FOREST TYPES CLASSIFICATION USING ETM+ DATA IN THE NORTH OF IRAN/ COMPARISON OF OBJECT-ORIENTED WITH PIXEL-BASED CLASSIFICATION TECHNIQUES

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ABSTRACT:

Different classification methods have been used for classification of satellite data by researchers. Addition to current classification, pixel-based methods, developments in segmentation and object oriented techniques offer the suitable analyses to classify satellite data. To compare the pixel-based with object-oriented classification approaches to extract forest types, a case study in a small area have been accomplished in the northern forests of Iran. The ETM+ data and some processed bands, which extracted by suitable processing analyses, were used due to high spectral resolution. Pre-processing of data was done for geometric correction of images and corresponding to ground truth map. The best suitable data sets have been chosen by seperability indexes. In the pixel-based classification approach, the maximum likelihood classifier classified images of data set. In the object-oriented approach, images were segmented to homogenous area as forest types by suitable parameters in some level. Classification of segments was done trough three classification methods of nearest neighbor, membership function and combination of both methods. A sample ground truth map of forest type did the accuracy assessment of the results. It was generated trough sampling method by 193 plots of one hectare. The accuracy assessment of the results showed that the object-oriented classification approach could improve considerably the results in compare to pixel based classification approach (19%). However, increasing of kappa coefficient from 25.5 % in the pixel based classification to 44.4 % in the object-oriented approach shows capability of multiresolution segmentation of data, which provide other useful attributes for classification in addition to spectral information (or overall accuracy from 44 % to 61%). The results of study indicate that integration of nearest neighbor with membership function technique can improve the results more than the both techniques individually. More researches to survey on these classification techniques will be necessary in future.

1. INTRUDUCTION

Forest types mapping trough current fielding ways, is time consuming and cost-intensive. Using satellite Imagery and its potentials are new tools in order to managing and mapping forest-covered area. Since, different classification methods and Satellite imagery have been used. Beside these, introducing a suitable data and method of classification are the main interesting for researchers.

During the last decades, researchers have mainly focused on the *pixel-based* classification in different applications. The pixel-*based* classification is a current method because satellite data sets are acquired digitally on the basis of pixel units. In the pixel-based classification method, Image Statistics is a base that pixel-based classification and pattern recognition are established on it. Current pixel based classifiers such as maximum likelihood; minimum distance and parallel-epiped were designed on this base. Since these approaches are based exclusively on the digital number of pixels and are used only spectral information, the results look like slat-peppery images.

In order to overcome these problems and to produce more homogenous pattern for classification, the researchers have also experienced per-parcel or per-field classification methods (Haralick et. al, 1973, Jensen, 1993, alpine et al., 1999). In a per-field analysis or 'pixel in polygon' analysis, pixel information is linked to a spatial database and boundary maps. Field or parcel refers to homogenous patches of land (agricultural fields, gardens, urban structures or roads) which already exist and are superimposed on the image.

On the other hand, the *eCognition* software was designed based on the object-oriented classification, including new classifiers and techniques by providing the new possibilities for multiresoultion segmentation of the images and the object-oriented fuzzy-rule classification. With these facilities, it was successfully applied in several different applications (Gorte, 1998; Baatz and Schape, 1999; Blascke et. al., 2000). The object-oriented classification has been used in some studies related to forestry. Application of these methods, following with a comparison of their results with pixel-based classification was examined in some case studies [Willhauck, 2000, De koke et. al., 1999]. They applied these methods on different data set and could get better results in compare to the pixel-based classification approaches. Schwarz and et. al (2001) applied the pixel based and the object oriented classification methods on SPOT and IKONOS data to recognize forest damage areas by storm. The results showed that extraction of the damaged area on IKONOS data by the object-oriented method could be done better in compare to the pixel-based method.

In the mixed forest like which forest exist in the north of Iran, grouping the similar specious of trees as stands or forest types is difficult and is generally determined by dominant species and percent of their existences in an area. Therefore, In the satellite data, reflectance of stands is referred to various trees together with open cover area. At the result, delineating of homogeneous area as stands or forest types is difficult and normally with error. Then, forest type classification by using of traditional pixel based methods often leads to noisy results, which refer to existent of heterogeneous pixels in a homogenous area.

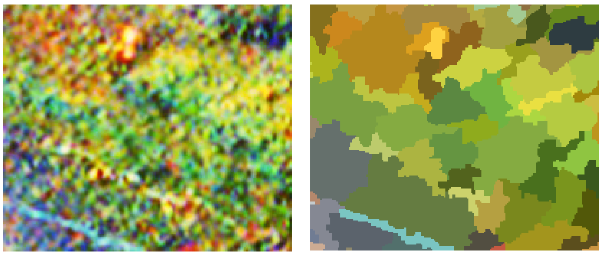
Segmentation of image and extraction of the homogeneous areas as forest types can be develop the classification results.
Hence, the main aim of this study was to compare of the pixel-based classification method with object oriented classification techniques on ETM+ data for forest type Mapping in mixed hardwood forests in the north of Iran. Among the object-oriented techniques, recognition of which method can accurately extract forest types on ETM+ data was another aim in this study.
Beside these, in the some studies it was resulted that adding artificial processed Bands facilitate improving the result classification. The Ratio transforms are often used in image processing to reduce radiometric effects of slope, sunlight angles or seasonal variability (Eva Ivits & Barbara Koch, 2001). The first three components contain more information contrary to each band individually. The brightness and greenness axes of the Tasseled Cap calculation can be useful in topographic variation and to differentiate between closed forest canopy conditions (Cohen and Spies, 1992). Then, in the study it was also investigated that these bands can be improve the results in the both classification methods.

2 Object oriented method

In general, the object-oriented approach and the image analysis process can be divided into the two principal workflow steps, *segmentation* and *classification*.

2.1 Segmentation

In a principal definition, "objects" or "local pixel group" information is basis for the object oriented classification approaches. Segmentation principally means the grouping of picture elements by certain criteria of homogeneity (Hildebrandt, 1996). In the object-oriented approach, an image is subdivided into *homogenous* objects by segmentation analysis. Therefore image will be heterogeneous and contrast of objects will increase (see figure 1).
Segmentation can be done in multiple resolutions in different levels of objects by criteria such as scale, color and form.



1A **1B**

Figure 1: small windows of study area 453 (RGB) before segmentation (1A) and after segmentation (1B) show contrast of objects in a forest area.

2.2 object oriented classification techniques

The meaningful primitive objects, which obtained by segmentation, can be classified through two methods: Sample-based classification by nearest neighbor classifier and
Rule-based classification by membership function technique.
The experiences were showed that when several different feature order objects into classes, the nearest neighbor method should be used and when only few discrete features can separate classes from each other, use of membership function is an optimal choice (Ivits. E. & Koch. B. 2000).

The nearest neighbor classifier, as a supervised classification method needs training area in a multidimensional feature space. It would be useful when user has no knowledge to describe feature spaces. In the nearest neighbor method or the sample-based method, the primitive objects are classified through similarity to training units or segments for each class. The rest of objects in the image are belonged to their nearest sample in each class. It usually uses spectral information of bands as feature space for description of classes that are to be classified.
After segmentation, in addition to spectral attributes, the objects will have extra information such as shape, texture, context attributes and topological relations between neighborhoods and other objects. This information can be used for exact extraction of each class in classification.
In the ***Membership Function*** (Rule-based) Method, segments are classified by membership functions, which are based on fuzzy sets of object features. Fuzzy logic is a mathematical approach to quantify uncertain statements (willhauck, 2000). To be aware of relevant information which can correctly classify classes play important role in this method as a knowledge-based system. In this method, the interpreters can define thresholds to be belonging objects to each class by suitable attribute trough fuzzy sets.

3. METHODOLOGY

3.1 Study area

The study area is located at educational and research forest, Faculty of Natural Resources of Tehran University in the north of Iran between 51°33'12"E and 51°39'56" E longitude and 36°32'08" N and 36°36'45 5" N latitude. The whole forest has been subdivided to seven Districts. The study has been performed on three districts (Patom, Namkhaneh and Gorazbon respectively), are about 3000 hectares (see figure 2). Altitude ranges from 50 m to 1350 m (sea level). Because of different aspects and range of altitude, a Variety of forest types have been established.

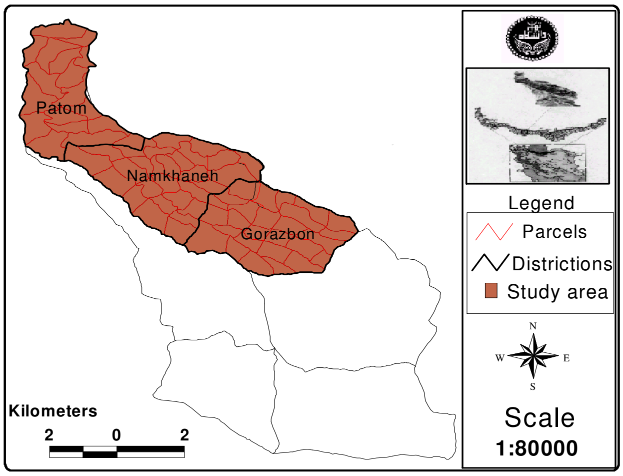


Figure 2: location of study area in the research forest of Tehran University (Kheyrodkenar) in the north of Iran.

3.2 Data

In order to investigate ETM+ data potential for forest types mapping, a small window on 164-35 Scene from 2nd August 2000 was selected. Except for thermal bands, all multi-spectral and panchromatic data were used for this study.
In addition, some ancillary data extracted DEM such as aspect and elevation maps were resized to spatial resolution of satellite

data. These data were imported as thematic layers in further classification process.

3.3 Ground Truth

For accuracy assessment of classification results and comparison of the pixel-based and the object oriented classification methods, a sample ground truth map of forest type was used. It had already been generated for another project in this study area through a systematic sampling network. It contained 193 plots that each plot was 1 hectare in size. In addition to plantation area, six types was recognized by dominant species frequency of 100 thick trees:

Forest Types	Frequency percent of species
Pure Fagus (beech)	>90 % Fagus Orientalis
Mixed Fagus	50-90 % Fagus Orientalis
Pure Carpinus ()	>90% Carpinus Betelus
Mixed Carpinus	50-90 % Carpinus Betelus
Mixed Alnus (alder)	>90 % Alnus Glutinosa
Mixed Hardwood	Other species, under 50%

Table 1: recognizing of forest types by frequency percent of 100 high diameters species (Shataee and Mohajer, 2002)

To avoid a breaking on the borders of samples due to difference between magnetic and geographic north (4° in north of Iran and in 2000), the ground truth map was rasterized to 10 meters resolution.

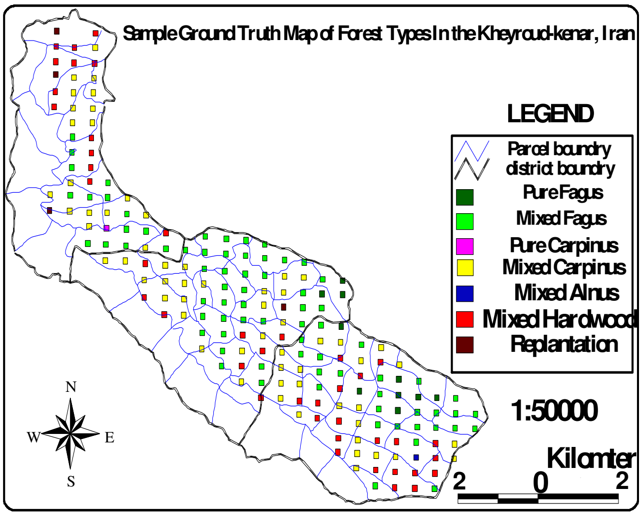


Figure 3: sampling ground truth map of types in the study area

3.4 pre-processing of data

The first step before the image analysis, it is necessary to per-processing of images for classification. Since, the raw data are received as orbit-oriented images and were registered to any references; The ETM+ bands were geo-referenced in two steps in PCI software. First, the panchromatic image was geo-referenced by a digital 1:25000 maps and ground control points. Then other images have been geo-referenced by using " image to image" technique. All images in corresponding to ground truth map were resized to 10 meters resolution by second order transformation and re-sampled by cubic convolution resampling method.

4 RESULTS

4.1 Pixel-based classification

In the pixel-based classification method, the suitable image analyses e.g. Tasseled Cap calculation, Principal Component analysis and some suitable ratioing transformations were applied to create the new artificial bands.
Based on ground truth map some training area was selected for each type. The best bands were selected based on spectral properties of training area by seperabilty measures such as Bhattacharya distance index (table 2). The maximum likelihood classifier has been chosen as a suitable classifier and was applied two times on different data set. First, ETM+ bands (multispectral and panchromatic bands) only accomplished classification. Second, the best artificial processing bands were added to ETM+ bands and classification was repeated.

ETM+ bands	Processing bands	The best artificial bands
1, 2, 3, 4, 5,7 and Pan	Pca1, Pca2, Pca3, Brightness, Greenness, Ratio(NIR-G), Ratio(NIR/G), Ratio(NIR/R+G), Ratio(NIR-MIR/NIR+MIR), Ratio(NIR -R/ NIR +R)	Pca1, Pca3, Brightness, Greenness, Ratio(NIR /G), Ratio (NIR/R+G)

Table 2: The ETM+, processing and Post processing bands selected by seperabilty measures

4.2 Object oriented classification approaches

In this study, first aim was to test the suitable object oriented classification methods for forest type extraction. So, the nearest neighbor classifier, membership functions and integration of both classifiers were examined individually:

4.2.1 The Nearest Neighbour (Sample-based) Method

The multiresolution segmentation was individually instructed on georefrenced data by suitable scale parameters and homogeneity criterion. The class hierarchy was made with forest types and non-forest classes (shadow and road).
The experiences in the pixel-based classification showed that use of only one or few bands could not well extract forest types. Therefore, the feature space by use of all mean bands was defined for description of each class. Some suitable segments were selected as samples for each class and then classification was done on segments.

4.2.2 Membership Function (Rule-based) Method

In according to ground truth information, main three Dominant types (mixed Fagus, mixed Carpinus and mixed hardwoods) are almost covered in Whole study area. Therefore, a few feature spaces were selected to separate them. Descriptions were determined through sample information by comparison of overlap rates of mean objects in each band as well as by optical interpretation. According to results of the primitive study, the 2, 4, 7 and pca3 bands could separate main types rather than other bands.
The membership function was used in three multiresulotion segmentations. In the first super level, the segmented objects were generally classified to main types and non-forest classes in class hierarchy by use of mean 2,4 and 7 bands and similarity expressions. In the middle level, to accomplish the refinement of general classes, the class hierarchy was extended to parent and children classes. First, all objects were classified to parent

based on their existence in supper object classes. Then in corrector classes they were belonged to their correct classes. In the lowest level, those objects, which were reclassified to their correct classes, were belonged to main types by logical" or" term. In order to extract special types from main types, those were subdivided into special type's classes and were classified by suitable descriptions. In addition to spectral information, the aspect and elevation attributes were used to separate pure Fagus from mixed Fagus.

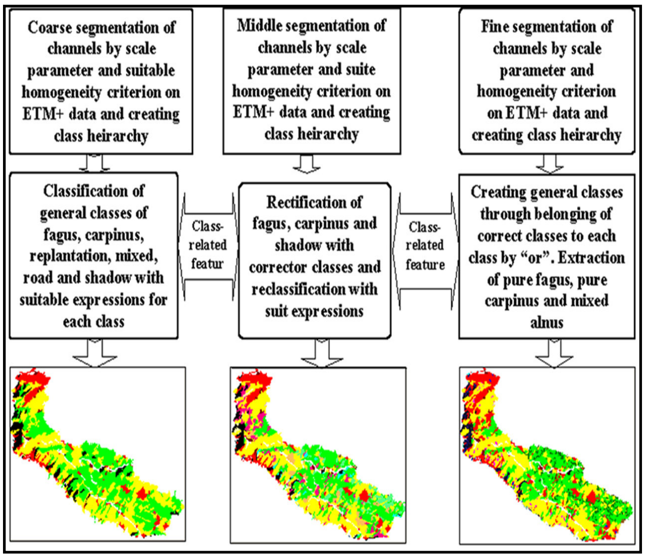


Figure 4: Flowchart of hierarchical forest types classification by membership function method on ETM+ bands and their results in each level

4.2.3 Integration of Nearest Neighbour and Membership Function

The last experiences were delineated that each of the nearest neighbour or membership function methods has advantages and disadvantages. In the nearest neighbour method, the spectral attributes can be only participated to classification. In the membership function method to get the best result, user should be find the best description for each class as well as should use more descriptions to classify all objects in different levels. In order to overcome these disadvantages, integration of both methods is offered for classification. Four multiresolution segmentations have been done for hierarchical classification of types (figure 5).

First, the roads and shadows were extracted by suitable descriptions on a fine segmentation and the segmentation based on classification was used to merge objects of each class. In next step, high-resolution segmentation (level 3) was only done on the "others "merged section of image. They were classified by training samples on main classes (Fagus, Carpinus, mixed and replantation) in the nearest neighbour method. The fine objects, which belonged to road and shadows classes were classified by membership function. In the next level (level 2), these main classes were subdivided into corrector classes and objects in each class were belonged to their correct classes. Also, the shadow objects were reclassified to class of their neighbour, which had more relation border. The all corrected classes were belonged to their correct classes by use of logical "or" term in the lowest level. Also the main forest types were subdivided into their special types and were classified to each class by aspect and elevation as well as spectral attributes.

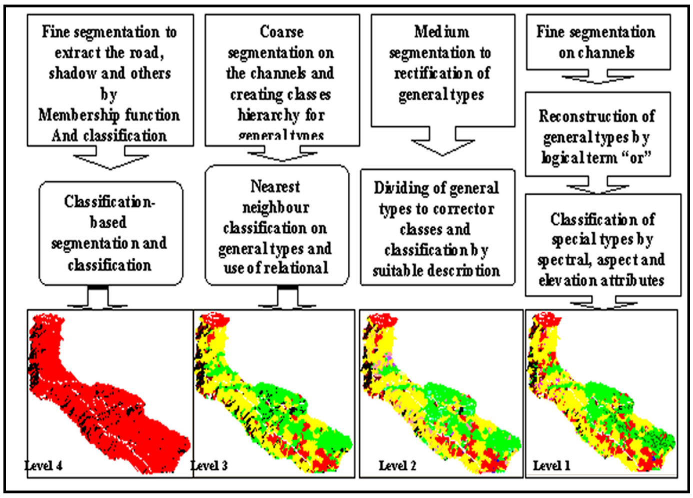


Figure 5: Flowchart of hierarchical forest types classification by integration nearest Neighbour & Membership function and results in each level.

4.3 Accuracy assessment

The results of the pixel-based and the object-oriented classification of the ETM+ images were compared, using a sample ground truth map that has already been generated in other project. The accuracy assessment of results was done in PCI programme. A confusion matrix was built to obtain all accuracy indices (see table 3) for assessing of quality of whole classification and each class.

Forest type	User accuracy	Producer accuracy	In class accuracy
Pure Fagus	0.2647	0.2920	0.1922
Mixed Fagus	0.6939	0.6341	0.9821
Pure Carpinus	0.2059	0.4200	0.1909
Mixed Carpinus	0.6162	0.7085	0.9669
Mixed Alnus	1.0000	0.7200	0.5714
Mixed Hardwood	0.6550	0.4986	0.6525
Replantation	0.8873	0.4300	0.6885
Overall accuracy: 60.65		**Kappa accuracy: 44.40**	

Table 3: An accuracy assessment table obtained by confusion matrix for result of integration of both methods

5 DISCUSION AND CONCLUSION

The results of accuracy assessment showed that the object-oriented techniques could classify forest types better than the pixel based classification method. The kappa index was about 20 % more in the object based method (see tables 4, 5 and figure 6).

As expected, the results of pixel-based classification had less accuracy in comparison with the object oriented classification (overall accuracy was 43.7%). In the pixel-based classification due to incorporating of only pixels spectral attributes in classification of images, the results looks like salt-peppery picture (see figure 6A). In other hand, in the homogenous area as forest type some pixels had different reflectance with their niehbour pixels so that they classified to other classes. However, in the results of the object-oriented classification, those are assumed as a homogenous area and an object.

In addition, it was investigated that adding artificial processed Bands facilitate improving the results in both approaches. Use of suitable processing bands such as those were used in the pixel-based classification together with main ETM+ bands could slightly improve the results (3%). These additional bands contained useful information, which have increased the seprabilty of forest types in the feature space as well as have reduced images errors. In addition, in the object oriented method, use of artificial bands in segmentation as well as in classification as suitable descriptions could improve the results (by 2.5 to 5.5 %).

	Pixel based method	Object oriented techniques		
		Membership function	Nearest Neighbour	Integration technique
Overall accuracy (%)	43.7	48.8	57.3	58.5
Kappa (%)	23.3	28.1	38.7	41

Table 4: comparison of classification results of pixel-based and objects oriented methods by main ETM+ bands

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	Pixel based method	Object oriented techniques		
		Membership function	Nearest Neighbour	Integration technique
Overall accuracy (%)	46.7	51.3	57.2	60.7
Kappa (%)	25.7	30.5	37.7	44.4

Table 5: comparison of classification results of pixel-based and objects oriented methods by main ETM+ and the best bands

In the object-oriented approach, image is segmented to different objects. Before segmentation at satellite images, the image objects are heterogeneous due to diversity of spectral information in pixels. After segmentation, heterogeneity of image objects will reduce. It led to easier seperabilty of objects, due to increasing of contrast between them. See figure 6B.

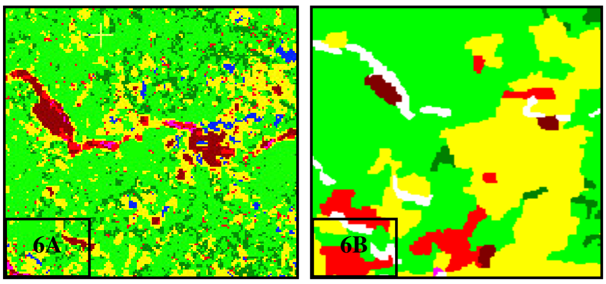

Figure 6: The pixel-based classification in a masked area (6A) and the object-oriented classification in the same area (6B). See salt-peppery image at the pixel-based method.

Among three objects oriented techniques, which were used to extract the forest types, integration of the nearest neighbor and membership function method showed high capability to stratify forest types.

In the membership function, determining of the suitable feature that exactly separates types was very difficult. Optical interpretation of images and their attributes could help to find the best descriptions. However, its result quality was low among other object-oriented methods (48.8 and 51.3 % in the both data set respectively).

As the results of pixel based classification and separabilty assessment showed, the forest types could not be completely separated by a few features. In the other hand, the nearest neighbor method classified the forest types in the multi-feature spaces. It caused better result than the membership function method (57.2 %).

By using of both the nearest neighbor and the membership function in the classification integrately, the overall accuracy of result increased to 60.7 %. Whereas, use of obtained information from training objects to define suitable descriptions of classes and use of membership function to re-correct classes were reasons of improvement.

Increasing of the kappa by 25.5 % in the pixel based classification to 44.4 % in the object oriented approaches showed the capability of multi-resolution segmentation of data to provide other useful attributes in addition to spectral information as well as reducing of heterogeneity in image objects.

The results show that since forest type's signatures have high overlaps on every band individually, they can not be separated by a few parameters (feature spaces). As the result, it is recommended to use the nearest neighbor method at first step and then membership to refine classification of images.

However, there are some reasons for low accuracy in both methods contrary to other image classifications such as land cover or land use. First, it refers to significant overlaps in the spectral attributes between the most of the mixed type and the mixed Fagus as well as the mixed Carpinus in some places in the study area. In addition, similarity of spectral attributes in the pure Fagus with the mixed Fagus types caused that they could not be completely separated well (see table 3). Second, the effect of topography and different illumination at the different aspects in the study caused that a similar type reflected different spectral attributes.

Although the considerable result have got by the object oriented methods in compare with the pixel-based classification method, but recognition of heterogeneous objects in forest area especially in the hardwood forests was difficult because of mixed species and also contrast of objects borders was low.

Use of different data in terms of resolution and spectral information can be examined to extract the forest types and certificate the results by the object-oriented approaches in future. Integrating of ancillary data in corporation with satellite data is expected to improve results.

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