Forest Boundary Mapping Using Multi-Temporal Satellite Images in Forested Areas of North Iran

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Key words: multi-temporal images, SPOT5, ASTER, forest boundary, accuracy

SUMMARY

Since separation of forest boundary using mono-temporal images is almost not possible, this study was performed in order to delineate Caspian forests boundaries using multi-temporal SPOT5 and ASTER images in forested areas in Northern Iran. The forests are composed of deciduous broad-leaved forests, afforested coniferous evergreen stands, tea and citrus orchards, as well as farms and orchards with deciduous species. SPOT5-HRG and Terra-ASTER images acquired between February and August 2002 were analyzed. Geometric correction (orthorectification) was applied using a precise digital elevation model. In addition, the images were geometrically co-registered. Following preprocessing, suitable training areas were determined and refined. Separation of above forest and non-forest classes was carried out using mono-temporal and multi-temporal classification approaches, as well as hierarchical and digital-visual hybrid approaches. In order to determine the accuracy of the resulting classifications, ground truth (forest boundary) data was prepared using field surveying with GPS. The total length of the forest boundary surveying route was 64.5 km. The results of the above classifications were compared with the ground truth and their accuracy was determined. The Kappa coefficient used for classification accuracy assessment resulted in growing season 28%, leafless images 43%, multi-temporal classification 57%, hierarchical approach 62%, and digital-visual hybrid interpretation 71% respectively. The most and least accuracy were related to digital-visual interpretation and classification of growing season image respectively. The overall accuracy was 87.30% for best approach. Based on these results, forest boundaries differentiation worked best using the hybrid-visible approach and worst using the growing season. For typical scales inventory mapping purposes, the highest three scoring results may still offer a suitable classification accuracy. We strongly suggest updating topographic maps using combined leafless season images and growing season images, in particular for the forests located in the Caspian region of Iran.

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1. INTRODUCTION

Forest planning is one of the most important steps to the better management of forest. Suitable forest planning needs precise quantitative and qualitative information such as forest coverage map. It is very important for forest managers to have all forest maps updated at the shortest time. Remote sensing data have frequently been used for forest mapping within the past two decades. Suitable temporal resolution of remote sensing data is the most important character which makes it unique in compare to conventional data. On the other hand, the forest and non-forest vegetation has phonological property. Phonological changes of forest and non forest vegetation and availability of remote sensing data with high temporal resolution convinced the experts to use multi-temporal remote sensing images. This kind of image is more helpful than mono-temporal image in the forest studies (Chacon-Moreno, E.J, 2004). In some cases, delineation of forest boundary with mono-temporal images is not possible because of the similarity between forest and non-forest area reflectance (Drarvishsefat et al., 2004). The present study was performed in northern forests of Iran to map the forest boundary. In addition to deciduous broad-leaved forests there are afforested coniferous evergreen stands, tea and citrus orchards, farms and orchards with deciduous species in the study area. Due to such a complex variety of vegetation cover in the area high accuracy forestry mapping using mono-temporal images were impossible. Present study aims to improve the accuracy of forest boundary using multi –temporal satellite images. Many studies were performed using multi-temporal image that increase the accuracy in contrast to mono-temporal image like forest cover assessment (Joshi et al., 2001), forest mapping (Chacon-Moreno, E.J, 2004; Kato et al., 2001; Liu et al., 2002), Land cover classification (Guerschman et al., 2003) and comparison of single data and multi-temporal satellite image classifications (Langley et al., 2001).

2. STUDY AREA AND METHOD

2.1. Study area

The study area is located in two Northern Provinces of Iran, Gilan and Mazandaran (Figure 1). Study area is a part of Caspian forests. It contains deciduous broad-leaved forest that is relatively dense and afforested coniferous evergreen stands in the forest section and tea-citrus orchards, farms and orchards with deciduas species in the non-forest section.

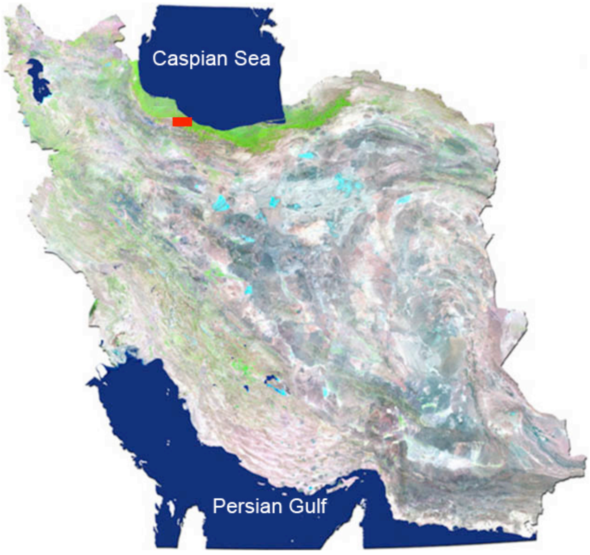


Figure 1: Study area Location in Iran

2.2. Data

A map oriented 1B scene of Terra-ASTER dated on 28 Feb, 2002, and a subset of an orbit oriented Spot5-HRG scene (147-276) in XS and Pan modes, acquired on 14 Aug, 2002 were obtained from Land Processes (LP) DAAC User Services and Forest, Range and Watershed Organization of Iran respectively. In addition to the satellite images, 5 sheets of digital topographic maps at the scale of 1:25000 were used.

2.3. Image preprocessing and enhancement

Radiometric errors were considered both quantitative and qualitative methods. In order to remove relief displacement in mountainous area, geometric orthorectification was performed using ground control points, digital elevation model and ephemeris data, separately for both SPOT and ASTER images. Orthorectification was implemented using Toutin model (cheng et al., 2002) to a RMS error of less than one pixel. An affine transformation and the nearest neighbor resampling were applied. Both SPOT-HRG and TERRA-ASTER images were resampled to 10m and geocoded images were checked for reliability in comparison with the digital topographic map. At last, the two images were registered to each other. In order to improve the information extraction, suitable spectral transformations like NDVI, PCA, rationing, RGB color composites (for visual interpretation) and data fusion were performed on the both satellite images.

2.5. Ground Truth

It is necessary to compare the maps derived from satellite images with those prepared on the ground (ground truth). Since the most errors occur in the boundary of phenomenon, the boundary of forest and non-forest was selected (64.5 km) for preparing of ground truth map.

All forest boundaries were surveyed with a GPS. In addition to forest boundary the small forest area inside the non forest area and small non forest area inside the forest area were surveyed with GPS. These data were entered into GIS and converted to a linear vector map. In order to compare the classified maps with ground truth data, it is necessary to have the ground truth as a polygon map. Therefore, a buffer with a width of 200 m was applied on both sides of linear map of ground truth. A buffer with a width of 100 m was also performed only on the external side of the surveyed polygons. Finally the resulting map converted to raster format and a ground truth map with two classes (forest and non forest) was prepared (Figure 2).

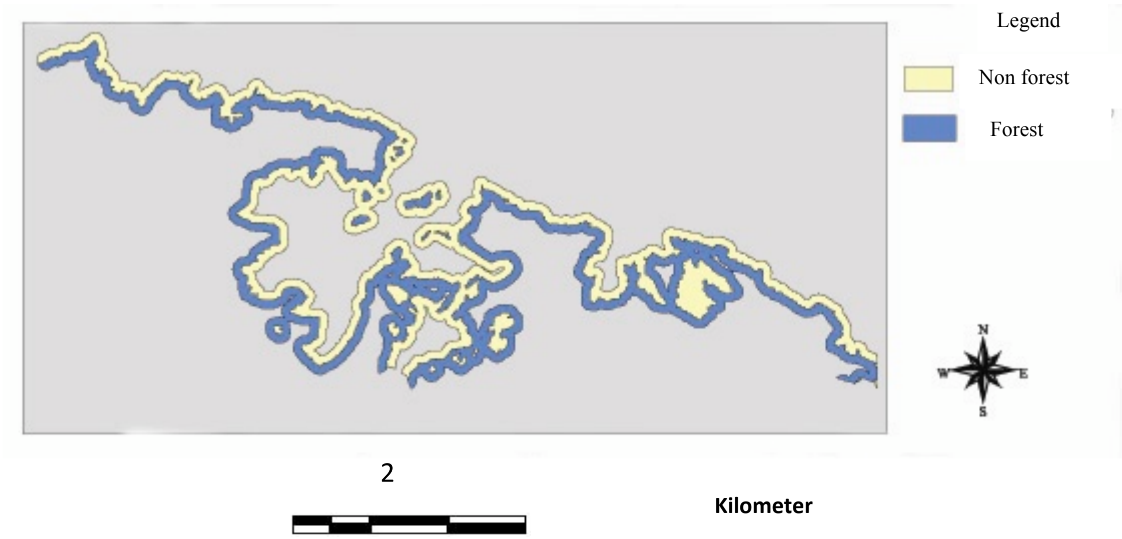


Figure 2: Ground truth map

2.7. Classifications of images

Study area consist water, urban areas, agricultural areas, gardens and forests. Training areas were selected through field surveying using GPS. The selected training areas were modified using both the statistic method and the rate of separability of the classes; then the suitable bands for classification were selected.

Four different techniques were used to delineate the forest boundary:

1- Both images from two dates were classified separately using Parallelepiped (PPD), Minimum distance to mean (MD) and Maximum likelihood (ML) methods.

2- Multi-temporal, multi-sensoral classification. In this method the appropriate bands were selected jointly from all images.

3- Hierarchical classification (figure 3). Following classes were step by step automatically classified: forest with shadow and needle evergreen forest as forest class, water, urban area, ever green gardens and agriculture as non-forest classes.

4- Hybrid digital-visual approach. The forest and non-forest classification was carried out using visual interpretation at computer display based on multi-temporal images. Hillshade, slope and aspect, which were derived from DEM, were also used as ancillary data. The main advantage of hybrid interpretation is that contextual information and expert knowledge can be used in the analysis more easily.

2.8. Accuracy assessment

The classified maps were compared with ground truth pixel by pixel. For accuracy assessment of the study, Overall accuracy, Producer's accuracy, User's accuracy and Kappa coefficient were calculated using error matrix.

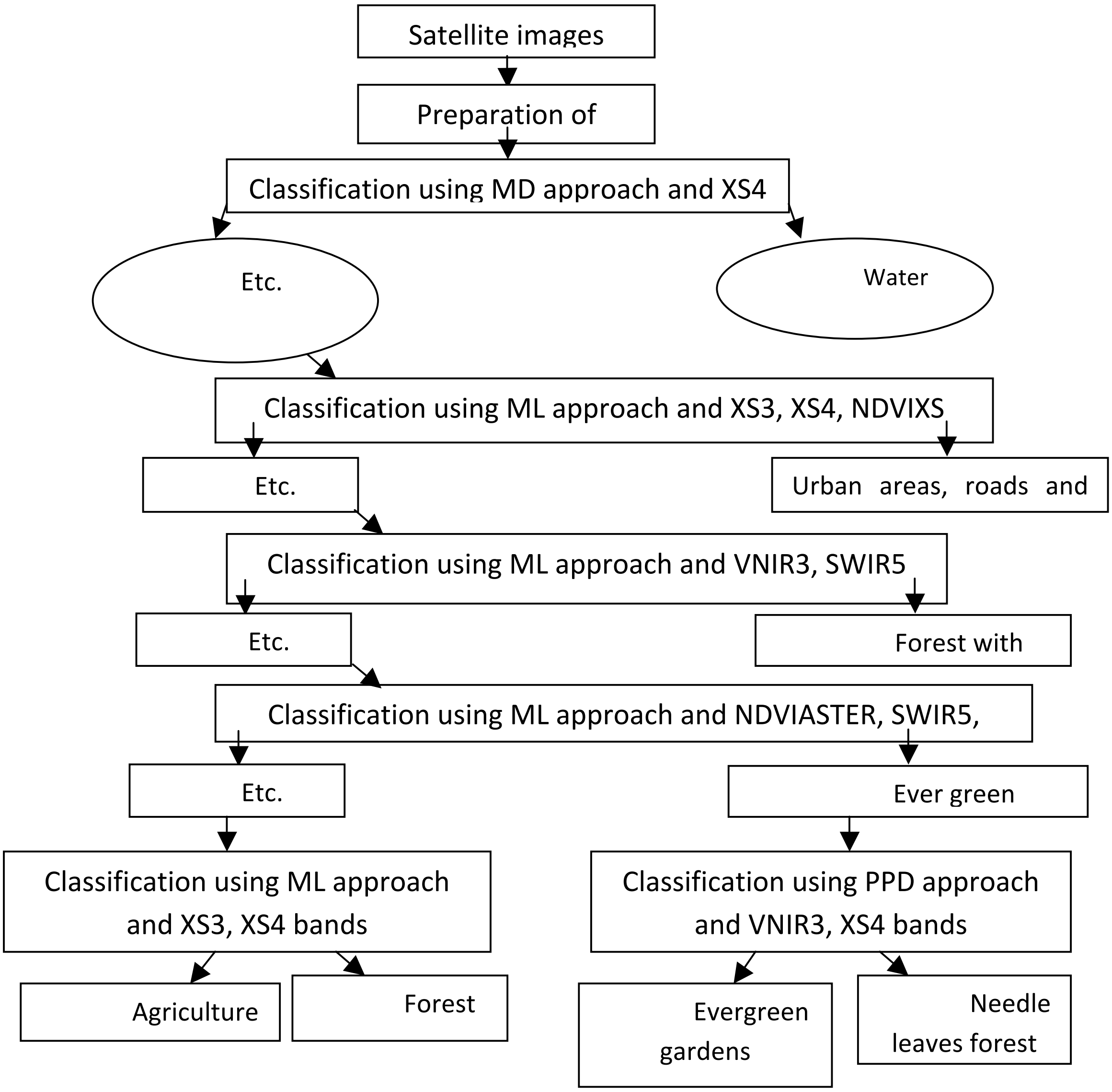


Figure 3: Flowchart of hierarchical classification

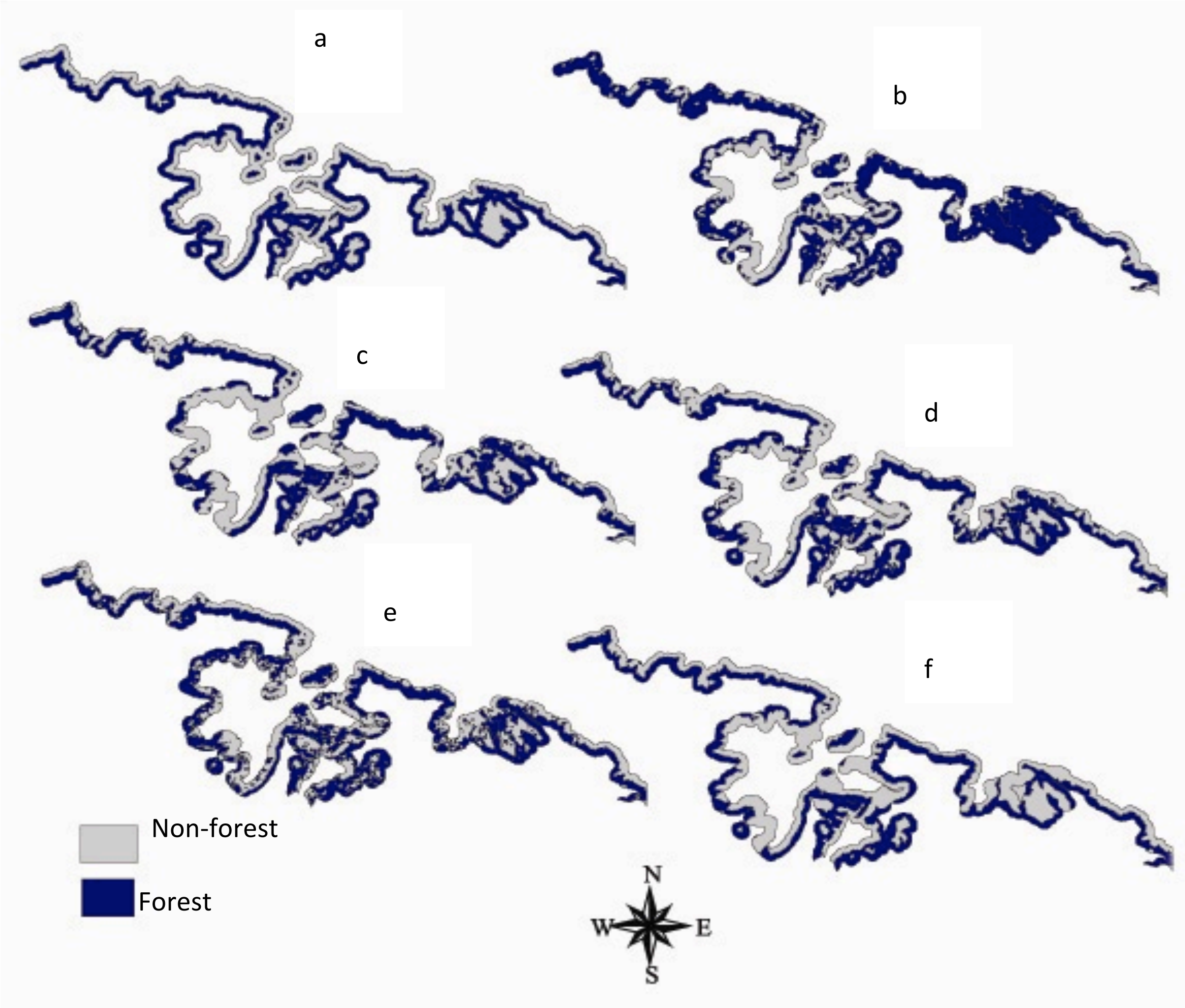
3. RESULT

Quantitative evaluation of satellite images showed that noise, disability of detector Failure and repeated scan lines do not exist in the images. Qualitative evaluation for striping error showed that error rate is less than 0.5 DN in all images.

Results of accuracy assessment showed that accuracy of ML approach is higher than MD and PPD approaches. The band set of [NDVI (XS), NDVI (ASTER)] showed best result for multi-temporal classification. Hybrid classification results were better than hierarchical classification and hierarchical classification results were better than multi-temporal approach (Table 1, Figure 4).

Table1: Results of accuracy assessment

Producer's accuracy (%)		User's accuracy **(%)**		Kappa coefficient	Overall accuracy (%)	Best set of bands	Classification approach	SENSOR
Non-forest	forest	Non-forest	forest					
56.61	57.60	69.3	60.50	.028	63.15	) (XS NDVI□XS3 (XS) PCA1	Mono-temporal	HRG
73.02	60.20	71.59	71.84	0.43	71.63	SWIR5□VNIR3□VNIR2 NDVI(ASTER)□Ratio1	Mono-temporal	ASTER
78.53	78.51	78.51	78.8	0.57	78.5	NDVI(ASTER), NDVI(XS)	Multi-temporal	HRG & ASTER
88.4	79.2	81.2	85.60	0.62	82.36	-	Hierarchical	HRG & ASTER
83.5	91.90	90.12	85.60	0.71	87.30	-	Hybrid	HRG & ASTER



Classification of those images belonging to different growing seasons (SPOT from summer and ASTER from winter) separately did not show high accuracy (Table1). But classification of images using multi-temporal approach showed better result than mono-temporal classification. Kappa coefficient in multi-temporal approach was 10 percent higher than mono-temporal classification. Results of many studies such as (Joshi et al, 2001), (Tuerner and Congalton, 1998), (Kato et al, 2001), (Chacon-Moreno, 2004), (Liu et al, 2002), (Collins and Wood cock, 1996), (Kurosu et al, 1999), (Alvarez et al, 2003), (Guerschman et al, 2003) showed that multi-temporal approach provide higher accuracies than mono-temporal analysis, which confirm the results of this study. Needle leaf forest stands, gardens with leaf less vegetation in winter and shadows are main cause for errors in the multi-temporal classification. Fusion of the high resolution panchromatic band with multispectral bands of SPOT image had improved the Kappa coefficient only 1 present. Interaction of reflectance of needle stands with non-forest classes partly resolved in the hierarchical approach. In this approach, kappa coefficient and overall accuracy were obtained 0.62 and 82.36% respectively. Kappa coefficient in the hierarchical classification was increased 5 percent compared with multi-temporal approach. Hybrid approach had presented the best results compared with the other three approaches. Kappa coefficient and overall accuracy of this approach were equal to 0.71 and 87.3% respectively. Achieving a high accuracy by this approach was due to not mixing of urban and agriculture areas with forest class. Needle leaf stands were caused most errors during visual separation of classes. Interpreter cannot recognize the needle leaf stands from evergreen gardens on separation of forest from non-forest classes. Although the ground truth was conducted along the boundary of classes, in which the most error may occurs, nevertheless the results of this study showed high accuracy of multi-temporal images in delineation of the forest boundary. The results of present study revealed that multi-temporal images are more suitable than the mono-temporal images for updating forest maps in such mixed and inhomogeneous covered area.

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