The Evaluation of the Usage of the Fuzzy Algorithms in Increasing the Accuracy of the Extracted Land Use Maps

Abstract:

This study aimed to evaluate the accuracy of object-oriented classification with and without the use of fuzzy algorithms, compared with pixel based algorithm in land use/ land cover classification. In order to compare different methods, AVNIR2 sensor images obtained from ALOS satellite were used to classify land use in Maragheh County. The results indicated that object-oriented classification approach produced more accurate results than pixel-based, So that the fuzzy knowledge based method yielded the highest overall accuracy of 93.28 percent as compared to the object-oriented method without the use of the fuzzy algorithms (88.06 percent accuracy) and pixel based algorithm with 83.79 percent accuracy. Based on the results of this research, it is recommended that the researchers use higher spatial resolution images with the proper algorithms in the extraction of features of land use classes.

Keywords: remote sensing, object-oriented classification methods, pixel base, fuzzy algorithms, land use map

1. Introduction

Essentially, the Earth has a dynamic nature, and is always changing and evolving. Accordingly and in line with planning and sustainable development of the natural and environmental resources, identification of a land and the optimal utilization of the resources have always been important (Safianian et al. 2011). One of the main preconditions for efficient use of land is being aware of the land use patterns and their changes over time (Assefa 2010). Today, satellite images and remote sensing techniques, by providing the up-to-date data and high availability of analysis are widely used in all sectors, including agriculture, natural resources, and land use mapping, as maps are used in spatial planning (Feizi Zadeh et al. 2008). In order to extract land use information from digital satellite images, different methods have been presented, of which each has its own advantages and disadvantages. In this regard, object-oriented techniques, by benefitting from the knowledge base algorithms have overcome the shortcomings of the pixel base in not using the geometric and textural data of objects (Blaschke 2010; Draguţ et al. 2012). The development of these knowledge base methods took place in the late 1970s until 1980, by the application in the industrial processing programs, and in the Markov random algorithms or unsupervised classification of tissues (Jain et al. 1991; Mao et al. 1992; Pal et al. 1993; Chaudhuri et al. 1995; Panjawani et al. 1995). However, recently the algorithms have been spread in the environmental programs (Dubuisson et al. 2000). Pixel based methods automatically attribute all the pixels of the image to the cover of the surface of the Erath (Van et al, 2006: 312). Therefore, the ability of the classic methods of the classification of satellite images is limited, when different objects have the same spectral information (Feizi Zadeh et al. 2015). In the contrary, in the object-oriented classification methods, the quality of segmentation, and determination of the scales of the segments have a direct relationship with the spatial resolution of the satellite images, and by increasing the spatial resolution of the images, high-quality segments can be produced, and the accuracy of classification increases significantly.

In the object oriented classification, given that the method uses information about the shape, texture, and the spectral information of the image, in the first stage, classification is done step by step, according to the definition of neighborly relations. Then in the next stage, due to the scale and spatial resolution of the image, topologic and segmenting relationships are connected between objects, and visual objects are classified. One of the main advantages of this method is the use of the segments as visual objects.Using this method, the image uniformity can be achieved (Oruc et al. 2004). Object-oriented techniques provide the use of fuzzy algorithms that calculate the membership degree of each of the parameters to be classified, and by determining the membership degree, the more effective parameters are used. In this method, by using a variety of fuzzy methods to calculate the membership degree (including Sigmund, J-shaped, linear), the possibility to calculate the membership degree and to identify influential parameters for the classification are provided (Blaschke et al. 2010; Mao et al. 1992; Pal et al. 1993; Panjawani et al. 1995; Hofmann et al. 1998; Martha et al. 2010).

In this study, performance of pixel-based and object-oriented classification with and without the use of fuzzy algorithms approaches have been tested using ALOS satellite imagery to classification land use in Maragheh County.

2. Presentation of the study and the data used

Maragheh County with an area of 2135.79 square kilometers is located in the southwest of the Eastern Azerbaijan Province (Figure 1). Agricultural applications, particularly "garden products" are the most important economic activities of the County. More than 36 percent (about 255,000 hectares) of the city's land area is agricultural and horticultural. Due to the perfect Topo-Climatic features, the county is one of the poles of horticultural products, and each year approximately 150 thousand tons of horticultural crops are produced in this county (Department of Agriculture of Maragheh County, 2013). In this study, in order to assess the mapping accuracy, AVNIR 2 sensor images of the ALOS satellite were used. The images were extracted with a spatial resolution of 10 m in four bands on 5 July 2010. ALOS satellite images in the object-oriented and pixel based were collected together with the digital model data of the elevation of the area, and were processed carefully by the sensor of SRTM with the spatial resolution of 30m. In addition, data of *Garmin GPS model* for training sample, ground control points, and analytic functions of the Software ArcGIS 10.2.2, ENVI 5.1, as well as eCognition9 Software for object-oriented classification were used.

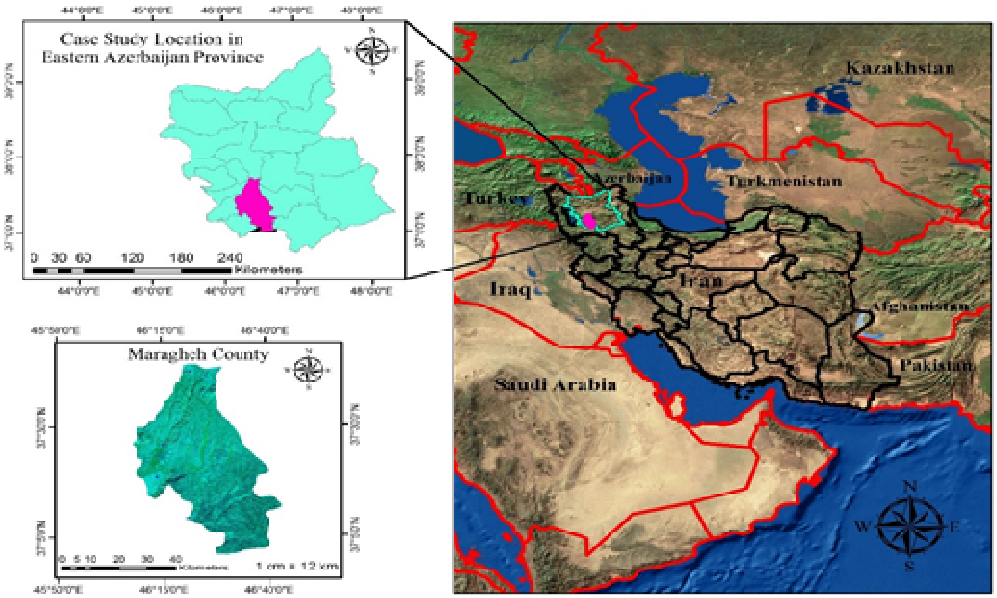


Figure 1. Geographical location of the studied area

3. Methodology

Combining the object-oriented processing methods of satellite images and fuzzy methods

The theory of fuzzy sets was introduced for the first time in 1962 (Klir & Bo, 1996). This theory has since received a lot of development and expansion, and has found various uses in various fields. Briefly, the theory of fuzzy sets is a hypothesis to act in conditions of uncertainty. This theory is capable of explaining many vague concepts, variables, and systems by presenting mathematical equations, and provides the grounds for argument, conclusion, control, and decision-making in the uncertain situations (Ranjbar 2004). In the conventional monitoring of the traditional classification of remote sensing, the training points and the classified results are based on *one* pixel of *one* class (a pixel can only belong to one class). In fact, in the classical methods of classification, borders of training areas change suddenly, and not gradually. The obvious limitations reduce the classification accuracy. The theory of fuzzy sets is used in order to eliminate uncertainty in the data. It is a new concept, which partial membership allows the information to be better displayed in more complex situations, such as mixed coverage or intermediate situations. In this theory, the membership degree can be considered a value between 0 and 1 (Safianian et al. 2011). The use of fuzzy logic in the classification of remote sensing data, is expanding significantly because of its unique abilities. These methods are used to display the cover mixtures. Fuzzy classification methods are among the methods, which can give results that agree with realities better. In this method, different values as the membership degree of each class are calculated based on the different covers. Object-oriented processing methods of the satellite images as a new approach in remote sensing provide the use of the fuzzy capabilities in image classification. In this regard, object-oriented classification is defined as a process that relates the land cover classes to the visual objects (Blaschke 2009; Feizi Zadeh et al. 2009; Yan 2003). In object-oriented techniques, the use of fuzzy theory facilities provides a membership degree in classification. The integration of object-oriented and fuzzy methods provides the classification of visual objects with a certain membership degree. In this process, the visual objects with different membership degree are classified in more than one class, and based on the membership degree of each class, the visual object is classified, which increases the accuracy of the final classification.

Object-oriented classification based on the fuzzy logic in accordance with the conditions that the interpreter determines for each class, This condition is defined by the expressed function for the class, which can be as a member function, and class simulations or the closest neighbors. In the fuzzy classification, by determining the characteristics of spectral data and geometric characteristics of the land use classes during image processing, the operations of fuzzy logic can be used including Max, and Or operators with the maximum returning value by the fuzzy value, arithmetic mean of the fuzzy value, geometric mean of the fuzzy value, and returning operator, as a result of the fuzzy value. The operators can be used for defining the conditions for the classification (Feizi Zadeh et al. 2009).

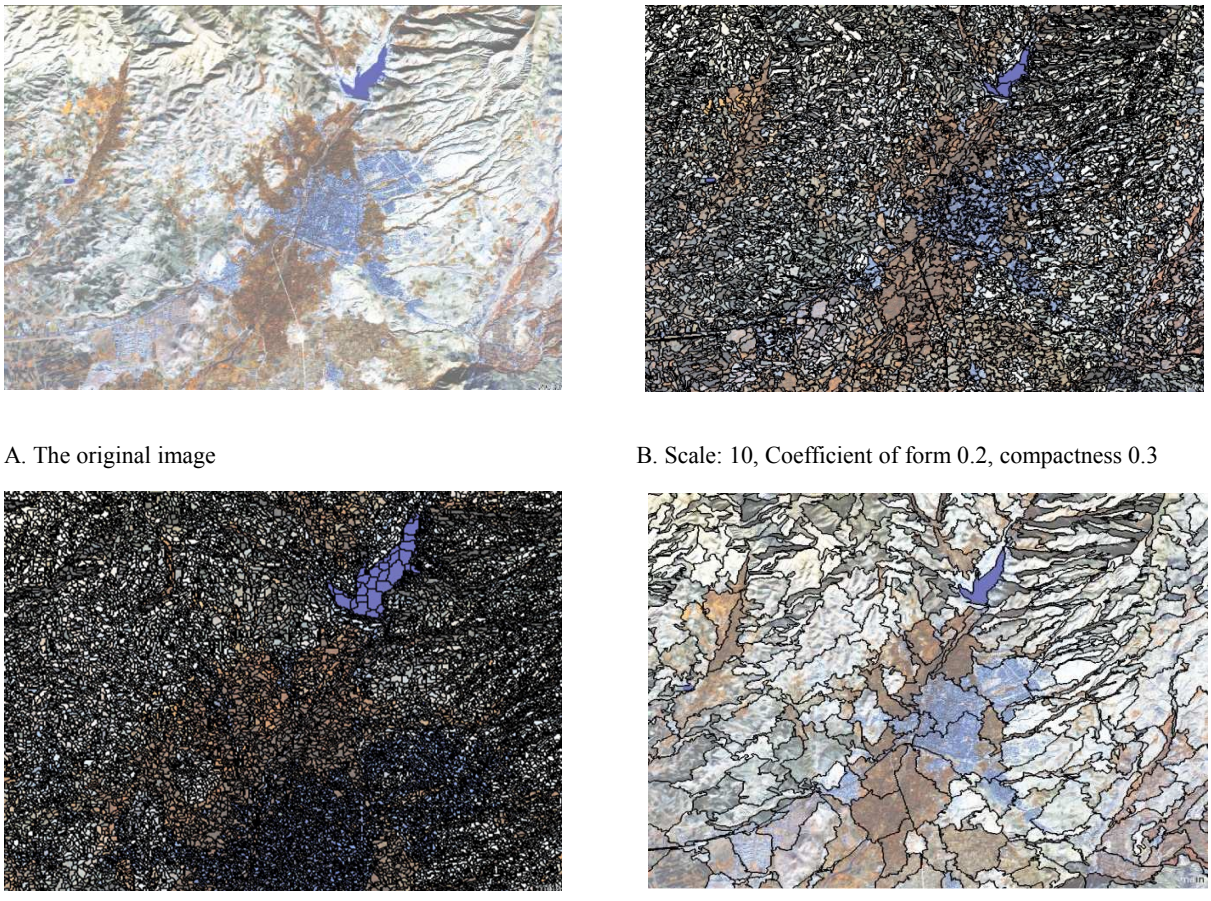
Stages of implementation of the models:

Segmentation of images in the object-oriented classification:

Segment means a group of neighboring pixels within a region that the similarity (such as values and texture, etc.) is the most common criterion of them (Feizi Zadeh et al. 2008). Re write sentence The visual objects resulting from the segmentation process are based on object-oriented classification, and they have many specifications and properties of their terrestrial phenomena corresponding to the picture. The more accurate the process is,the better the quality of object-oriented classification (Baatz et al. 2000; Chaudhuri et al. 1995; Feizi Zadeh et al. 2009). The segmentation process took place based on the scale, color, and shape, or their composition with compactness or filters (Dragut et al. 2012).

The influential parameters in segmentation are the determination of an appropriate scale that indirectly admits the size of objects, color or shape coefficient, which depends on the uniformity of the color and shape of objects – the more amount is selected, the greater is the range and more objects are selected – and softness or compactness coefficient of the textile that is determined by the geometric characteristics of the land (Oruc 2004). In this study, in the segmentation process, the data of different classes of land use characteristics (shape, size, texture, etc.) were used. This process was performed using Image Object, and to this, by the analysis of the segmentation results of the image were selected with different scale parameter, spatial resolution of the scale image 3, coefficient

of form 0.2, and compactness coefficient 0.5. It should be noted that in the segmentation process, if the coefficient of form is selected more than 0, the user could choose a proper coefficient of form and softness according to the context and the type of coverage. As a result, the classification will be effective (Figure 2).



A. The original image

B. Scale: 10, Coefficient of form 0.2, compactness 0.3

C. Scale: 3, Coefficient of form 0.2, compactness 0.5

D. Scale: 50, Coefficient of form 0.3, compactness 0.2

Figure 2. Display of the original image and segmentation in scale, coefficient of form, and various compactness (source: authors).

Definition of the class and the determination of the parameters affecting the classification of each class

The definition of class is the first step in the pixel base classification. For this purpose, land use classes within Maragheh County have been identified in (Table 1). In determining land use classes, taking into account the spatial resolution of the satellite images, as well as the type of land use classes in the area, an integration of levels 2 and 3 of Michigan Classification System (Anderson et al. 1976) has been considered. Object-oriented classification in the environment of *eCognation Software* is according to the conditions, which the interpreter determines to the class. These conditions are defined by the expressed function for the class, which can be as a member function, class simulation or the nearest neighbor. As it was mentioned in the previous section, one of the important features of the *eCognation Software* is that before classification, the effect of influential parameters can be defined in separating each class. In this study, in the definition of class in object-oriented method without the use of fuzzy algorithm, the effective parameters in the classification (spectral and geometric characteristics) were used (Table 1). Moreover, in object-oriented method based on fuzzy algorithm, in addition to these parameters, the membership functions of each class were used (Figure 3). In this way, in addition to checking the classification parameters, by examining the membership degree, the method tries to choose the most appropriate parameters to increase the accuracy of classification. Figure 4 indicates the membership degree of effective parameters for the classification of each class. In this stage, the influence of various

parameters is determined in all classes, and the classification of each class will be based on the parameters that have had the highest membership degree in the class. This stage has a great influence on the increasing of the classification accuracy.

Table 1. Evaluating of the effective parameters on the classification of each class for the object-oriented classification (source: authors)

General index	**The effective parameters**	**Coverage**							
		Garden	Harvested	Urban Area	Rang 1,2,3	Arid	Agriculture	Fallow Land	Water Surface
Standard deviation	Std-Blue								*
	Std-Green	*							*
	Std-Red	*	*						
	Std-NIR	*							*
Mean	Mean-blue	*			*	*			*
	Mean-Green	*			*	*			*
	Mean-red				*	*			*
	Mean-NIR	*					*		*
	Brightness	*							*
Geometric	Max-diff			*			*	*	
	BorderLenght								
	Length				*			*	
	Length-width								*
	Length Thickness								
	Thickness								
	Area								
	Shape,Elliptic fit				*		*		
	Density		*	*	*				
	Index					*		*	
	Compactness		*			*			
	Roundness					*			
	Border index		*						

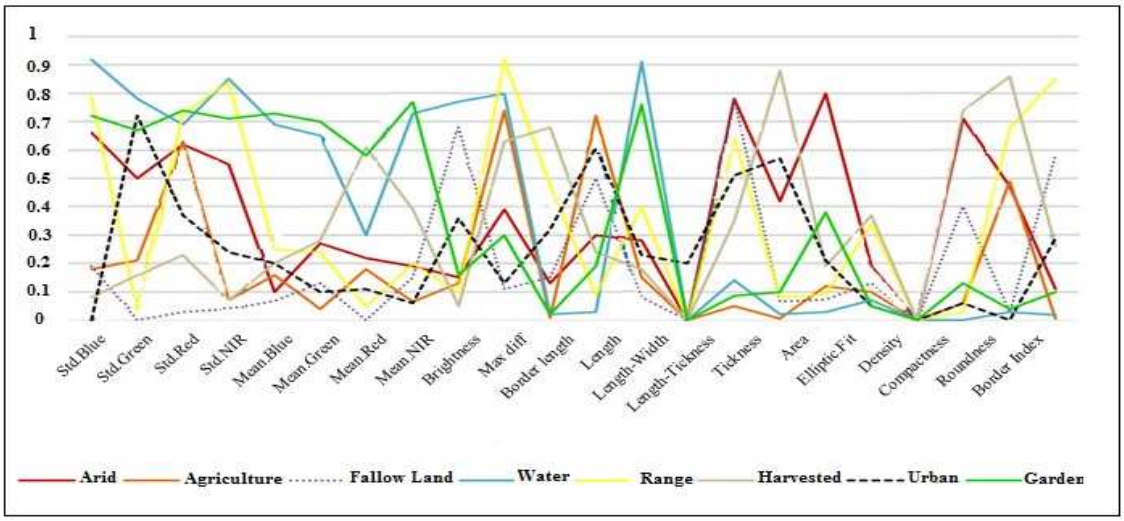


Figure 3**. Membership degree of the effective algorithms in classification of each class**

Object of the training examples

Classification requires training samples. In the pixel base classification, after determining the number of the classes, based on the spatial extension of each class over the study area, by using of the GPS, training samples were collected for the classification. Table 2 shows the number of the collected training samples for each user class.

Table 2**. Land use classes and the number of collected samples with GPS for each class based on the pixel base classification**

Land Use	Cover Type	Number of Training Samples
Agriculture	Agriculture	100
	Harvested	100
	Follow Land	100
	Garden	100
Range	First-hand Range	50
	Second-hand Range	60
	Third-hand Range	80
Water	Water Surface	40
City	Urban Areas	50
Arid Lands	Arid Lands	60

In *eCognation Software*, the range of the training samples is determined by sample visual objects. Compared with the classification algorithms of the pixel base method, the classification with the nearest neighbor algorithms in object-oriented method requires less training samples (Feizi Zadeh 2007). In the object-oriented image analysis, educational objects form the training samples for each class. In this study, training samples were collected by using the GPS during a field study. Then, the *eCognation Software* was used on the surface of the image.

Classification of the Images

In the pixel base processing method, a pixel is considered as the main unit, and the numerical

values of images shape the base of classification. This classification is done based on the monitored/ non-monitored statistical methods, in which a pixel only belongs to one class. The view is based on the classical theory of binary. With this theory, a pixel is classified in one or any of the classes, and remains unclassified. According to the theory of binary, pixels in the range of overlapping complications are classified in only one class, while the pixels are correlated with other classes, and the correlation is an important factor in reducing the accuracy of the pixel base classification (Feizi Zadeh & Helali 2009; Collingwood 2009; Zhaocong et al. 2009). In this method, after performing the geometric and atmospheric corrections on the satellite images, the classes were determined, and based on the training samples, the classification was done. In object-oriented classification, in order to reduce the class interference and increasing the classification accuracy, in addition to spectral data and visual textures such as shape, color, tone, etc., other influential parameters were used including length to width ratio to separate the linear phenomenon, form factor as an effective factor in the separation of fallow agricultural lands from the barren land too long class, etc. In object-oriented classification based on fuzzy algorithm, in addition to the features of membership degree, each of the parameters was measured in different fuzzy algorithms, and parameters that had the highest degree of membership in each class were taken into account for their effectiveness. A total of 22 effective variables were selected in the classification, and in each class, the membership degree of the parameters was tested on 20 samples (object), and finally by averaging, the parameters that had the highest membership degree were entered into the classification. Finally, the classes of applications in the area were identified and defined by performing field operations in 10 landuse and groups. After defining land and cover use, to provide training areas by the use of the recorded points of GPS during field visits on a false color image, the objects that were intended to represent real use or cover were selected as training areas. Too long sentence and meaningless. The objects were selected in to include only a particular user. Finally, after the above steps, the classification was done based on the nearest neighbor algorithm. The following figure schematically shows the algorithm of the research implementation(Figure 4).

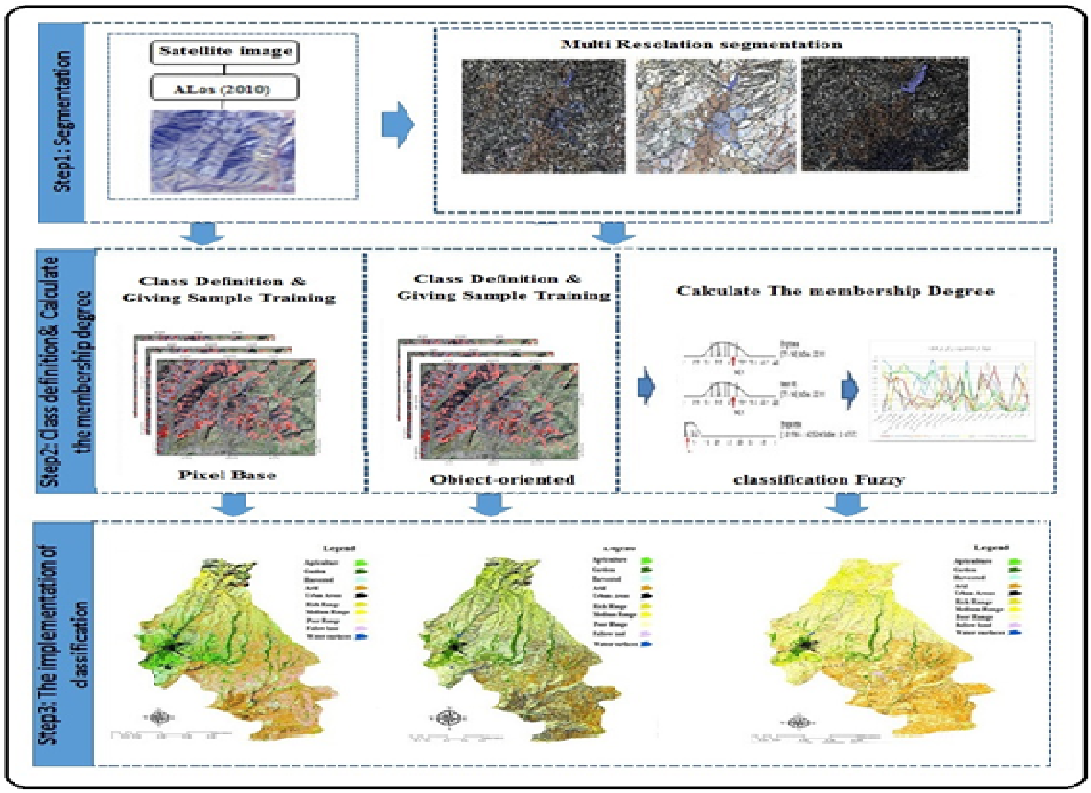


Figure 4. Kharazmic (Schematic) Steps of Classification

Evaluation of the classification accuracy

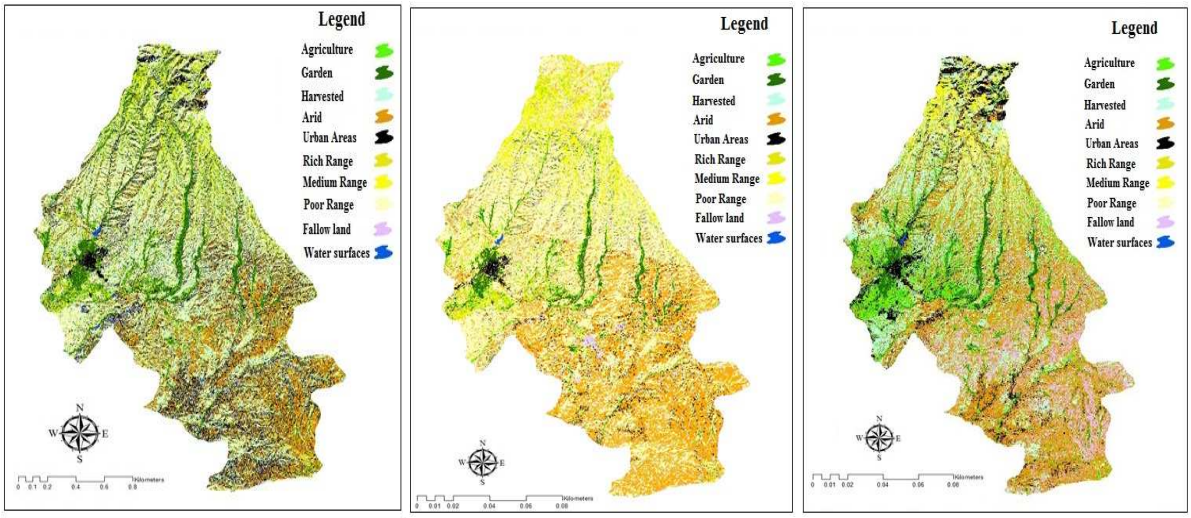
The necessity of using any type of subject information is the awareness of its accuracy. In this study, to determine the stability of the classification, the *Stability Algorithm* was used. That is, the classification process is applied to different objects, which are located in the same primary class.

4. Summary and conclusions

In this study, three methods of classification including object-oriented algorithms of the satellite images classification without the use of fuzzy algorithms, algorithm based on fuzzy algorithms, and pixel based algorithms were compared in land use classification using the AVNIR2 image sensor obtained from ALOS satellite. To compare the actual results, in all three methods, the same training data was used for the classification. Then, the most important evaluating methods, including the overall accuracy and *Kappa* Coefficient of classification were extracted and determined. The classification method based on the fuzzy algorithm compared to the pixel based classification method and the knowledge base classification method without the use of fuzzy algorithm had the maximum, 9, and 7 percent (in both overall accuracy and kappa coefficient classification), respectively, which indicated a greater accuracy in the image classification (Table 3, Figure 5). The value of the increased accuracy of object-oriented classification method based on the fuzzy algorithm is greatly depended on the selection of the appropriate parameters for classification, and the use of the appropriate algorithms to obtain the membership degree.

Table 3. Evaluation of the accuracy of object-oriented classification methods based on the fuzzy algorithm, and of object-oriented classification

Class Type	Object-Oriented Classification Method Based on the Fuzzy Algorithm		Object-Oriented Classification Method		Pixel Base Classification Method	
	Producer	User	Producer	User	Producer	User
Garden	1	1	1	1	0.92	0.69
Agriculture	0.46	0.49	0.77	1	0.55	0.30
Follow Land	1	1	1	0.87	0.57	0.21
Water Surface	1	1	0.46	1	0.54	0.60
First-hand Range	1	1	0.71	0.55	0.58	0.94
Second-hand Range	1	1	0.2	0.5	0.92	0.98
Third-hand Range	1	0.78	1	0.75	0.23	0.21
Urban Areas	0.46	1	0.92	0.76	0.99	0.98
Arid Lands	0.76	0.74	0.71	0.83	0.31	0.33
Harvested Lands	1	1	0.46	0.80	0.15	0.36
Overall Accuracy of Classification	0.93		88.06		83.79	
Kappa Coefficient of Classification	0.92		0.84		0.81	



(1) (2) (3)

Figure 5. Results Of Classification: (1) Object-Oriented, (2) Object-Oriented By Fuzzy Algorithm, (3) Pixel Base

5. Recommendation

In line with the survey results, of the future researches should be based on the use of algorithms and other fuzzy operators in the object-oriented environment, in order to achieve a higher accuracy in the classification of images. Based on the results of this research, it is recommended that the researchers use higher spatial resolution images with the proper algorithms in the extraction of features of land use classes. The results of the study will be applicable for the executive agencies (such as the Ministry of Agricultural, Department of Natural Resources, Regional Water and Power Department, etc.) for planning and management of water and land resources.

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