chiefly by rice paddies, wheat and soybean. Recent years, affected by human activities, mainly the agricultural production activities within the catchment area, water quality deterioration and eutrophication becomes worse than before.

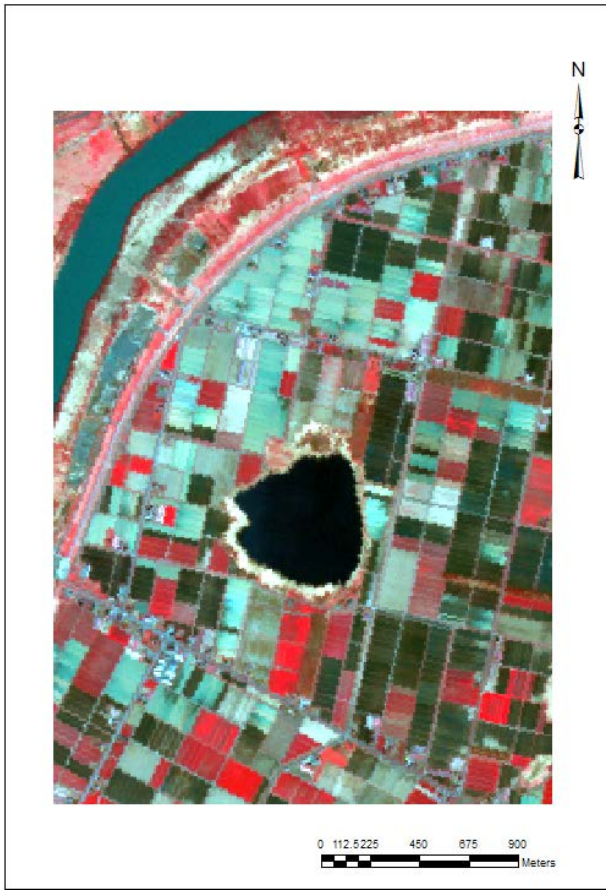


Fig.1 The study area (SPOT 5 remote sensing image, R: green G: red B: near IR)

Satellite image data and land use types

A sub scene of SPOT5 satellite image was used in this research, it was taken in 15th, May, 2010 with a 10 kilometers radius around the Miyajimanuma. Geo-referencing was carried out for the image using ground control points. The image was georeferenced to the coordinate system used in the topographic maps was the Universal Transverse Mercator (UTM) zone 154N with spheroid and datum WGS84 in order to most realistic response to spatial structures of agricultural land use.

Ground information around the Miyajimamuma area, in addition, was derived from fieldwork which collected the field information at 35 locations in 16th, July, 2010. A GPS unit was used to visit each location and the location was placed into one of the five land use classes. Land use was classified into 5 categories as follows: water bodies, paddy fields, bean fields, wheat fields and others (including windbreak, roads, rare areas, and building, etc.).

Dimension reduction

While certain computationally expensive novel methods can construct predictive models with high accuracy from high-dimensional data, it is still of interest in many applications to reduce the dimension of the original data prior to any modelling of the data. One of the problems with high-dimensional datasets is that, in many cases, not all the measured variables are “important” for understanding the underlying phenomena of interest. Principal component analysis (PCA) is the best, in the mean-square error sense, linear dimension reduction technique. PCA is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. This transformation is defined in such a way that the first principal component has as high a variance as possible (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (uncorrelated with) the preceding components. The PCA was used because a major goal of this research is to reduce feature space for supervised classification. In terms of this research, even only four band data in the original data, but the huge number of pixels will lead to a disaster of calculation; therefore, compressing data dimension is very necessary.

Training data pre-classification based supervised classification

The classifier chose in this research is minimum distance classifier, because it is most easy to archive. Five classes training data was not directly used to train the classifier, but firstly be classified into some sub groups according to the difference of the spectral value, and then using the sub groups to train the classifier, finally, the classification result which correspond to the sub groups was merged into the original classes.

K-means clustering was used to perform training data pre-classification. The K-means algorithm is a fast iterative algorithm that has been used in many clustering applications. It is a point-based clustering method that starts with the cluster centers initially placed at arbitrary positions and proceeds by moving at each step the cluster centers in order to minimize the clustering error. On these bases, each sample was classified into a certain class (Vrahatis, Boutsinas, Alevizos, & Pavlides, 2002). It employs a simple iterative scheme that performs hill climbing from initial centers, whose values are usually randomly picked from the training data. Although K-means algorithm is very efficient, it suffers two serious drawbacks that its performance heavily depends on the initial starting conditions and easily convergence to local optima, so global solution of large problems cannot found with reasonable amount of computation effort. In this research, PSO was used to find the optimal initial starting conditions for the K-means algorithm.PSO, inspired by social behavior in nature, is a population-based search algorithm. In PSO, each single candidate solution can be considered a particle in the search space. Each particle makes use of its own memory and knowledge gained by the swarm as a whole to find the best (i.e., optimum) solution. All of the particles have fitness values, which are evaluated by a fitness function so that they can be optimized. In this method, K-means inherent the result of PSO module as the initial clustering centers and continue processing the optimal centers to generate the final results for minimum distance classifier. Therefore the result of pre-classification is the optimal sub groups.

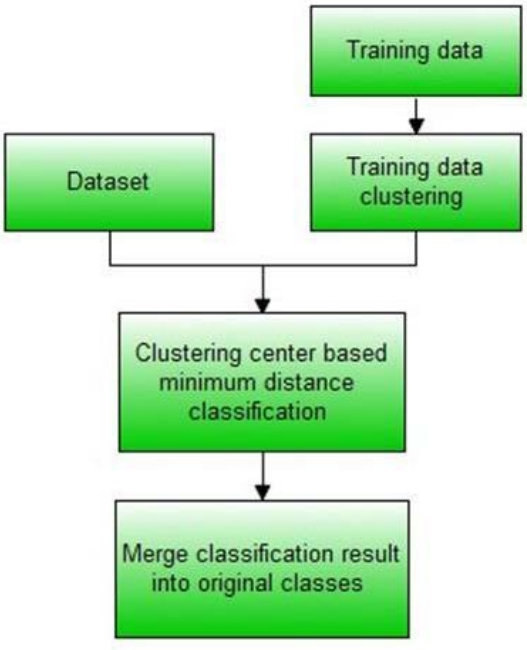


Fig.2. Flowchart of pre-classification based MDC.

Based on the clustering centers of the sub groups, the cluster of these sub groups was used to take place the mean of original training data to do minimum distance classification using Euclidean distance. The dataset was divided into the different sub group using supervised classifier the flowchart of PSO-K-means based minimum distance classifier (MDC) is shown in Fig. 2.

Land parcels extraction and re-classification

In an effort to further increase classification accuracy, watershed transform, a famous image segmentation algorithm was applied to the SPOT 5 image. Watershed transform, introduced in image analysis by Beucher and Lantuejoul (Beucher & Lantuejoul, 1979), considers a two-dimensional one band image as a topographic relief. The value of a pixel stands for its elevation, the brighter pixels represent higher altitudes or the ‘hill’ and the darker pixels correspond to the ‘valleys’ (Wang et al., 2010). The watershed lines, the divide lines of ‘domains of attraction’ of water drops, divide the image into catchment basins, so that each basin is associated with one minimum in the image.

The first component of the PCA results was used to do the watershed transform in this research. As a gray-level image, it was, for one thing, satisfied the requirement of the watershed transform algorithm, for the other thing, it retained the information from the original dataset as much as possible (cumulative proportion is 85.83%). The output of the watershed transform is a partition of the image composed of regions (sets of pixels connected to the same local minimum) and of watershed pixels (the borders between the regions) (Tarabalka, Chanussot, & Benediktsson, 2010).

The result of the watershed transform and training data pre-classification based supervised classification were finally combined by the statistic progress. In terms of the agricultural land use, the crop planted in the same land parcel was limited or uniform. In this research, we assume that the class which less than 30% of the total pixels in one parcel will be divided into the class in which the pixels number is biggest.

Finally, the boundary points of the segmentation results were divided into certain class according to the state of its neighbors. In the case of the result of the watershed transform, large numbers of the pixels were divided to be a special class - boundary. Actually, the boundary reflect the variable of the land use parcels, cannot be an independent class for the land use. In this research, the boundary points were divided into classes which have largest number in its neighbor parcels.

The flowchart of the methodology was given in Fig. 3.

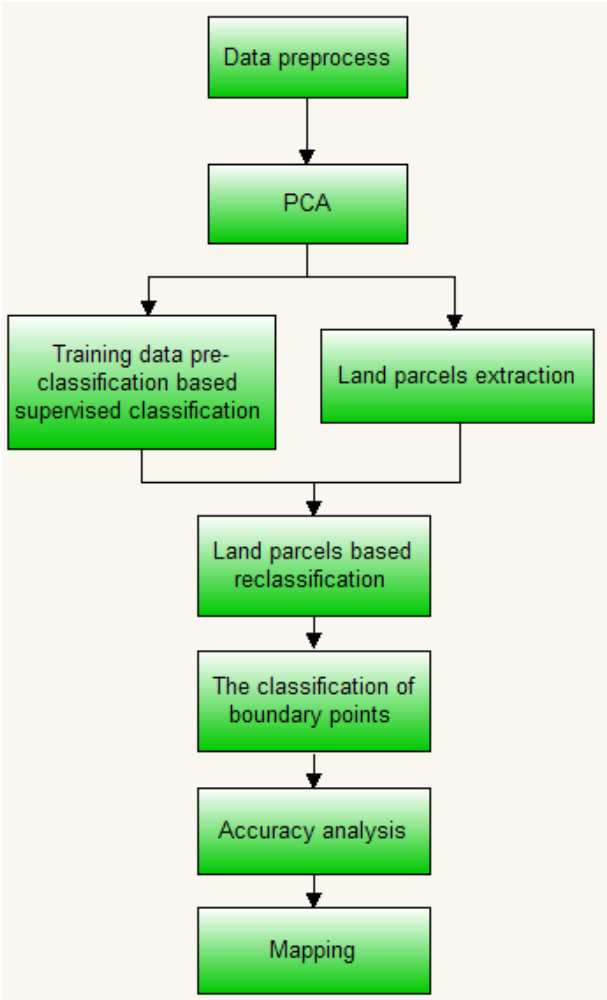


Fig. 3. Whole progress of the methodology.

Classification accuracy

Estimating the accuracy of a classifier induced by supervised learning algorithms is important not only to predict its future prediction accuracy, but also for choosing a classifier from a given set (model selection), or combining classifiers. Throughout the classification process of this research, the accuracy of classification maps was assessed by a set of 395 points sampled stratified random sampling.

For each map, a confusion matrix was created and accuracy measures were calculated. The use of measures such as overall accuracy, Kappa statistics, producer's accuracy, user's accuracy and the conditional Kappa, are quite common and explained in detail in numerous publications.

RESULTS

In this research, classic MDC, and land parcel-PSOK-MDC was compared for remote sensing imagery classification. Firstly, a classic MDC

was used to do the imagery classification. In this progress, the distance between each pixel and the means of each kind of samples was calculated, and classified into certain class. Land parcel-PSO-K-means based MDC, actually, made a training data pre-classification progress, and used the cluster center of each subclass to instead of the “mean” in classic MDC to calculate the distance; and then, the land parcel information was obtained by using watershed transform method; finally, the class in the parcels were reclassified according the property that the plant is always uniform or limited in same parcels.

As we can see from the Table 1 and Fig.4, no matter the overall classification accuracy but the private classification accuracy got using classic MDC is very low. It is obvious that this method cannot distinguish paddy field from the water body, and the others class almost was totally divided into wheat and bean, that means this method cannot extract the information of windbreak, roads, rare areas, and building etc. Bean fields even were totally divided into others. Using this method only can keep the water body, but due to in the result it also includes some information of paddy field; the whole results become no meaning.

Table 1 Confusion matrix and accuracy measure for MDC

class		Reference data				
		Bean	Paddy	Water	Wheat	Others
Classified data	Bean	0	0	0	0	36
	Paddy	0	36	52	0	0
	Water	0	0	154	0	0
	Wheat	0	4	8	31	0
	Others	15	0	0	57	2

Producer’s Accuracy	User’s Accuracy	Conditional Kappa
0.00%	0.00 %	-0.04
90.00%	40.91%	0.34
71.96%	100.00 %	1
35.23%	72.09%	0.64
94.74%	2.70%	-0.07

Overall Classification Accuracy = 56.45%.

Overall Kappa Statistics = 0.40.

Compared with using classic MDC, the results got using land parcel-PSOK-MDC is much better even perfect. Table 2 describe that only small part of the paddy field wheat field and others were not correct divided,

and the small part of the wheat was not corrected, and the others almost are perfect. The overall classification accuracy 96.45% and overall Kappa Statistics 0.95 told us the final results are acceptable.

Table 2 Confusion matrix and accuracy measure for land parcel-PSOK-MDC

class		Reference data				
		Bean	Paddy	Water	Wheat	Others
Classified data	Bean	36	0	0	0	0
	Paddy	0	88	0	0	0
	Water	0	0	154	0	0
	Wheat	0	12	0	29	2
	Others	0	0	0	0	74

Producer's Accuracy	User's Accuracy	Conditional Kappa
100.00%	100.00%	1
88.00%	100.00%	1
100.00%	100.00%	1
100.00%	67.44%	0.65
97.37%	100.00%	1

Overall Classification Accuracy = 96.45%.

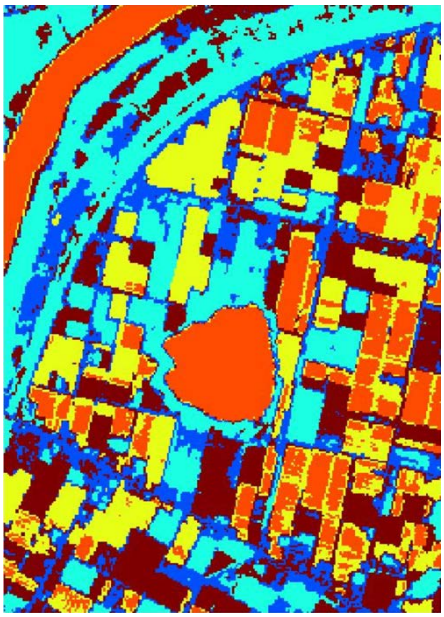
Overall Kappa Statistics = 0.95.

DISCUSSION

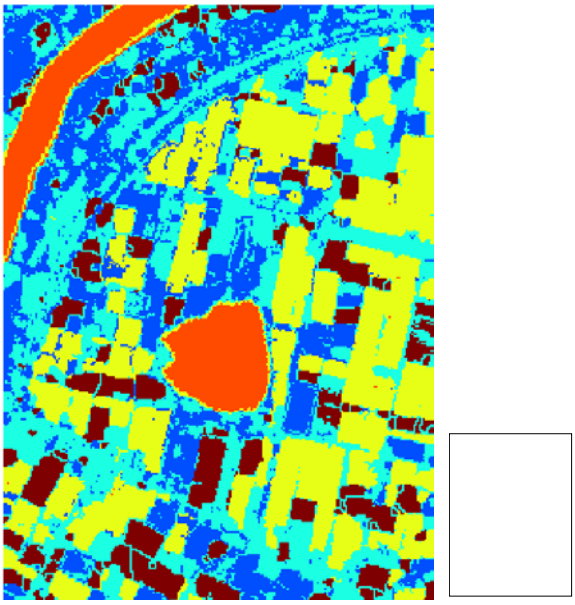
Training data pre-classification was first used for satellite image supervised classification in this study. In terms of agricultural land use, the diversity of crop growth status has decided that even the same kind of crop, it would have different spectral feature. For this reason, the samples prepared for the supervised classification would include some kinds of information, it is unreliable just use the mean of one class sample to be the cluster centre, in order to decrease the affection of this phenomenon on the classification results, it is necessary and better to make a sample pre-classification, and then using the mean of subclass to be the cluster centre supervised classification, a PSO-K-means based MDC was developed. In this progress, the samples, training data for the supervised classification, was divided into some small sub group, the cluster center of these sub group was used to take place the mean of original data centers to calculating the minimum distance. Although K-means algorithm is very efficient, it suffers two serious drawbacks that its performance heavily depends on the initial starting conditions and easily

convergence to local optima, so global solution of large problems cannot found with reasonable amount of computation effort. In order to overcome local optima problems PSO was used in this study. By this method, the optimal clustering centers were gotten for the MDC.

High-precision result with small feature space was got in this research. One issues met in the imagery classification is that the complex spectral feature make the train progress become a complicate progress which spent a lot of time. No matter what classifier has been chosen, a formation of a suitable feature becomes of paramount relevance. This is an open and difficult problem to define an absolutely optimal feature space due to the lack of evaluation criteria (Ng, Dorado, Yeung, Pedrycz, & Izquierdo, 2007). The problem of forming of the feature space in the case of images is even more complicated. On one hand, we have a lot of different alternatives. On the other hand, the diversity of images contributes to the elevated level of complexity and difficulty. By now, large number of the researcher seem not satisfied the performance of the original spectral number, so it is easy to find the texture and band ration (Beekhuizen & Clarke, 2010) information etc. were added into the feature space. however, the increase of the number of input features may introduce additional complexity related to the increase of computational time and the “curse of dimensionality”, overwhelming the expected increase in class associated with inclusion of additional feature (Pacifici, Chini, & Emery, 2009). It is obviously that less feature data if they can get a good classification result is better for the calculation progress.



(a) Results of Standard MDC



(b) Results of LP-PSOK-MDC

Fig.4 Land use map derived from SPOT 5 image using different methods

In addition, in terms of the agricultural land use, land parcels based agricultural planting decide that land parcels is very important for agricultural land use information extraction. With the emergence of high-precision classification, large number of segmentations was appeared in the final mapping results. Land parcel based method which does the segmentation based on the land use parcel seems better for agriculture land use classification, because crop planting is regular and limited in certain land parcel. A combination method based imagery segmentation and imagery classification is being evaluated in our laboratory. Using the proposed method in this research, almost optimal classifications result by now just use PCA component was gotten. Efficient extraction of image information is the most basic requirements and purpose for remote sensing imagery classification, but an problem met in the progress of remote sensing imagery classification is that the accuracy reached by the classification system is often lower than that requested by the end user (Giacinto, Roli, & Bruzzone, 2000). In this research, the developed method was performed to do the extract agricultural land use, and easily get good classification accuracy. the accuracy rates has up to 96.45% and Kappa statistics has up to 0.95 for a land use map of Miyajimanuma catchment area with five classes, which is comparable to or better than achieved in the literature using automated methods for land use classification, and obviously higher than the frequently adopted overall accuracy of 85%.

CONCLUSION

A new agricultural land use information extraction method was development. The method included the remote sensing image classification using samples pre-classification method and the watershed image

segmentation algorithm was for getting the land parcels information, land use information within the parcels were reclassified according to the classification and segmentation results. In the progress of classification, an overlay technique within the GIS framework was applied to analyze the information from the thematic maps in order to develop a final map illustrating the spatial distribution of land use pattern. Results from the study indicate that land parcels with different size could be clearly extracted using the gray-level image, and the land use information in the parcels could be reclassified using the classification results. Using this method is easily to get good classification accuracy. As such, the proposed methodology could be of interest to researcher involved in the environment protection, precision agriculture, since these researchers need a more explicit view in the small region and clear information on land use.

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