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Land use/cover change and driving force analyses in parts of northern Iran using RS and GIS techniques

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Abstract To accomplish integrated watershed management and land use planning, it is necessary to study the dynamic spatial pattern of land use and cover change related to socioeconomical and physical parameters. In this study, land use and cover change detection was applied to the Lajimrood Drainage Basin in northern parts of Iran, an area characterized by rich and diversified agricultural and forest mosaic. The main of changes in the study area were forest–arable land transformation, which was only considered in this study. In order to detect these changes, at first, based on 1:25,000 digital topographic maps dated 1967 and 1994 and ETM$^+$ satellite image dated 2002, land use map in these three dates were prepared. The results showed that the area with forest land use decreased about 3.2% in transition 1967–2002. Also, arable land increased about 36.9%. We suggested a method to analyze the driving forces and the spatial distribution of land use change. The maps of elevation, slope, and aspect were derived and classified by using digital elevation model (DEM). Also, the maps of distance from road, drainage network, and building area were selected as socioeconomical factors. These maps were overlaid and crossed with land use change map and land use change area ratio was computed. The results showed that the elevation, slope, and aspect were physical effective factors in land use changing. Also, by increasing the distance from building area and roads, deforestation rate was reduced.

Keywords Digital map · Land use change · LucAR · Satellite imagery · Spatial pattern

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Introduction

Land use and land cover changed drastically in the end of the twentieth century in the northern forest of Iran due to a plethora of factors. It is clear that changing land use affects on-site landscape properties, such as flood (Schoorl and Veldkamp 2001; Sullivan et al. 2004), soil erosion (Glade 2003; Kelarestaghi 2007; Tarantino et al. 2007), and soil properties (Islam and Weil 2000; Genxu et al. 2004). There are some global examples in countries of Asia (e.g., Vietnam, Sakamoto et al. 2009; India, Kaul et al. 2009), Africa (e.g., Madagascar, Vagen 2006), America (e.g., United States, Wang et al. 2009; Mexico, Geissen et al. 2009; Paraguay, Huang et al. 2009; Nicaragua, Zeledon and Maggi Kelly 2009), Europe (e.g., Poland, Łowicki 2008; UK, Fuller et al. 2003; Spain Serra et al. 2008), and even Australia (Pannell 2008).

Land cover changes are determined by complex interactions of environmental and socioeconomic factors. Comprehensive knowledge of these dynamics may be useful to reconstruct past land use and land cover changes, as well as to predict future changes, and thus may help to elaborate sustainable management practices aimed at preserving essential landscape functions.

The decrease of the forest area in the north of Iran is one of the serious problems in recent years. Because these forests have unique economical and environmental values, so it is necessary to protect them. Satellite imagery has been used as an effective means to acquire information about the earth surface in order to map land use and cover (Lo and Fung 1986; Reger et al. 2007). The use of satellite remote sensing has been proven to be a good choice for detecting and monitoring land use transformation (Longley 2002).

At the medium resolution of 30 m, Landsat Thematic Mappers (TM, ETM, and ETM^+) data enable mapping of important crops and primary cover types (Darvishsefat 2000; Dontree 2003; Gao et al. 2006; Vasconcelos et al. 2002; Wang et al. 2007). Change detection is the process of determining changes in land use and cover (Shalaby and Tateishy 2007). Changes can be detected from overlaying multiple land use and cover maps produced from multi-temporal aerial photos or satellite images in a geographic information system (GIS; Kaufmann and Seto 2001). Repetitious and up-to-date land use change information is necessary to assess environmental impacts of such changes (Giri et al. 2005). Some researchers studied forest area decrease in relation to socioeconomic and physical parameters (Pirbavaghar 2003; Reger et al. 2007; Wang et al. 2008). Tipaniat and Nitin (2003) developed a red, green, and blue Normalized Difference Vegetation Index (NDVI) to display and quantify mangrove forest changes using three dates of Landsat satellite images. Dontree (2003) used remotely sensed data composed of Landsat MSS in 1972, Landsat TM-5 in 1989, Landsat ETM^+ in 2000, and three dates of aerial photos in 1989, 1991, and 1996 to investigate land use dynamics. Cropper et al. (1999) investigated the factors that affected the location of deforestation in northern Thailand. They presented a model to predict where deforestation is likely to occur and examined the effects of two government policies—road building and establishment of protected areas—on land use change. Kelarestaghi et al. (2006) studied monitoring land use dynamic in the northern parts of Iran in the past four decades and revealed that the forest area decreased by 2.99% and dry farming increased by 9.2%.

The aims of this study were to monitor land use changes using remote sensing and GIS and to investigate spatial patterns of land use changes in relation to physical and socioeconomical factors.

Study area

The study area is located between the north latitude 36°10′22″–36°22′15″ and east longitude 53°03′14″–53°11′45″ in the northern part of Iran, Mazandaran province at the forest area called Hyrcanian forests (Fig. 1). It covers about 141.512 km^2. The amount of precipitation is about 500 mm yearly and the mean annual air temperature is 13°C. The altitudes of the area vary from about 210 masl in the north to 1,720 masl in the south. The most important forest species are *Fagus orientalis*, *Carpinus betulus*, *Quercus castanifolia*, *Alnus glutinosa*, and *Acer velutinum*. This area has a good potentiality for agriculture expansion under suitable management of water and land.

Materials and methods

Data and sources of data

Three sets of materials were used here. First, digital topographical maps digitized from hardcopy topographic maps dated 1967 and 1994 in 1:25,000 scale were used mainly for geometric correction of the satellite images and for some ground truth information. Also, these data sets were used to prepare land use map dated 1967 and 1994. They have 63 different data layers including residential area, roads, railway, forest, ranges, gardens, and others.

Second, ETM^+ satellite data were used to generate land use map for 2002. We preferred to use Landsat ETM^+ data (April 29, 2002) after level 1G processing (geometrically and radiometrically corrected). It is worth mentioning that the data are for growth season under clear sky.

Third, field data was gathered between October and November 2008 for the purpose of supervised classification and classification accuracy assessment.

Land use mapping

To meet forest–arable land use change detection, it was necessary that the forest and dry land farming area map be created into two or more than two dates. Therefore, the land use maps were extracted from 1:25,000 digital maps in the Micro Station Software and imported in the Arc/View 3.2 Software. Therefore, the land use maps on 1967 and 1994 were created. Also, ETM^+ satellite data were used to generate land use map dated 2002. To assess image quality, quantitative method was done. In this method, the mean of the digital number in the Caspian Sea homogenous region with the dimension of 200×300 pixels were selected and analyzed. An accurate digital topographic map and a fine digital elevation model (DEM) combined with field observation were used to orthorectify the images to the Universal Transverse Mercator (UTM) coordinate. Then, training samples were collected using field works, digital topographic maps, and false color composites interpretation. Also, different suitable spectral transformations such as rationing (NDVI), principal component analysis (PCA), tasseled cap transformation, and data fusion were performed on the Landsat ETM^+ images (Kelarestaghi et al. 2006). Image classification were accomplished by using supervised classification, maximum likelihood, and minimum distance classifier utilizing original and synthetic

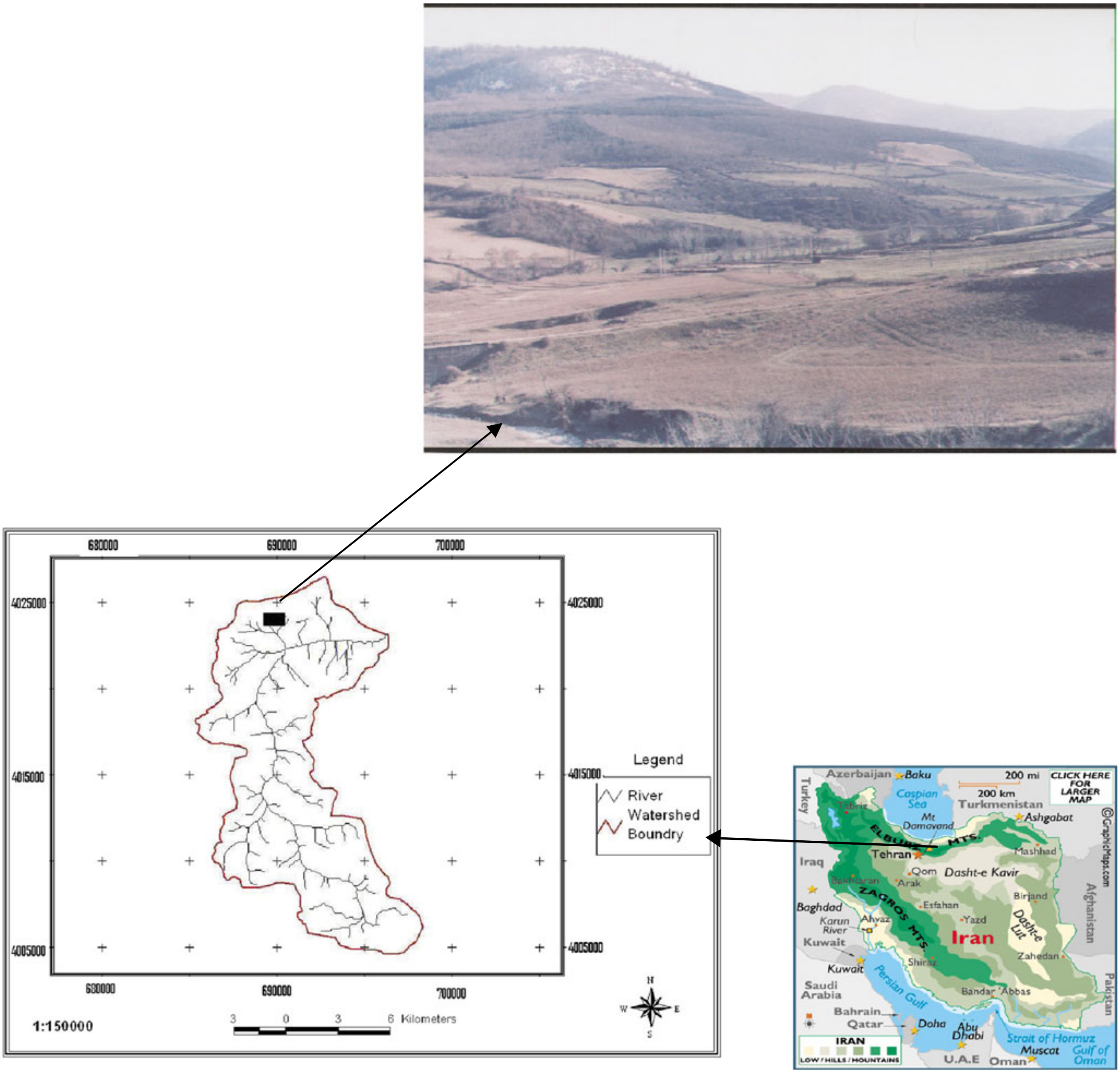

Fig. 1 Location and deforestation in the study area

bands resulted from divers spectral transformation in Envi 3.5 and Erdas 8.5 software. Systematic random samples from each land use were collected to assess the map accuracy. Consequently, a ground truth map was prepared through field works. Some criteria of accuracy assessment such as overall accuracy (Eq. 1) and kappa coefficient (Eq. 2) were computed to analyze images accuracy:

$$\%Overall\ accuracy = (n_{ci}/N_i) \times 100 \quad (1)$$

and:

$$Kappa\ coefficient = \theta_1 - \theta_2/1 - \theta_1 \quad (2)$$

where n_{ci} is the total pixels classified accurately, N_i is total pixels of classification, θ_1 is the overall accuracy, and θ_2 is chance agreement.

A standard overall accuracy for land use and cover maps is set between 85% and 90% (Anderson et al. 1976; Lins and Klechner 1996).

Spatiotemporal variation of changes

Three maps of land use in 1967, 1994, and 2002 were compared using change detection extension of Arc/View 3.2 software and the results were analyzed.

The result is a new image that shows the locations of all combinations of the categories in the original images.

Driving forces analysis

Some physical and socioeconomical factors were selected to investigate spatial distribution on forest–arable land use change. For achieving this aim, it was necessary to prepare data layers of these parameters. So, the maps of elevation above sea level, aspect, and slope were extracted from DEM with a spatial resolution of 30 m. Also, the maps of distance from road, distance from drainage network, and distance from building area were extracted and classified from digital topographic maps. Then, each of these maps was multiplied by forest–arable land change map to determine their role in land use change in the study area.

In the study area, the land use change area ratio (LucAR) was computed to analyze the spatial pattern of land use change in order to determine driving forces. This approach was performed, formerly, in landslide susceptibility analysis and mapping based on landslides density in each factor and their subclasses by Rautela and Lakhera (2000), Van Westen (1997), and Wang et al. (2007). Based on this approach, we propose the following formula in land use change analysis:

$$\mathrm{LucAR} = \ln\frac{\mathrm{Densclass}}{\mathrm{Densmap}} = \ln\frac{\frac{\mathrm{Npix(Si)}}{\mathrm{Npix(Ni)}}}{\frac{\mathrm{SNpix(Si)}}{\mathrm{SNpix(Ni)}}}$$

where Npix(Si) is the number of pixels that contain a land use change in a certain parameter class, Npix(Ni) is the total number of pixels in a certain parameter class, SNpix (Si) is the total number of pixels that contain a land use change, and SNpix(Si) is the total number of pixels in a watershed area.

Results

The land use maps of two dates, 1967 and 1994, which were extracted from digital maps, are shown in Figs. 2 and 3. ETM^{+} satellite data were used to generate land use map dated 2002. For doing this, in image quality evaluation, the results indicated that the rate of stripping error was less than 1 pixel (Fig. 4). Therefore, the quality of the image was very good and no radiometric and stripping was found. The images were rectified with 26 ground control points and the RMS error was 0.84 pixels. Visual interpretation that resulted from overlaying the vector layers such as roads with corrected images showed that the images conformed perfectly. The NDVI values were classified for the extraction of more information. The brightness and greenness components that resulted from tasseled cap transformation were used in the classification processes. The results of PCA showed that band 4 has a low correlation compared with the others (Table 1). Therefore, the implication of different bands in the classification processes was done as an elective, separately. Most accurate land use map dated 2002 was created after accuracy assessment (Fig. 5).

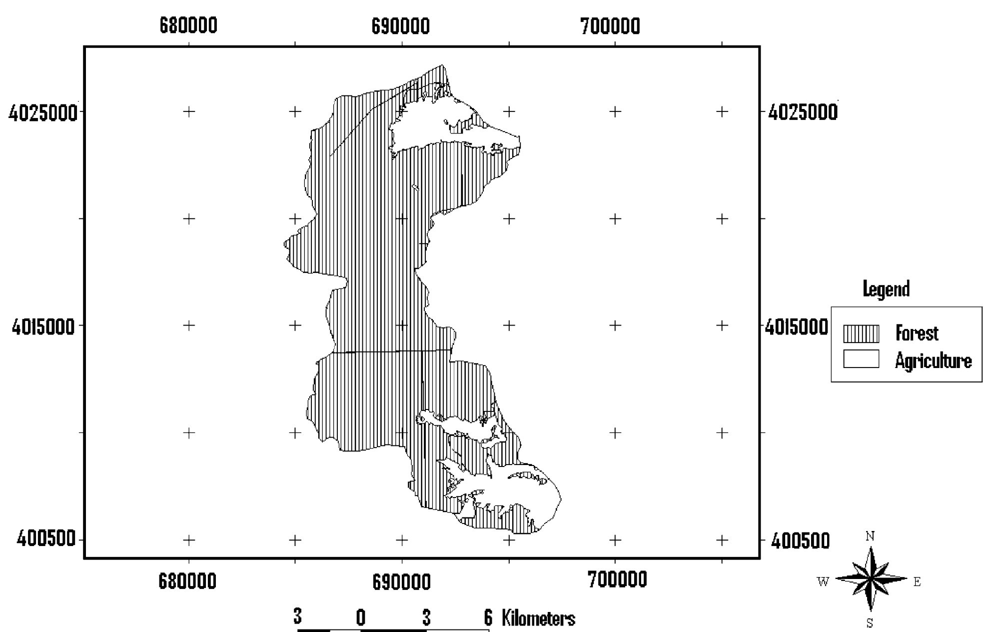

Fig. 2 The map of land use dated 1967

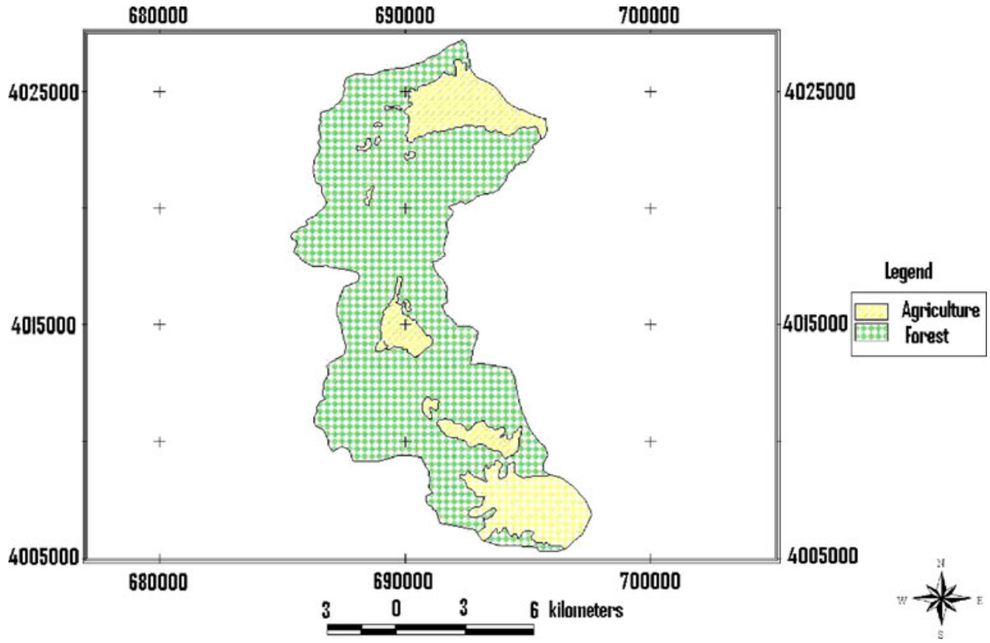

Fig. 3 The map of land use dated 1994

Overall classification accuracy and kappa coefficient were found to be 93.02% and 0.841 for land use map dated 2002 in the maximum likelihood classifier (Table 2). The results of the maps accuracy assessment are shown in Table 2. The results implied that a combination of the bands PCA 1, 2, and 3, PCA 5 and 7, B4, NDVI, brightness component of tasseled cap transformation in the maximum likelihood classifier with 93.02% overall accuracy, and 0.841 kappa index has presented the most accurate map of forest area (Fig. 5).

The results from analysis of land use change detection in the study period are shown in Table 3 and Figs. 6 and 7. Out of the 12,347 ha that was forest in 1967, 11,955 ha is still forest in 2002 but 392 ha was transformed. At the same time, the increase of farmland from 1967 to 2002 was 484 ha. The results showed drastic reduction of forest to farmland.

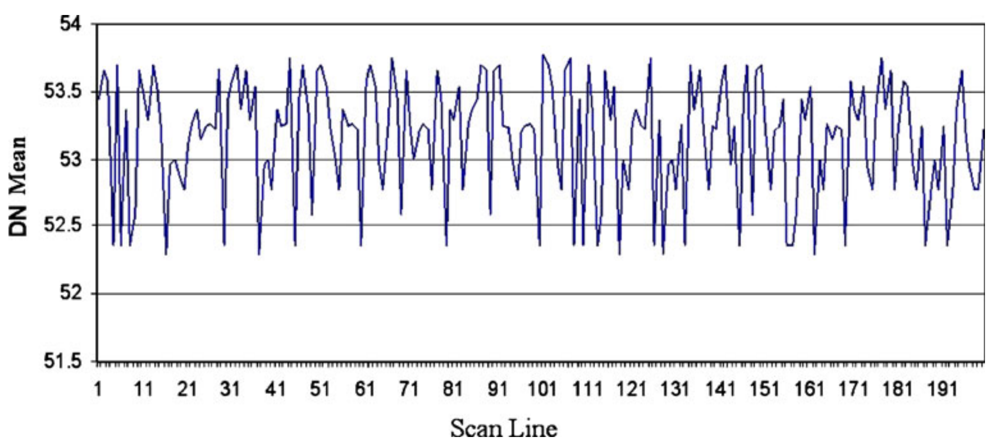

Fig. 4 The result of stripping error evaluation in ETM^+ images

Table 1 Correlation matrix resulted from PCA transformation

Correlation matrix	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
Band 1	1.000000	0.997032	0.974508	0.922062	0.962030	0.963390
Band 2	0.997032	1.000000	0.985312	0.903575	0.955628	0.967811
Band 3	0.974508	0.985312	1.000000	0.826551	0.917442	0.963887
Band 4	0.922062	0.903575	0.826551	1.000000	0.960558	0.884229
Band 5	0.962030	0.955628	0.917442	0.960558	1.000000	0.975426
Band 7	0.963390	0.967811	0.963887	0.884229	0.975426	1.000000

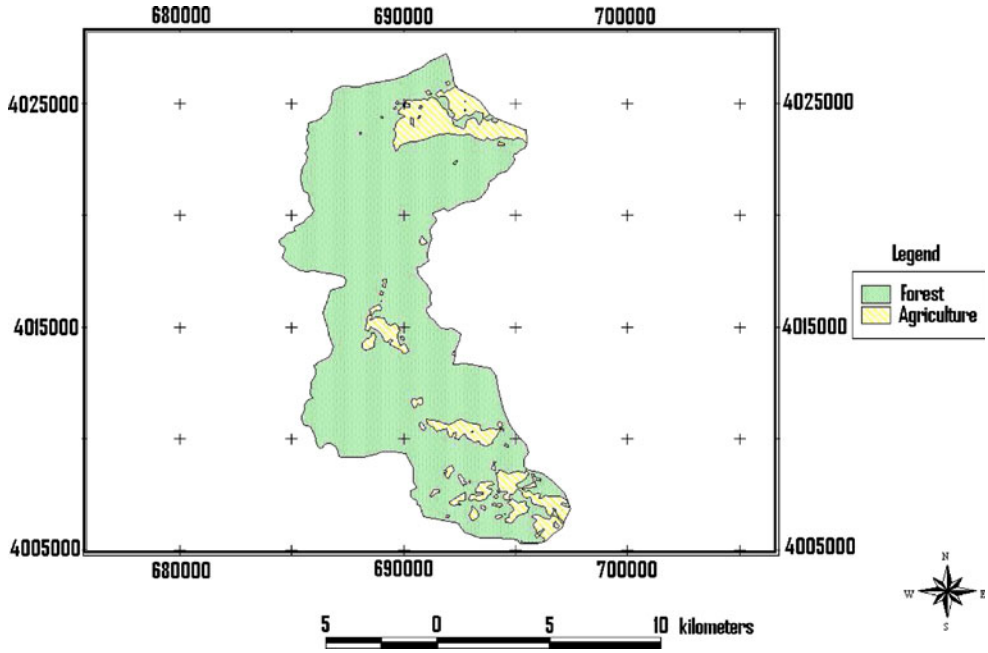

Fig. 5 The map of land use dated 2002

Table 2 shows that about 3.2% of forested lands were lost during 1967–2002 and 36.9% of farmland was gained.

The maps of the physical and socioeconomical factors are shown in Fig. 8. A noticeable land use change is detected by LucAR analysis in areas with low slope (Fig. 9). The main reason for this conversion is accessibility for human and livestock. In a study conducted by Dontree (2003), the effective factors in conversion of dense forest to

Table 2 The results of accuracy assessment in different bands of the ETM$^+$ image

Bands	Maximum likelihood method		Minimum distance method	
	Kappa coefficient	Overall accuracy	Kappa coefficient	Overall accuracy
$B_{1,2,3,4,5,7,8}$	0.814	90.72	0.641	82.01
$PCA_{1–7}$, NDVI, bright, B_8	0.815	90.82	0.643	82.34
$PCA_{1–3}$, $PCA_{5–7}$, B_4	0.766	88.42	0.611	80.99
$PCA_{1–3}$, $PCA_{5–7}$, B_4, NDVI, bright	0.841	93.02	0.675	85.96
$PCA_{1–3}$, $PCA_{5–7}$, B_4, NDVI	0.373	69.56	0.341	63.52
$PCA_{1–3}$, $PCA_{5–7}$, NDVI, bright	0.714	85.93	0.604	79.49
Fus_3, Fus_5, NDVI, bright	0.819	91.56	0.669	83.86
Fus_3, Fus_5, NDVI, bright, B_8	0.832	92.65	0.671	85.41
$Fus_{1,2,3,5,7}$	0.806	90.18	0.667	83.29

$PCA_{1–3}$ first component of PCA bands 1, 2, and 3, *bright* brightness component result from tasseled cap transformation, *$PCA_{5–7}$* first component of PCA bands 5 and 7, *NDVI* normalized different vegetation index, *$PCA_{1–7}$* first component of PCA bands 1, 2, 3, 4, 5, and 7, *Fus_3* band 3 fused with band 8, *$Fus_{1,2,3,4,5,7}$* bands 1, 2, 3, 4, 5, and 7 fused with band 8, *$B_{1,2,3}$* bands 1,2, and 3, *$B_{1,2}$* bands 1 and 2

Table 3 Area and percentage of different land use classes of the 1967, 1994, and 2002 classified images

Land use	1967		1994		2002		Land use change between 1967 and 2002
	Area (ha)	%	Area (ha)	%	Area (ha)	%	
Forest	12,347	87.2	12,041	85.1	11,955	84.5	−392
Dry farming	1,311	9.3	1,565	11.1	1,795	12.7	+484

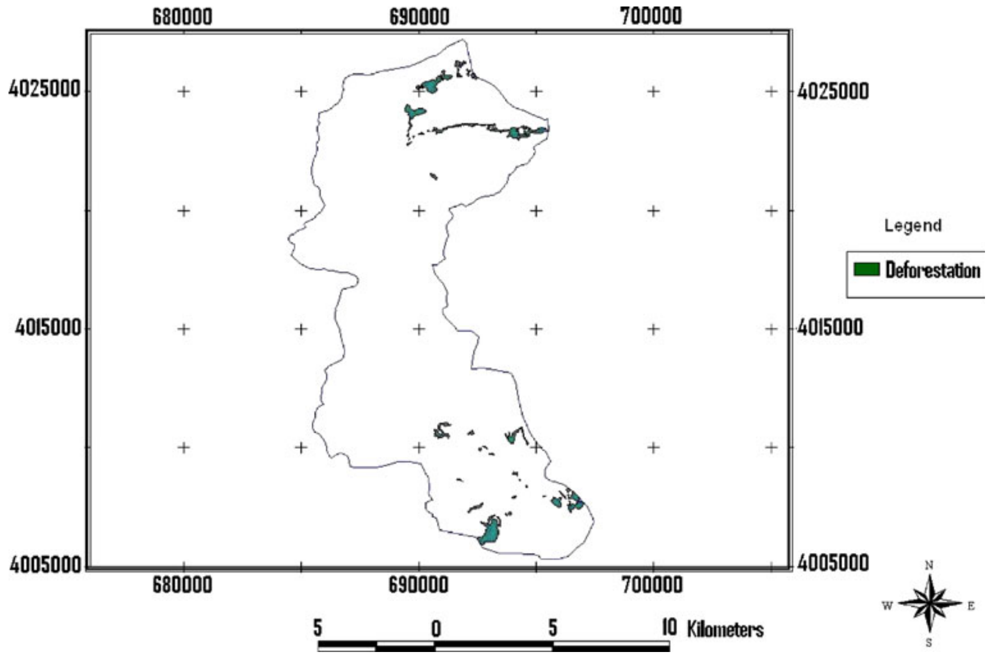

Fig. 6 The forest–arable land use change map dated 1967–1994

disturbed forest and agricultural lands from 1989 to 1996 were similar to our study. The main reasons for the decline in forest lands are their conversion to dry land farming. LucAR analysis showed that, by increasing the distance from roads and residential areas and villages, the deforestation rate was reduced (Fig. 9). In these areas, forest exploitation is overdone because of accessibility.

Discussion and conclusion

In this study, land use changes (deforestation) in the north of Iran were detected using a combination of digital and satellite data. Excessively pursuing higher land use benefits likely results in serious environmental degradation. It is clear from field visits and focus group discussions with local people that the forest is decreasing

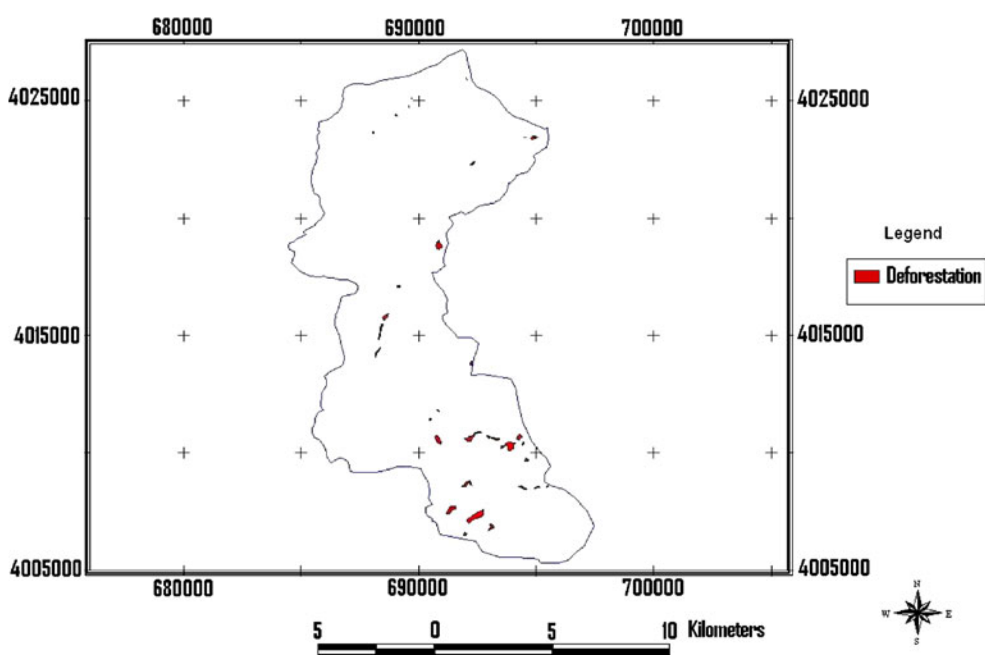

Fig. 7 The forest–arable land use change map dated 1994–2002

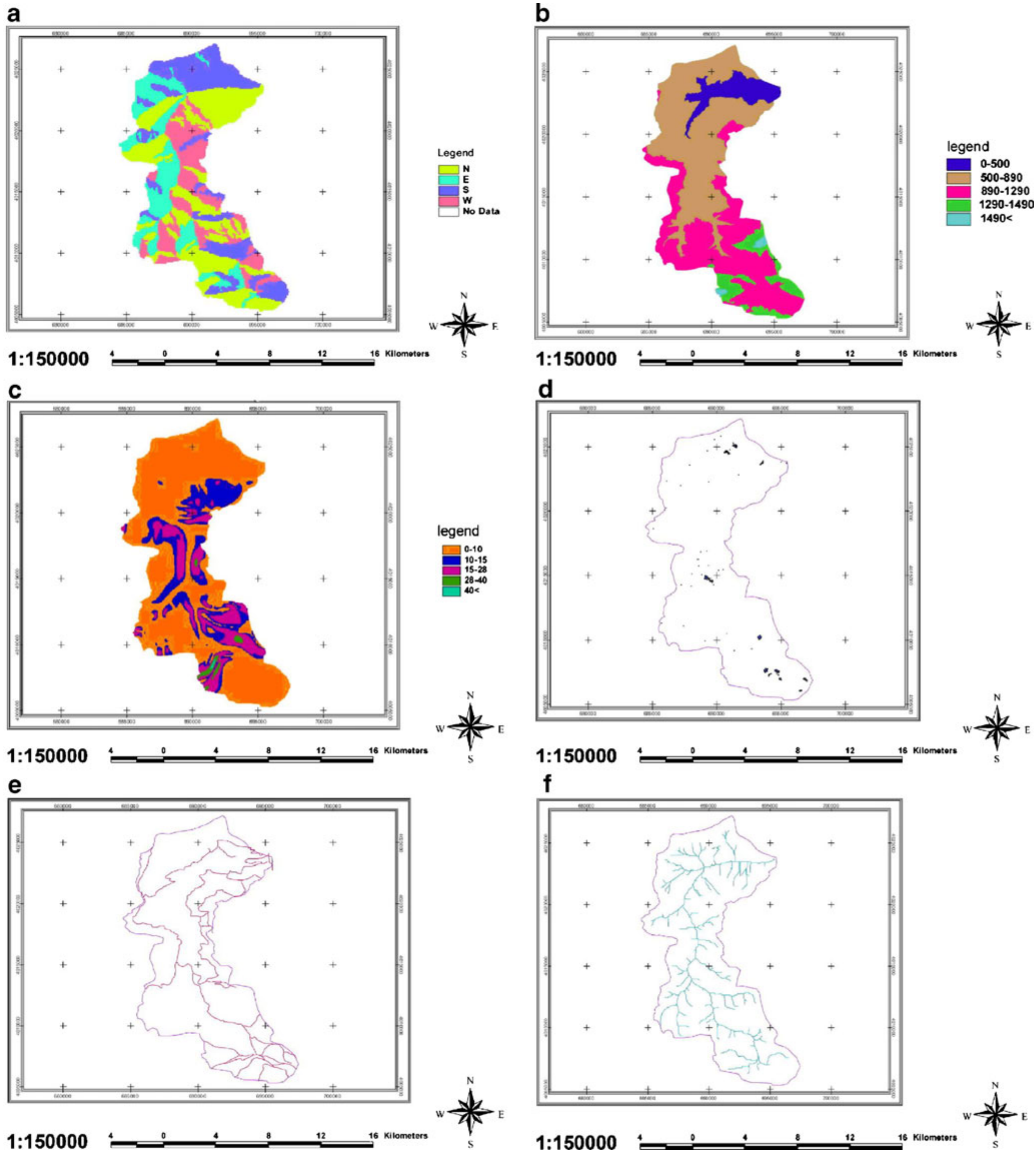

Fig. 8 The maps of physical and socioeconomical factor: **a** aspect map, **b** elevation map, **c** slope map, **d** rural area map, **e** roads map, and **f** drainage network map of the study area

day by day due to unplanned deforestation, cropland expansion, and collection of fire wood. The environmental impact of the high loss of forest are soil erosion, degradation and physicochemical properties change, climate change, biodiversity, effect on hydrologic cycle, and decrease of natural beauty.

This study could reveal the importance of integrating remote sensing and GIS in the study of land cover change detection. It provides most important information about spatiotemporal land use and cover changes. The results of this research have shown that the spatial resolution of Landsat images is still large compared with

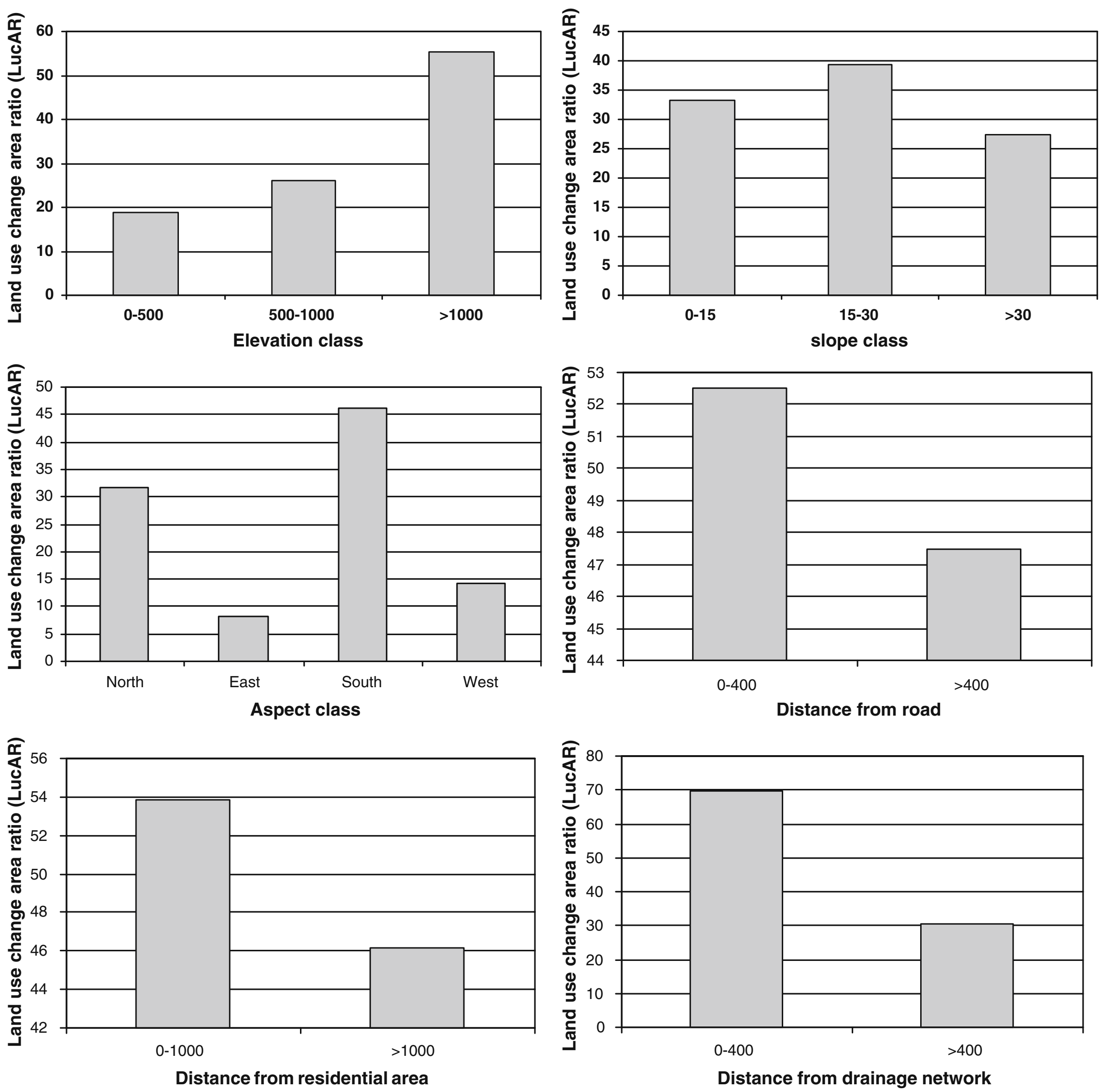

Fig. 9 Driving forces analysis using LucAR

other data sets, but there is high spectral resolution that presented a spectral reflection of all types of land cover. Also, it has a panchromatic band (15-m resolution) supporting the high spatial resolution due to the possible creation of a data fusion technique. It is suggested that more accurate mapping will be possible if satellite data with high spatial and spectral resolution and improved processing methods are used (Carlson and Sanchez-Azofeifa 1999; Giri et al. 2005; Reger et al. 2007; Richards and Xiuping 1999).

It was found that, during the study period, a very severe deforestation has taken place as a result of agricultural development projects. Driven largely by farmers' tendency for maximization of income, agricultural expansion was also found in the ecologically fragile and economically underdeveloped lands in the north of Iran. Conversion of forest into croplands also occurred in the temperate South America in the last century due to the aptitude of their soils and the adequate climatic conditions. However, the rate of agricultural expansion rises considerably due to technological changes and market circumstances at present (Baldi et al. 2006).

The shrinkage of forest was also due to the fact that the local people prepare their meals and warm their houses with fuel wood. Especially in areas surrounding permanent settlements, forest loss was common in the study area, resulting in serious soil erosion. This situation also occurred in Mexico (Geissen et al. 2009). It has been estimated that, in Mexico, around 19 million people prepare their meals with fuel wood. In the highlands of Chiapas, Mexico, a higher and increasing rate of deforestation occurred in areas surrounding permanent settlements (Ochoa-Gaona and Gonzalez-Espinosa 2000).

In the eastern highlands of Madagascar, intensive cultivation of slopes increased during 1972–2001, a significant part of which came from cultivation of grassland savanna (Vagen 2006).

Change detection studies can be useful for managers and policy makers to recognize susceptible areas which in the possibility of deforestation and degradation are more than the other areas. Also, suitable strategies can be considered to prevent deforestation and to perform sustainable yield and management in these areas.

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