Land use changes detection and spatial distribution using digital and satellite data, case study: Farim drainage basin, Northern of Iran

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Abstract

Land use change may influence many natural phenomena and ecological processes, including runoff, soil erosion, sedimentation and soil conditions. Decreasing of forest area in the North of Iran is one of the critical problems in recent years. The aims of this study are to detect land use changes between 1967 to 2002 using satellite images of Land Sat 7 ETM^+ (2002), aerial photos and digital topographic maps (1967 and 1994) and to investigate the effect of some physical and socio economical factors on land use dynamic. The forest maps of 1967 and 1994 were collected from 1:25000 digital maps in Micro Station and then Arc/View 3.2 software. The interpretation of the maps of other land uses was derived using aerial photos. ETM^+ satellite data were used to generate land use map dated 2002. The images quality assessment and georeferencing were performed on images. Different suitable spectral transformations such as rationing, PCA, Tasseled Cap transformation and data fusion were performed on the images in ENVI and IDRISI software. Image classification was done using supervised classification maximum likelihood and minimum distance classifier utilizing original and synthetic bands resulted from diverse spectral transformation and the forest area was separated from non forest area. Unsupervised classification was used to separate other types of land use. Change detection has shown that the forest area decreased between 1967 and 2002 by 2.99% from 7322.22 to 6947.23 ha. Also, the area with irrigated land farms have been increased to 202.01 ha (1.61%) and the dry land farming area decreased to 9.2%. Overlaying the map of land use change with roads and residential maps showed that by increasing the distance from roads and residential areas and villages, deforestation rate and conversion of forest to arable lands were reduced, but conversion of arable lands to released lands increased. Also, the most quantity of deforestation was observed in lower slope angle, but the dry land farming converted to release lands was observed in higher slope angle.

Keywords: Land use map, Change detection, spectral transformation, Farim Basin, Iran

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Introduction

Human population growth and associated demands are exerting an accelerated pressure on soil and water sources (Verburg *et al*, 1999, Dontree, 2003, Rasul et al, 2004). Over the past century, the area of agricultural lands has been doubled worldwide (Etter *et al*, 2006). In different parts of the world, for example, in the China, the arable lands were decreased by 1.9 %, from 96.8 to 94.9 * 10^6 ha between 1985 and 1995 (Verburg *et al*, 1999). There are some global examples in countries of Southeast Asia (e.g. Indonesia), tropical Africa (e.g. Cameron), Latin America (e.g. Brazil, Colombia, Ecuador and Bolivia) and even Northern Australia. Almost, all of the researchers believe that land use change is one of the most important factors in some of the hazards such as flood (Sullivan et al, 2004), soil erosion and sediment yield (Asselman et al, 2003, Glade, 2003), ecological and environmental dynamics and soil properties changes (Fu et al, 2000, Islam and Weil, 2000).

Decreasing of forest area in the North of Iran is one of the critical problems in recent years. In spite of the scientist and governmental agencies important warning, the accurate information and maps from the area of forests in Iran are not available. Rapid development of agricultural lands derived from forest transformation was dominated by land use dynamic especially in the last decades. To study land use change, it is necessary to create land use maps in two or more than two dates (Mapedza et al, 2003, Pirbavaghar et al, 2003, Dontree, 2003). In land use researches, remote sensing (RS) and Geographic Information System (GIS) could provide useful information for land use planning and watershed management (Cropper et al, 1999, Tipaniat and Nitin, 2003, Balaselvakumar et al, 2003, Mapedza et al 2003, Rasul et al, 2004). Using satellite data, the various, up to date, cheaper and repetitious information can be extracted (Richards et al, 1999, Darvishsefat, 2000). Remote sensing is a major source of data and information which is used in different fields. To prepare a land use map using satellite data, image classification is a powerful method of information extraction (Karteris. 1990, Kelarestaghi et al, 2006). Successful use of satellite remote sensing for land use/cover change detection depends upon an adequate understanding of landscape features, imaging systems and information extraction methodology employed in relation to aims of analysis. Land use changes are equipped due to the natural and human activities, it can be observed using current and archived through remotely sensed data (Cautam and Narayan, 1985, Verburg et al, 1999). The study of forest area decreasing in related to socio-economical and physical parameters in northern parts of Iran was conducted by

Pirbavaghar (2003) using digital topographic maps and by Rafieian (2002) using ETM^+ satellite data. Their researches showed the rapidly expanding in deforestation in the north of Iran. Tipaniat and Nitin (2003) developed a RGB-NDVI to display and quantify mangrove forest changes using three dates of Land Sat satellite imagery. Composition of Land Sat MSS in 1972, Land Sat TM5 in 1989 and Land Sat ETM^+ in 2000 and three dates of aerial photos in 1989, 1991 and 1996 were used by Dontree (2003) to investigate land use dynamic in the regions of Thailand. Forest land use change and spatial distribution in related to some environmental characteristics using GIS were studied by Puzzola and Folving (1999). Cropper et al (1999) studied the factors which affect the location of deforestation in Northern Thailand. The authors 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 this likelihood.

The aims of this study were first, to detect land use changes and transformations between 1967 and 2002, second, to evaluate of ETM^+ images potential for land use mapping and third, to investigate the effect of physical (slope) and socio economical (roads and residential areas) factors on land use transformation.

Material and Methods

Study Area

The Farim Drainage Basin (study area) is located in the North of Iran, Mazandaran province at the forest area called Hyrcanian forests, with area about 125.5 Km^2 (Figure 1). Height values in the area vary from about 637 m above sea level (a.s.l) in the east to 1765 m a.s.l in the south. The region has an average annual rainfall of 552.7 and annual minimum and maximum temperature are as 7.7 and 21.1°c, respectively. In the study area, the most serious forest species are *Fagus orientalis, Carpinus betolus, Quercus castanifolia, Alnus glotinisa,* and *Acer velutinum*. The study area's staple land uses are forest, dry land farming of barely and wheat, rice irrigated lands, release lands and residential areas. This region is located into 3992679.16 to 4009007.68 North Latitude and 693724.45 to 707472.61 East Longitude.

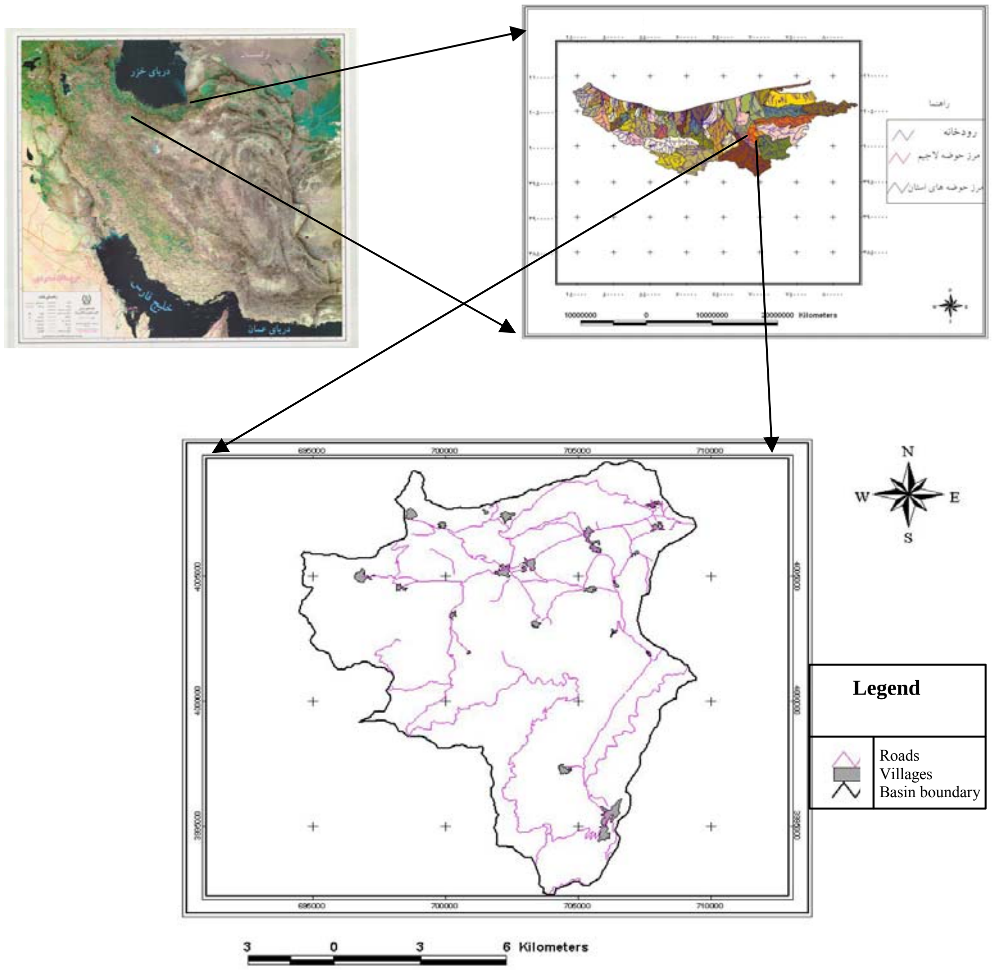


Figure 1: Location of the study area in Iran, Mazandaran Province

Data Sources

Data in this study are composed of digital topographic maps dated 1967 and 1994 and also two dates of aerial photos in 1967 and 1994. The names of these maps are Sarkam, Sangdeh, Margav and miana with 1:25000 scale. ETM^+ satellite data were used to generate land use map 2002. It was preferred to use Land sat ETM^+ data (April 29, 2002) after 1G level processing (geometrically and radiometrically corrected). This is worth to mention that the data are for growth season under clear sky.

Preparing land use map 1967 and 1994

The forest maps of 1967 and 1994 were extracted from 1:25000 digital topographic maps in Micro Station software and imported to Arc/View 3.2 software. Therefore, the forest area maps 1967 and 1994 were created and values of 0 and 1 were labeled to non forest and forest area, respectively. Using contemporary aerial photos interpretation were derived from other land use maps including Dry land farming, irrigated land farming, abandon areas, water pond and village area, dated 1967 and 1994, so the final land use maps were prepared using combination of above mentioned single maps.

Preparing land use map 2002

Using ETM^+ satellite data, land use map dated 2002 was generated by following different stages.

Stage 1: Image quality assessment and rectification

The quality assessment performed on the images. In the quantitative analysis, the mean of DN in the Caspian Sea homogeneous region with dimension 200*300 pixels were selected and analysed. An accurate digital topographic map and so a fine digital elevation model was used for georeferencing of images.

Stage 2: Image enhancement

Different appropriate transformations were performed on the images in order to improve information extraction. These transformations were rationing, PCA, Tasseled Cap and data fusion with HSV technique carried out in ENVI and IDRISI software (Kelarestaghi et al, 2006). The wavebands representing of near-infrared and visible-red region were extracted from Land Sat ETM^+ images. The Normalized Difference Vegetation Index (NDVI) is used to transform multi-spectral data into a single image band which representing vegetation distribution. Data fusion was done as the availability of the simultaneous panchromatic bands with the multi-spectral bands gives the best opportunity to generate effective multi spectral bands with higher spatial resolution. We also applied principal component analysis in which correlation matrix between different bands was prepared for selecting different bands for image classification.

Stage 3: Image classification

Training samples were collected for image classification and forest area mapping, using field works, digital topographic maps and interpretation of false color composite. Image classification was carried out using supervised classification under maximum likelihood and minimum distance classifier with original and synthetic bands (resulted from diverse spectral transformations). This resulted to separate the forest and non forest area. For this purpose, all multi spectral bands (Band 6 was ignored because of its thermal characteristics and low spatial resolution 60m), fused bands and synthetic bands such as those derived from PCA, ratios and Tasseled Cap were used by classification mechanism. Also, unsupervised classification was conducted to classify other land use types using interpretation of many false colors compositions and above transformations. Finally, single map of above land use combined to prepare land use map 2002.

ETM^+ images potential evaluation

One of the study aims was to assess potential of images in land use mapping. An accurate ground truth map was prepared through field working under systematic random sampling to evaluate ETM^+ images potential for land use mapping. Sample points covered on the final land use map were used for recording of land use type in the field. The ground truth points covered the whole of the study area was about 2.72% of the total area of the images (Figure2) and the location of these points was recorded with GPS in the field. As some ground control points were unavailable, the nearest available points were selected. After classification, the resulted maps were filtered with majority filter in a 5*5 moving window to remove noise. Finally, to assess the capability of data source in distinction of different land uses, the resulted maps from classification were compared pixel by pixel to the ground truth map. For representing of accuracy, the rate was used from some criteria of accuracy such as overall accuracy, producer accuracy and Kappa coefficient (Equations 1,2 and 3).

$$\%\text{Overall accuracy} = (n_{ci}/N_i) * 100 \quad \text{Equation1}$$

Where: n_{ci} = total pixels classified accurately

N_i = total pixels of classification

$$\%\text{Producer accuracy} = (n_{cix}/N_{ix}) * 100 \quad \text{Equation2}$$

Where: n_{cix} = total pixels classified accurately in category X

N_i = total pixels category X in ground truth map

$$\text{Kappa coefficient} = \Theta_1\text{-}\Theta_2 / 1\text{-}\ \Theta_1 \quad \text{Equation 3}$$

Where: Θ_1 = overall accuracy

Θ_2 = Chance agreement

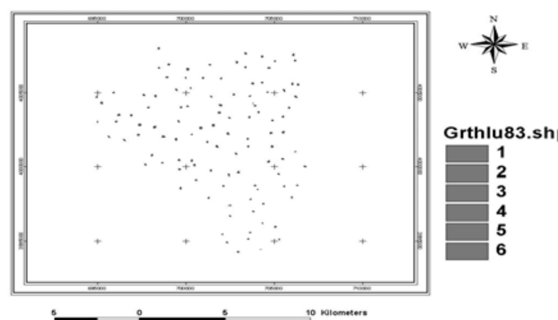


Figure 2: Location of training samples collection

Change detection

Three maps of land use in 1967, 1994 and 2002 were compared using change detection extension of Arc/View 3.2 software. Thereafter the land use change detection was accomplished and analyzed. The land use change map overlaid with slope, distance from roads and residential areas maps in order to investigate the effects of these factors (Figure 3).

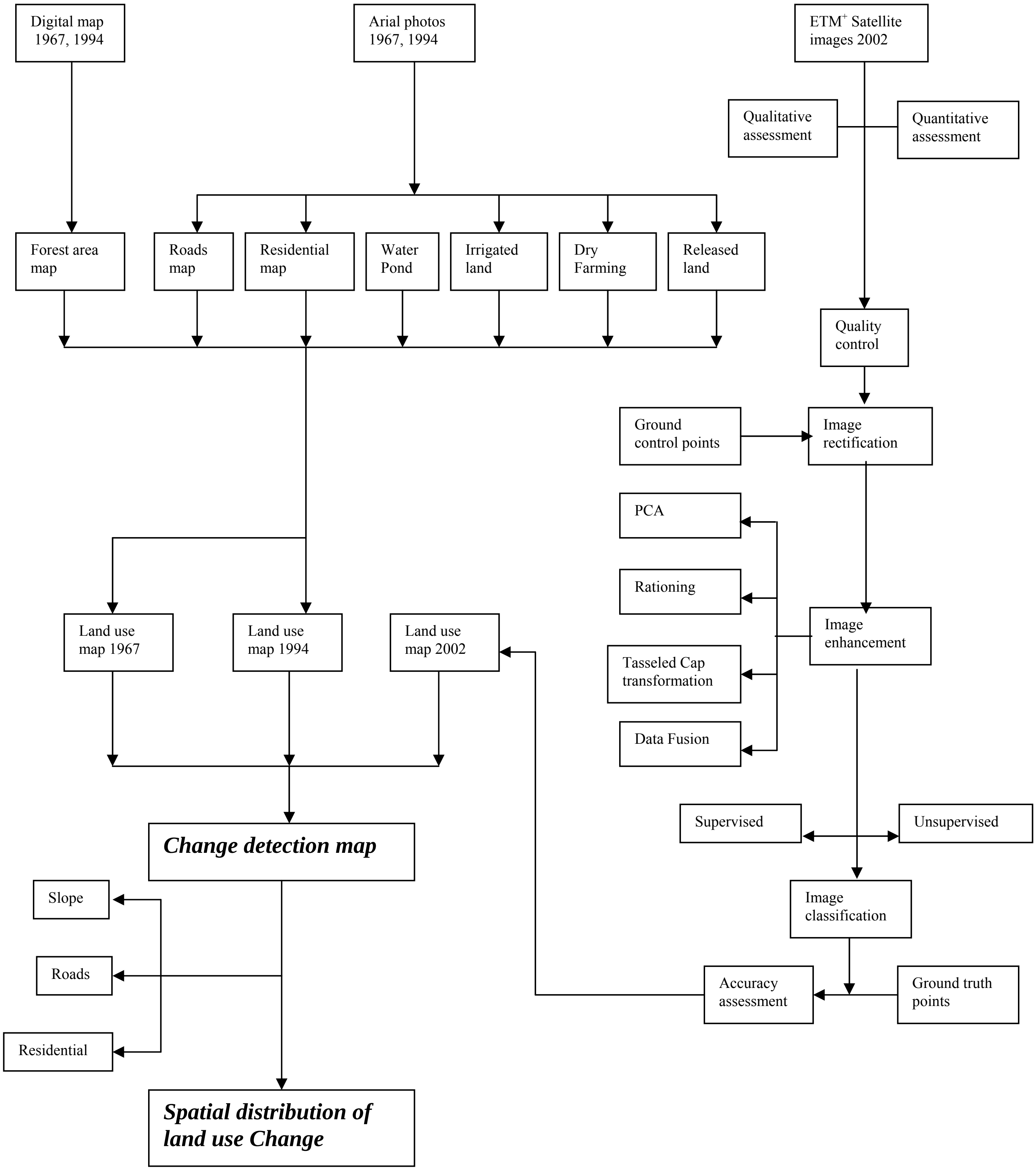


Figure 3: The stages of methodology as a flow chart

Results and Discussion

The land use maps of two dates 1967 and 1994 which extracted from digital maps and aerial photos interpretation are shown in figures 4 and 5.

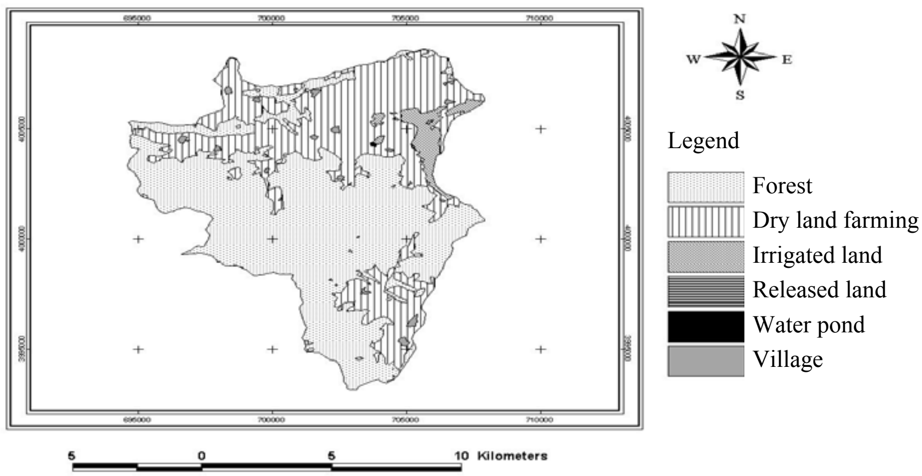


Figure 4: Land use map date 1967

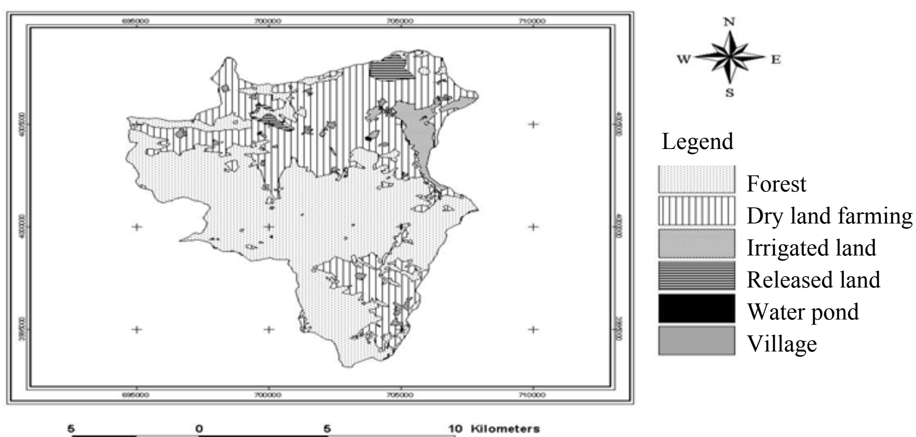


Figure 5: Land use map date 1994

<u>Image enhancement and classification</u>

Quantitative and qualitative analysis indicated that the rate of striping error was less than 1 pixel. Therefore, quality of the image was very good and no radiometric and striping error was found. Also, the images were rectified with 32 ground control points and the RMS error was 0.71 pixels.

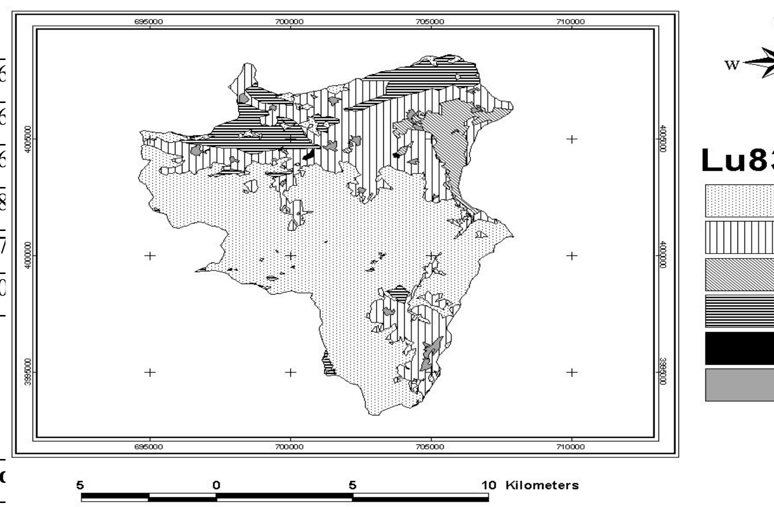
Overlaying the vector layers such as roads and drainage network with corrected images showed that the above images were conformed perfectly. The NDVI values indicated the amount of green vegetation percentage in the pixel and classified for more extraction of information. Also, the brightness and the greenness components resulted from Tasseled Cap transformation was used in the classification processes. The results of PCA showed that band 4 has a low correlation with the other bands (Table 1). So, the implementation of different bands in the classification processes was done as elective separately. The results of the maps accuracy assessment are shown in table 2. The results implied that combination of the bands $PCA_{1,2,3}$, $PCA_{5,7}$, B_4 , NDVI, Bright in the maximum likelihood classifier with having 93.02% overall accuracy and 0.841 Kappa index, has presented the most accurate map of forest area. Using unsupervised classification utilizing synthetic bands and false color composite and field works, the other land uses were extracted and the land use map dated 2002 was generated (Figure 6).

Table 1: correlation matrix resulted from PCA transformation

Correlation Matrix	Band1	Band2	Band3	Band4	Band5	Ba[illegible]
Band1	1.000000	0.997032	0.974508	0.922062	0.962030	0.96
Band2	0.997032	1.000000	0.985312	0.903575	0.955628	0.96
Band3	0.974508	0.985312	1.000000	0.826551	0.917442	0.96
Band4	0.922062	0.903575	0.826551	1.000000	0.960558	0.88
Band5	0.962030	0.955628	0.917442	0.960558	1.000000	0.97
Band7	0.963390	0.967811	0.963887	0.884229	0.975426	1.00

Table 2: The accuracy assessment of forest area mapping resulted from ETM+ images

Bands	Maximum likelihood method		Minimum d[illegible]	
	Kappa coefficient	Overall accuracy	Kappa coefficien[illegible]	
$B_{1,2,3,4,5,7,8}$	0/814	90/72	0/641	82/01
CA_{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
$_3$, PCA_{5-7},B_4,NDVI,Bright	0/841	93/02	0/675	85/96
A_{1-3}, PCA_{5-7},B_4,NDVI	0/373	69/56	0/341	63/52
$_{-3}$, PCA_{5-7}, NDVI,Bright	0/714	85/93	0/604	79/40
Fus_3,Fus_5, NDVI,Bright	0/819	91/56	0/669	83/8
Fus_3,Fus_5, NDVI,Bright,B_8	0/832	92/65	0/671	85/4
$Fus_{1,2,3,5,7}$	0/806	90/18	0/667	83/2



LEGEND:
PCA_{1-3}: First component of 1,2,3 bands PCA
NDVI: normalized different vegetation index
PCA_{1-7}: First component of 1,2,3,4,5,7 bands PCA
$Fus_{1,2,3,4,5,7}$: Bands 1,2,3,4,5,7 fused with band 8
$B_{1,2}$: Bands 1,2
PCA_{5-7}: First componen
Bright: Brightness comp
Fus_3: Band 3 fused with
$B_{1,2,3}$: bands 1,2,3

Figure 6: Land use map date 2002

The results of matrix error derived from accuracy assessment of the land use map dated 2002 with ground truth map have shown in the table 5. Results have shown that the overall accuracy and Kappa index were 91.5% and 0.826, respectively.

Also, the results of overlaying and change detection in period of 1967-2002 have shown in the tables 3 and 4 and figure 7.

Table 3: Land use changes between 1967 and 2002

Land use	1967		1994		2002		Land use change		
	Area	%	Area	%	Area	%	1967-1994 Changed area	1994-2002 Changed area	1967-2002 Changed area
Forest	7322.22	58.34	6857.28	54.64	6947.23	55.43	-464.97	+89.95	-375.02
Dry land	4727.61	37.67	4863.33	38.753	572.91	28.46	+135.72	-1290.42	-1154.70
farming	389.52	3.11	456.12	3.63	591.53	4.71	+66.6	+135.41	+202.01
Irrigated farming	-	-	226.08	1.80	1240.15	9.88	+226.08	+1014.07	+1240.15
Released land	3.96	0.03	5.76	0.05	15.30	0.12	+1.18	+9.54	+10.72
Water resources	106.83	0.85	141.57	1.13	183.02	1.46	+34.74	+41.45	+76.19
Rural land	12550.14	100	12550.14	100	12550.14	100			
Total									

* The area is as Hectare

The results from analysis of land use change detection in the study period have shown diverse land use dynamic (Table 4, figure 7). The most dominant land uses dynamic were transformed from forest to dry land farming and vice versa, forest and dry land farming to release land. Table 4 shows that in fact about 8.7 % of forested land was lost between 1967-2002 (combination of the area forest to dry land farming and irrigated lands) and then 5.7 % was gained.

Table 4: The results of Land use change detection between 1967 and 2002

Land use Change types	Transition period					
	1967-1994		1994-2002		1967-2002	
	Area	%	Area	%	Area	%
Forest to Dry land farming	659.07	5.25	172.08	1.37	831.15	6.62
Forest to Released lands	3.69	0.03	255.96	2.04	259.65	2.07
Dry land farming to Forest	197.82	1.58	515.70	4.11	713.52	5.69
Dry land farming to irrigated lands	64.17	0.51	134.55	1.07	198.72	1.58
Dry land farming to water resources	0.8	0.01	9.54	0.08	11.34	0.09
Dry land farming to Released lands	222.57	1.77	762.48	6.08	985.05	7.58
Dry land farming to rural lands	63.36	0.5	61.74	0.49	125.1	0.99

- The area is as Hectare

Table 5: Error matrix and producer accuracy resulted from accuracy assessment of land use map 2002

Land use	Forest	Dry land farming	Irrigated land	Released land	Water resource	Villages	Total	Producer accuracy
Forest	1048	78	0	0	0	0	1126	93.07
Dry land farming	40	352	0	6	0	4	402	87.56
Irrigated land	0	2	114	0	0	0	116	98.27
Released land	16	12	0	196	0	0	224	87.50
Water resource	0	0	0	0	8	0	8	100
Villages	0	6	0	0	0	50	56	89.29
Total	1104	450	114	202	8	54	1932	

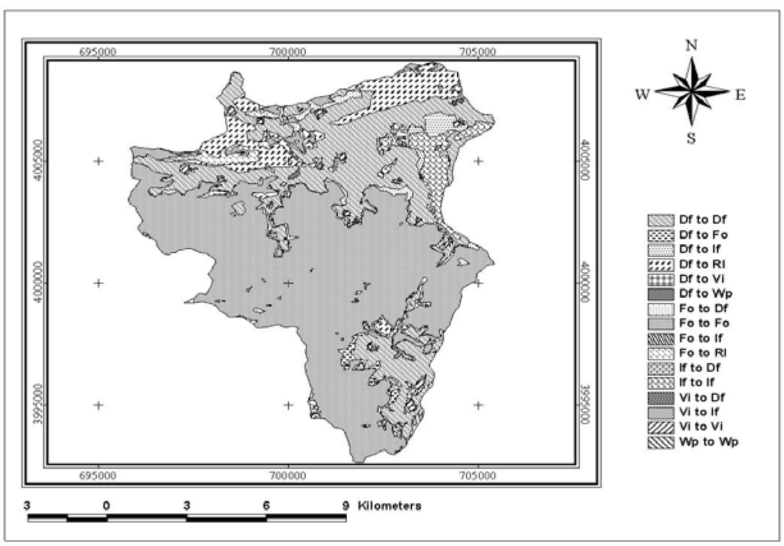


Figure 7: Land use change detection map

LEGEND:
Df = Dry farming, Fo= Forest, If= Irrigated Lands,
Rl= Released Lands Vi= Village, Wp= Water Pond,

Conclusion

Combination of digital topographic map and aerial photos is useful procedure to prepare land use map, especially for last decades. Digital maps have 63 different layers including roads, rail way, residential area, forest and etc. Interpretations of these maps have done as digital under Micro Station computer software. This method that was used by Pirbavaghar (2003), presented very good results to prepare forest land mapping. The contemporary aerial photos interpretation revealed this result.

It has been suggested that more accurate mapping will be possible if satellite data with high spatial and spectral resolution and improved processing methods are used (Richards et al, 1999, Naseri et al, 2003, Rafieian, 2002). The results of this research have shown that although, the spatial resolution of land sat images is still large compared to other data sets, but there is high spectral resolution that presented spectral reflection of all types of land cover. Also it has panchromatic band (15 meter resolution) supporting high spatial resolution due to it make possible data fusion technique. Accuracy assessment of the prepared maps overlaid to ground truth map implied that the maximum likelihood classifier gave better results than the minimum distance classifier. The results of Naseri (2003) and Rafieian (2003) carried out in Kerman and Mazandaran provinces, respectively, have shown better results for minimum distance classifier for sparse forest (Kerman) and maximum likelihood classifier for dense forest (Mazandaran). As for maximum likelihood based on normal distribution, high frequency of data is very important. Therefore, that can be concluded in the north of Iran with dense vegetation cover; maximum likelihood classifier has presented better results than other classifier algorithms.

Change detection and monitoring involve the use of multi-data images or aerial photos to evaluate differences in land cover due to environmental conditions and human actions between the acquisition dates of images. Change detection has shown that the forest area decreased and increased between 1967 and 2002 by 8.7 % and 5.7 %, respectively. In the study of land use change not only deforestation rate is important, but also that is necessary to know the age in which forest lands was lost or gained. It is clear that 8.7 % of lost one was likely mature, while the 5.7 % was in the form of a new young forest which will have very different effects on ecological processes such as soil erosion, run off generation and soil properties. By virtue of the intense deforestation and since these forests have unique economical and environmental values, so it is necessary to protect them. Dontree (2003), Verburg et al (1999), Mapedza et al (2003), Islam and Weil

(2000), Pirbavaghar et al (2003) and Rafieian (2002) gained similar results in their studies. Also, the area with irrigated land was increased to 202.01 ha (1.61%) because of high demands for food. The increased irrigated lands was located in lower slope at the near of river to supply water need. The main reason for the decline in forest lands is the conversion of them to dry land farming, released lands and building area. Also, the main cause for decreasing in dry land farming (1154.7 ha in this period) is the loss of land as result of degradation, top-down plowing, steep land cropping and migration of young population (going to work) toward city centers. Overlaying the map of land use change with roads and residential maps showed that by increasing the distance from roads and residential areas and villages, deforestation rate was reduced, but conversion of arable lands to released lands was increased. In these areas, because of easy of access, forest exploitation is overdone. Also, in this study, the most quantity of deforestation was observed in lower slope angle, but in higher slope angle the dry land farming was converted to release lands. The main reason for this conversion is easy access for human and livestock. The research findings of Dontree (2003), the effective factors in convert dense forest to disturbed forest and agricultural lands into 1989-1996 period, was similar to ours. Change detection studies can be useful for managers and policy makers to recognize susceptible areas in which the possibility of deforestation and degradation are more than the other areas. Also, suitable strategies can be considered to protect deforestation and to perform sustainable yield management in these areas.

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