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Land Cover Classification in Makkah Area using Frequency-based Contextual Classifier

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***Abstract*—Classification of land cover is one of the most important tasks and one of the primary objectives in the analysis of remotely sensed data. Recall that the aim of the classification process is to assign each pixel from the analyzed scene to particular class of interest such as urban area, water, land, etc. The image resulting from labeling of all pixels is referred as thematic map. Such maps are very useful in many remote sensing applications especially those concerned with agriculture monitoring, land change detection and environmental purposes. The objective of this study is to evaluate the types of land cover in Makkah area by using Frequency-based Contextual (FBC) classification technique. Contextual classifier that utilized both spectral and spatial information is able to reduce the speckle error and improve the classification performance significantly. A total of five classes could be classified clearly within the study area and 82.3% accuracy was achieved in the classification process.**

Keywords-land cover; frequency-based; contextual; remote sensing; ALOS AVNIR-2

I. INTRODUCTION

Remote sensing technology has been used for many years to acquire data such as for land cover application. It allows large scope for analysis, classification and interpretation of the image data, whereby it gives a lot of information from a single image. Land cover is one of the most frequently extracted information from remote sensing data. It represents a complex mixture of natural and anthropogenic ground classes [1]. Land cover map is used in capturing of current physical situation of land surface for natural resources management and environmental monitoring. Up to now satellite land cover map is made usually by supervised or unsupervised classification method. The first approach requires interactive training area selection and knowledge on the study area. This method cannot be automated by any way. The second approach is carried out mainly by clustering technique. This is done automatically based on a number of chosen classes and seperability measure among them. The monitoring task can be accomplished by supervised classification techniques, which have proven to be effective categorization tools [2]. In this paper we only concern with the supervised approach.

Recently, there are many advance classifiers used for classification. One of them is the use of spectral information integrated with additional information called spatial information during classification. Such technique is called contextual classification. For each point to be classified, we can examine its neighbourhood in the feature space to get an idea of the local class distributions around the point and integrate the information in the decision making process [3]. Contextual information is one kind of such spatial relationship and has drawn our particular interest for remotely sensed imagery interpretation shown in this study. Contextual information may be defined as how the probability of presence of one object (or objects) is affected by its (their) neighbors. Generally, in remote sensing land use/land cover classification, a pixel for example, labeled as forest is likely to be surrounded by the same class of pixels unless that pixel is located in boundary area. If such contextual information can be well modeled, the classification accuracy may be improved significantly [4, 5].

The aim of this study is to generate map of Makkah and its surrounding area using Frequency-based Contextual (FBC) classification method for the purposes of land cover mapping.

II. STUDY AREA

The Holy City of Makkah is at an elevation of 277 meter above sea level, and approximately 80km inland from the Red Sea. The elevations of Makkah are a group of mountains and black rocky masses which are granite basement rocks. The geographical coordinate of the area of interest are: lat (21°21' to 21°27') N and long (39°47' to 39°59') E.

Makkah climate is different from other Saudi Arabian cities, retains its warm temperatures in winter (November to

Figure 1. Location of the study area.

Mac), which can range from 17^{o}C at midnight to 25^{o}C in the afternoon. During summer (April to October), temperatures are considered very hot and break the 40^{o}C mark in the afternoon dropping to 30^{o}C in the evening. Rain is very rare with an average of 10-33 mm usually falls in December and January, and the humidity ratio is about 45-53%. Winds are northeastern most of the year. Some unusual events often happen during the year, such as dust storms, coming from the Arabian Peninsula's deserts or from North Africa [6].

These selected area located in the desert terrain and bounded by hills and mountains in every direction. Nevertheless, this area becomes famous especially to Muslims. It is reported that around 2 millions people around the world will gather together in this area to perform the Hajj every year. Location of the study area is shown in Fig 1.

III. Material And Method

A. Material

Two set of satellite data were used in order to execute this study. The first satellite imagery is multi spectral ALOS AVNIR-2 data with 10m spatial resolution. The satellite imagery containing 4 bands (blue band, green band, red band and near infrared band) was acquired on April 28, 2009. The second imagery is geocoded SPOT-2 satellite data. This satellite image is required as a reference data in order to perform the registration of the ALOS AVNIR-2 satellite image.

All image processing analyses in this study was performed by the PCI Geomatica version 10.3 digital image processing software packages.

B. Methodology

There are five steps need to be done in order to obtain the classified land cover map. The process begins with the data acquisition, image pre-processing, training area collection, image classification and accuracy assessment. In the data acquisition, the satellite image was used as a main source of the data. This ALOS AVNIR-2 satellite data was subtracting to the desire area. Prior to the image analysis, a number of pre-processing steps were undertaken. The role of pre-processing can be important for improved classification performance. For instance, image enhancement and geometric correction was performed to the image. Enhancement is the process of improving the visual appearance of digital images. In the meantime, geometric correction was done by using image to image registration technique with the geocoded SPOT-2 data as the reference image in order to register the 2009 image (ALOS AVNIR-2).

The classification process was based on supervised approach. In supervised classification, there are three basic steps involved in the image analysis which are training, classification and output phases. In the training phase, samples were collected from the image as a training data. These training sets are used to train the system to recognize the characteristics of pixels in the image based on their spectral signature. Hence, the establishment of the training phase is the most important part in the supervised approach. In the classification phase, one of the techniques from supervised approach was selected to classify the images into land cover classes. Here the image classification was performed by using Frequency-based Contextual classification method. This method utilized both spectral and spatial information during the classification process. The integration of the spatial information into the spectral information could be increased the classification accuracy. For the output phase, the land cover map was generated as thematic map and ready to be analyzed.

The other important component in land cover classification project was accuracy assessment. No land cover assessment is completed without checking their accuracy of the classified images that generated from the classification process. For that reason, accuracy assessment was carried out to check the correctness of the output result. A total of 297 sample points were chosen for the accuracy assessment. These sample points were generated randomly by the system. A common method for accuracy assessment of a classification images though the use of error matrix. Some important measures, such as overall accuracy, producer and user accuracies, can be calculated from the error matrix [7]. Fig 2 illustrates the classification analysis flow chart.

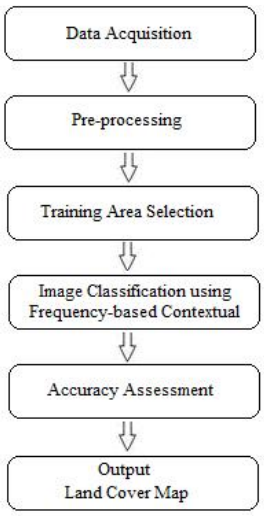

Figure 2. Flow chart for data processing of the image.

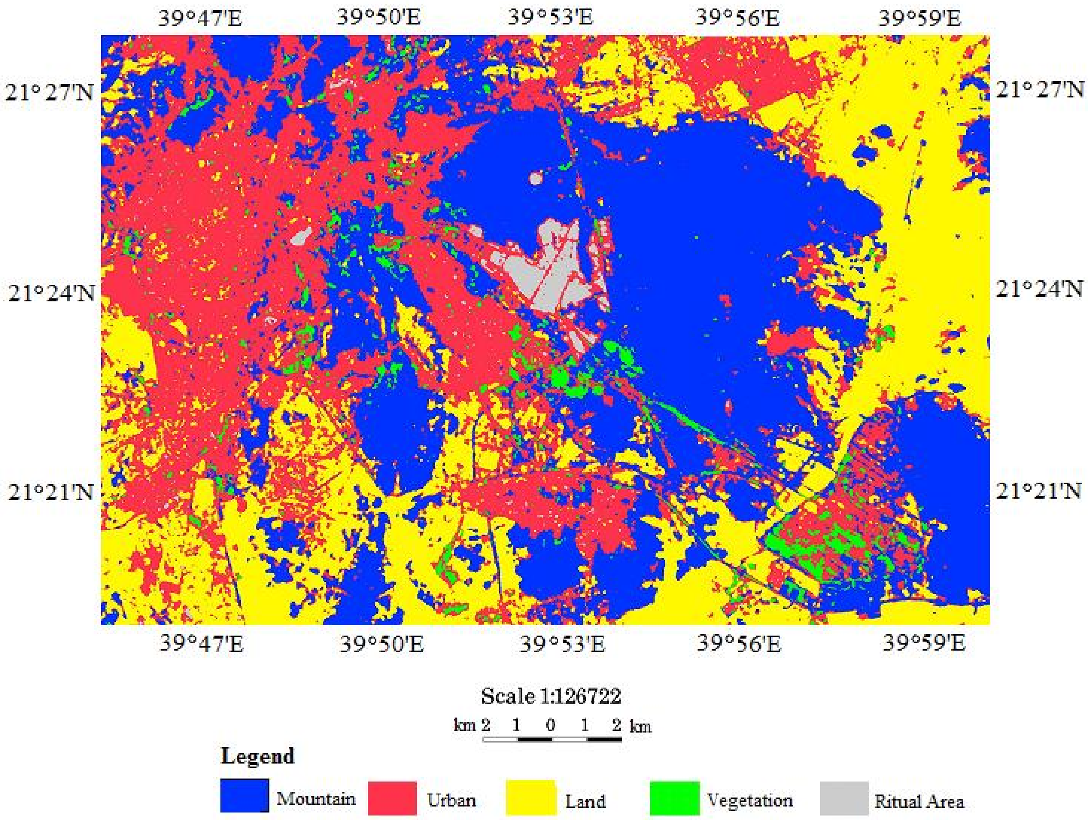

Figure 3. Classified land cover map over Makkah using frequency-based contextual classification.

IV. Frequency-based Contextual Classifier

The frequency-based contextual (FBC) classifier performs classification of multi spectral imagery using a grey level reduced image and a set of training site bitmaps. The FBC performs the second of two steps in FBC classification of multi spectral imagery. It inputs a grey level vector reduction image (must be 8-bit layer) and a set of training site bitmap layers, and creates a classification image under the specified output window. Each input bitmap can be assigned a unique output class value for the classification image. The contextual classifier uses a pixel window of specified size around each pixel [8].

We do not intend to elaborate the detail explanation about the classifier in this paper. However, a brief explanation will be included. Detail explanations of the classifier can be found in [9]. The success of the contextual approach in land cover classification depends largely on the appropriate pixel window size being selected for the classification process. If the window size is too small, sufficient information cannot be extracted to a frequency table to characterize a land use type. If window size is too large, much spatial information from other land use type could be included [9].

V. Results And Discussions

The total area for this study was approximately 433 km^2. The digital image was classified into 5 classes, namely *Mountain, Urban, Land, Vegetation* and *Ritual area*. The largest is *Mountain* with the total area of 160.6 km^2 representing 37.1% of the entire image whereas the smallest class is *Vegetation*. It only covered 3.4 km^2 which is less than 1% of the entire area. The other classes resulted 138.9 km^2 (32.1%), 117.2 km^2 (27.0%) and 13.0 km^2 (3.0%) for *Urban, Land* and *Ritual area* classes respectively. *Ritual area* comprises a grand mosque (Masjidil-Haram) in Makkah and a group of tents in Mina. The full result of the classification is shown in Table I.

The classified image using FBC classification technique is shown in Fig 3. Table II shows the result of error matrix. The table also shows the result of overall accuracy, Kappa coefficient, producer and user accuracies. FBC classifier produced high degree of accuracy and Kappa coefficient with 82.3% and 0.739 respectively. The use of spatial information is able to improve the classification accuracy and reduce the speckle problem in the image. User accuracy and producer accuracy were used in order to analyses each classes. For user accuracy, *Mountain* obtained 90.2%, 66.7% for *Ritual area*, 100% for *Vegetation*, 83.1% for *Land* and 74.5% for *Urban*. On the other hand, the accuracy for each class for producer accuracy was as followed: 85.9% for

Mountain, 100% for *Ritual area*, 66.7% for *Vegetation*, 76.6% for *Land* and 82.4 for *Urban*. User accuracy reached the highest value of 100% for *Vegetation*. Lowest value was obtained for the *Ritual area* with 66.7%. The result was expected because *Vegetation* is very easy to classify due to their spectrally different from other classes. On the other hand, pixels confusion among the *Ritual area* and *Urban* was identified as a main problem caused the lowest percentage of the *Ritual area* class. The pixels confusion occurred especially in the border section of these two classes. The class specific for producer accuracy varied between 66.7% for *Vegetation* and 100% for *Ritual area* class. Producer accuracy gives the analyst an estimate of how successful the classification procedure is in the different classes. User accuracy gives the user an estimate of how reliable the thematic map is as a predictive device in the different classes [10].

The detail explanation of the each class can be explained by analyzing the error matrix table. The matrix shows that 110 out of 122 observations for the *Mountain* class had been correctly classified. Only 12 points had been classified wrongly which is 9 points were misclassified as *Urban* and 3 points as *Land*. Overall, *Mountain* is the most tested pixels as it represented the largest area in the map. For the *Land* category, it is shows that out of 71 pixels that had been tested, 59 pixels were correctly classified and 8 pixels were misclassified as *Mountain* and 4 pixels as *Urban*. The same pattern was obtained for *Urban* class where most of the misclassified pixel is caused by the misclassification of the *Mountain* and *Land* classes. But a total of 70 out of 94 observations had been correctly classified. Hence, we can conclude that these three classes have their own relationship between each other if we analyze based on the pattern of the misclassified pixel that we have. The result is acceptable because the selected area is located in the desert terrain. So the possibility of spectral confusion to be occurred among each category from these three classes is high. For instance, the mountainous area in the desert is filled by rocks and stones. Unlike in the equator region, most of their mountainous area is covered by jungle and others green area. So the surfaces of the mountain, land and urban area in the desert terrain looks like same color and tend to have similar spectral characteristic. This is the reason why the misclassified pixels always happen between these three classes. In the meantime, *Vegetation* and *Ritual area* make a small part of the image (approximately 4% of the entire image) and is not hard to classify both classes. All tested pixel had been correctly classified for *Vegetation* and only 2 points were misclassified as *Urban* for *Ritual are*a class.

In term of window size of the FBC, 9 x 9 pixel window was used in order to perform the classification. Selection of the suitable window size is not easy to determine. It is depending on the complexity and resolution of the images. If the image is too complex, the larger window size is better to use. But if the image is simple (smooth images), it is enough to use the smaller window size. However, an appropriate window size is determined empirically and 9 x 9 pixel window size was chosen as the best window for the classification for this study. One of the advantages using the contextual classifier is the consideration of the spatial information during the classification process instead of depending on spectral information alone. The integration of the spatial component can reduce noise problem in the image. From the viewpoint of land cover assessment perspective, usually the existing of noise is happen in the mixed area. In our case, these refer to the *Urban* area. Urban areas are characterized by a large variety of built up environments and natural vegetation cover which not only determine the surface features of a city, such as land use patters, but also influence ecological, climatic and energetic conditions of land surface processes [11]. There are a lot of information could be extracted in the urban area so that the possibility of the mixed pixels to be occurred is high. Hence, the increasing of the mixed pixels may lead to the increasing of the noise problem in the image. So by using the contextual classifier this problem can be solved due to their ability to handle the large number of mixed pixels problem and reduced the speckle errors significantly. Although widely used, conventional statistical classification techniques may not always be appropriate for mapping from remotely sensed data. For examples, the requirements and assumptions of the maximum likelihood classification, one of the most widely used techniques, are often unsatisfied. The statistical maximum likelihood classifier cannot handle the complex images so that many pixels cannot be classified correctly [12].

VI. CONCLUSION

This paper highlights the determination of the land cover types in Makkah province. There are 5 classes could be classified clearly within the study area which are *Mountain, Urban, Land, Vegetation* and *Ritual area*. In this study, the proposed classification technique of a frequency-based contextual classifier in order to classify land cover from ALOS AVNIR-2 satellite image data has been successfully presented. The classified map shows the potentiality of Frequency-based Contextual classifier for producing high degree of overall accuracy and Kappa coefficient with the value of 82.3% and 0.739 respectively. This classified map could be used for future development especially in township planning.

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TABLE I. RESULT OF THE TOTAL AREA FOR EACH CLASS

Class	Total Area (km^2)	Percentage of the Entire Image (%)
Mountain	160.6	37.1
Urban	138.9	32.1
Land	117.2	27.0
Ritual Area	13.0	3.0
Vegetation	3.4	0.8
Total	433.1	100.0

TABLE II. ERROR MATRIX TABLE DERIVED FROM FREQUENCY-BASED CONTEXTUAL CLASSIFIER (WINDOW SIZE: 9 X 9)

Classified Data	Reference Data						
	Frequency-based Contextual Classification						
	Mountain	*Ritual Area*	*Vegetation*	*Land*	*Urban*	*Total*	*User Accuracy (%)*
Mountain	110	0	0	3	9	122	90.2
Ritual Area	0	4	0	0	2	6	66.7
Vegetation	0	0	4	0	0	4	100.0
Land	8	0	0	59	4	71	83.1
Urban	9	0	2	13	70	94	74.5
Total	127	4	6	75	85	297	-
Producer Accuracy (%)	85.9	100.0	66.7	76.6	82.4	-	-
Overall Accuracy (%) = 82.3							
Kappa Coefficient = 0.739							

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