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A Comparative Analysis and Evaluation of Neka River Basin Deforested Land from 1977-2006 using MSS, TM and ETM Satellite Images

Hassan Ahmadi and Mehdi Pourtaheri
Department of Geography, Tarbiat Modares University, Jalal Ale Ahmad Highway,
P.O. Box: 14115-111, Tehran, Iran

Abstract: The main objective of this study is to find out the loss of forest area through analyzing it in different periods. In general, deforestation can be regarded as one of the most important elements in LULC and the scenario of global changes is taking place around the world. Therefore, it is worth assessing its trend and the rate at which it is taking place now. These changes will play a significant role in bringing about some changes in regional climate and accordingly on biodiversity. The loss of forest in Iran is going on since 1960 onwards in the Neka river Basin. The estimation of forest loss was not reported to be done by using Satellite data. The changes occurring in forest cover were reported by a series of four satellite images in different time intervals by using Remote Sensing (RS) and GIS such as Land satMSS of 1977, Land satTM of1987, ETM 2001 and ETM^{+} 2006. The forest covers were analyzed and maps from four temporal satellite datasets were prepared. Based on 1977, 1987, 2001 and 2006 satellite data interpretation, the forest cover was converted to geospatial database. According to the results obtained from these images, there was a decrease in forest area (7096.63), productive forest area, as well as degraded forest area. However, the total forest area showed a decrease in the first period (1977-1987) although an increase was reported again during the second period (1987-2001) to 2418.82 hectares (3.5% of the study area), this trend continued even between 2001-2006 and the mixed forest cover increased by856.08 hectares (1.31%). This increase was due to few hectares of mixed forest area was converted into manmade forest.

Keywords: Deforestation, Iran, land use, Neka basin, remote sensing

INTRODUCTION

Anthropogenic disturbances such as deforestation, soil erosion and losses of productive land covers and biodiversity have increasingly played a significant role in threatening ecosystem productivity and health on the local and global scales (Kilic *et al*., 2006, 2004). In addition, the change in land use/land cover can play an important role in environmental changes and contribute to global change and biodiversity loss (Chen *et al*., 2001; Wu *et al*., 2006). Furthermore, according to Chen *et al*. (2001), changes in land-use and land cover can have some influence on natural resources, especially forest ecosystems, by their impacts they can have on soil and water quality and climatic systems (Chen *et al*., 2001). Kilic *et al*. (2004) added that LULC and the changes in forest cover can be considered as the most popular reason for losing biological productivity and biodiversity in aquatic and terrestrial landscapes.

Remote sensing with multi-temporal high resolution satellite data has become a strong tool for monitoring aspects such as vegetation cover, forest biomass, soil degradation, urban expansion and more generally for most types of LULC changes (Gueler *et al*., 2007). Several studies have used remote sensing to map patterns of deforestation and to analyses the rates of forest cover change in the tropics and elsewhere (Hall *et al*., 1991; Kimes *et al*., 1998; Stephen and David, 2003; Wood and Skole, 1998). Satellite image classification, change analysis (Armenteras *et al*., 2006; Mas *et al*., 2004) and econometric modeling are used to identify the rates, and drivers of deforestation in global hotspots of biodiversity and tropical deforestation (Chowdhury, 2006) re-viewed spatial methodologies aimed at identifying driving forces of land use change and applied one such methodology to understand deforestation in Mexico. Monitoring of change (be it deforestation or reforestation) is frequently perceived as one of the most important contributions of remote sensing technology to the study of global ecological and environmental change (Apan and Peterson, 1998; Roughgarden *et al*., 1991). Map comparison was co-registered and these maps are integrated into a GIS database, identifying differences between the two dates and quantification of these changes; is a straightforward way to assess changes. However,

Corresponding Author: Hassan Ahmadi, Department of Geography, Tarbiat Modares University, Jalal Ale Ahmad Highway, P.O. Box: 14115-111, Tehran, Iran

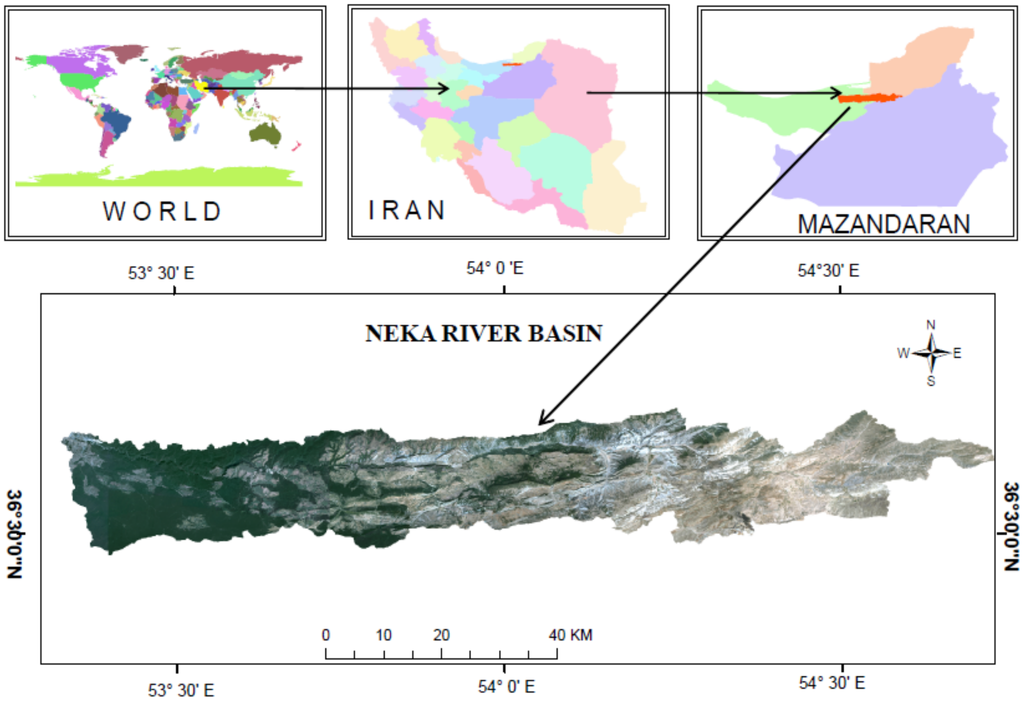

Fig. 1: The location of the Neka River basin

while applying map comparison, inherent features such as scale, classification scheme, accuracy and mapping methods were taken into account (Comber *et al*., 2003, 2004; Fuller *et al*., 2003; Petit and Lambin, 2002). Forest cover changes are also the most common cause of loss of biological productivity and biodiversity in aquatic and terrestrial landscapes (Kilic *et al*., 2004).

In addition, land cover change can be regarded as one of the most important causes of changes in the Earth System. Among all land cover changes, deforestation is more significant due to the magnitude of the resultant transformations in biophysical and ecological properties. Furthermore, regarding the relationship between forest cover change and other factors, we can name factors such as the global carbon cycle, the hydrological cycle changes, a recognition of the causes of changes in biodiversity and in understanding the rates and causes of land use change (Band, 1993; Houghton, 1999; Pandey, 2002a, b). In addition, a number of national and international programs have focused their attention on routine monitoring of global forest changes such as the Global Observation for Forest and Land Cover Dynamics (GOFC-GOLD) (Skole *et al*., 1998; Townsend *et al*., 2004), Global Climate Observing System (Bradley *et al*., 2004) and the U.S. Global Change Research Program (Wilbanks and Kates, 1999). Land sat-class data which have principally been utilized for forest change detection at relatively local scales (Skole and Tucker, 1993; Steininger *et al*., 2001; Tucker and Townshend, 2000; Zhang *et al*., 2005) can be counted as some of the few studies which focused on wall-to-wall change detection at national scales. The United Nations Food and Agriculture Organization (FAO) Forest Resource Assessment (FRA) collected a small number of Land sat-based sampling of change detection to contribute to the estimation of global tropical forest change rates taking place during the years 1990-2000. Some other researchers such as (Czaplewski, 2003; DeFries *et al*., 2002) calculated global tropical forest change based on AVHRR data along with regional rates of changed estimated from Land sat data. Although the last two studies made use of selected Land sat imagery and products, they were not utilized to carry out wall-to- wall change mapping for the whole study area.

The objective of this study is to generate the total loss of forest area using different time period satellite data and also to establish the accuracy assessment of the work.

Study area: Neka Watershed is situated in the northern part of Iran. The Neka River basin is one of the largest watersheds in the Iranian province of Mazandaran. The Neka River is flowing down the northern flank of the Alborz Mountains towards the Caspian Sea and it goes through Neka City and divides this city into two parts - eastern and western parts. The Neka watershed is covered with Quaternary formations. Climate is temperate with mild winter and hot summer. The study area is used as rain-fed agriculture and rangeland of cattle-grazing. The geographical location of the Southern Neka basin is shown in Fig. 1.

MATERIALS AND METHODS

Materials: In order to classify forest cover change of the area under study during a period, deforestation by human activity was identified as an important driver of environmental degradation, Land sat MSS, TM and ETM^+ satellite imageries were selected. The main data used in the research included four Land sat satellite images acquired for the years 1977 (MSS), 1987 (TM) and 2001 and 2006 (ETM^+). A brief description of the satellite images is shown in Table 1.

Land sat MSS (1977), Land sat TM (1987), ETM^+2001 and ETM^+ 2006 images were downloaded from the Global Land-Cover Facility site hosted by the University of Maryland (Glcfapp. umiacs.umd.edu). Land sat images were obtained during the dry season because it can make us sure that the images are completely free of any clouds and therefore enable us to distinguish forest from non-forest areas, with a greater degree of accuracy. The image, which was free of defect and cloud, had the highest quality. Summer and early fall image data were used for this study. In order to separate the forest cover boundary from other types of land uses, Aster DEM of 2009 was used, in addition, Land sat MSS, TM and ETM^+ data were also selected. This enabled us to make the best use of the better spectral and spatial resolution for the dates available in the area selected for the purpose of this study. Topographic maps of 1/25,000 scales produced by the Geographical Association of Iran were used for rectification and forest cover type map that were originally generated from both the stereo interpretation of black and white aerial photos with an average 1/25,000 scale. Later, ground measurements with 250×250 sampling points were used for "ground-truth". Apart from topographic map, the Google earth image was used to perform overlay analysis. The accuracy assessment testing was done keeping topographic map and the Google image for classification of land use from MSS, TM and ETM^+ images.

Methodology: Subsets of satellite images were rectified first for their inherent geometric errors using 1/25,000 topographic maps in Universal Transverse Mercator coordinate system (ED 50 datum). Registration was carried out by using distinctive features such as road intersections and stream confluences which are clearly observable in the image. The methods of first-degree rotation scaling, translation transformation function and the nearest neighbor re-sampling were utilized for the purpose of this study. This re-sampling method uses the nearest pixel without any interpolation to create the warped image (Jia and Richards, 1994). A total of 40 ground points were used for registration of Land sat MSS image sunset with the rectification error of less than 1 pixel. The TM and ETM^+ images were registered to the already registered Land sat MSS image through image-to-image registration technique with rectification errors of 0.2 and 0.6 pixels, respectively. A very high level of accuracy in geo-referencing of the images was possible because of the use of digital source as the reference data that allowed zooming to the nearest possible point location (Gautam *et al*., 2003).

Pre-processing of the satellite data: It is necessary to correct the images geometrically, radio metrically and topographically before they could be used to assess changes in forest cover. The orthorectified Land sat satellite data (UTM/WGS 84 projection) provided by Global Land Cover Facility was downloaded from the website (http://glcfapp.umiacs.umd.edu:8080/esdi/) geometric correction was done using orthorectified Land sat images. False color composite images were produced using several band combinations (Fig. 2). All datasets were corrected with sub pixel level accuracy Image analysis.

All image processing, classification and GIS analysis were carried out using the ERDAS Imagine™ 9.1 image processing software and Arc GIS 9.3. Supervised maximum likelihood classification method was used for the classification of all the images. Training sample was derived from the satellite images using reference maps. Maximum likelihood classifier assigns a pixel to a particular class based upon the covariance information and a substantially superior performance is expected from this method compared to other approaches (Jia and Richards, 1994). Ground reference data was gathered from more than 100 ground truth points as signatures. The points were sampled on the cover type (stand) maps of Neka river watershed

Table 1: Data source for land use classification and accuracy assessment

Data type	Number of bands	Pixel resolution	Observation data	Source	Purpose
Land sat 2(MSS)	4	57×57	06.06.1977	GLCF	Classification
Land sat 5(TM)	7	28.5×28.5	16.06.1987	GLCF	Classification
Land sat 7(ETM+)	8	28.5×28.5	31.07.2001	GLCF	Classification
Land sat 7(ETM+)	8	28.5×28.5	10.06.2006	GLCF	Classification
Topography map	-	1:50000	1965	The Iranian geographical organization	Accuracy assessment
Topography Map	-	1:25000	1994	The Iranian geographical organization	Accuracy assessment
Google(Spot)	3	1.50 X 1.50	2010	Google earth	Accuracy assessment
Band 8)Land sat 7	1	14.5	2001-2006	GLCF	Accuracy assessment
AsterDEM	-	29	2009	Aster GDEM	Boundary delineation

Table 2: A description of forest cover classes

Forest cover classes	Description
Forest (F)	Temperate Dense Rain Forest with broad canopy and Manmade forest
Dense vegetation (DV)	Agriculture land with wheat and patches of forest vegetation and dense pasture land
Low vegetation (LV)	Low pasture land with patches of fallow land and settlements
Bare soil (BS)	Land without vegetation left fallow and barren with rock surface in patches.

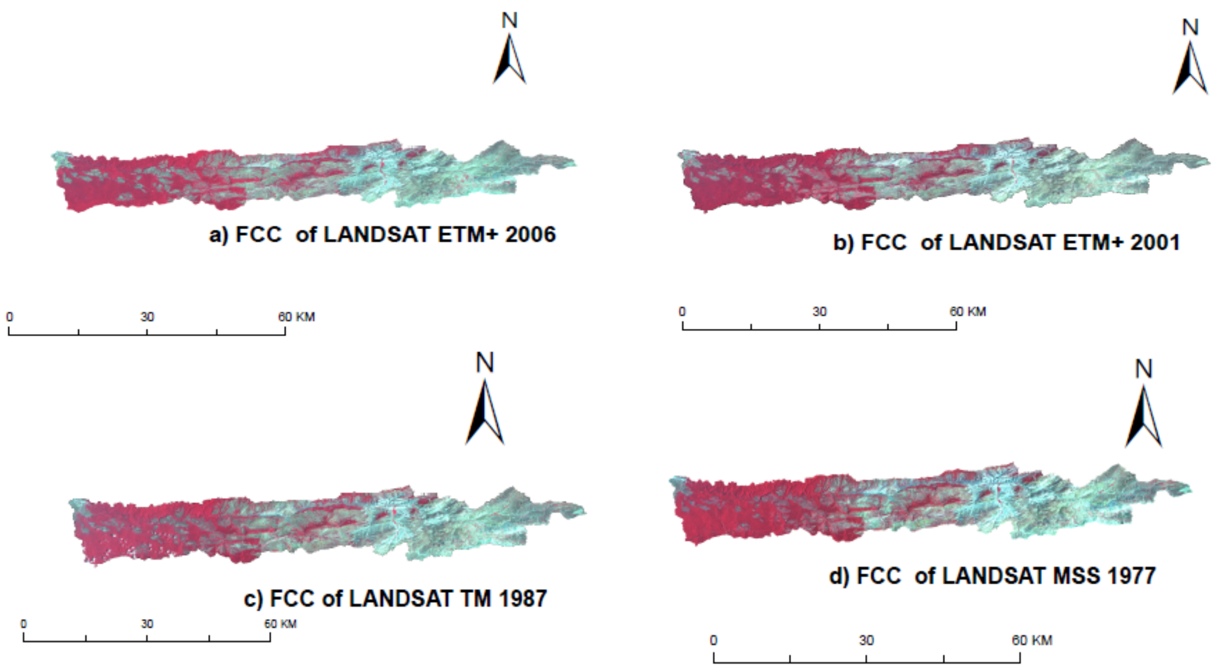

Fig. 2: False colour composite (FCC) MSS, (a) Land sat 1977, (b) TM 1987, (c) ETM 2001 and (d) ETM 2006 image of Neka delineated watershed area of IRAN

was finalized from Topography map and through Google image corrections. The classified images were checked to control the accuracy using ground data points that are not used in the classification process. In order to investigate changes taking place during the years of 1977, 1987, 2001 and 2006 for the purpose of producing forest cover maps, the following four classes were considered in image classification: (1) Forest (F); (2) Dense vegetation (DV); (3) Low Vegetation (LV); (4) Bare Soil (BS); A brief description of each of the forest cover classes is given in Table 2.

As Antrop (2000) believes, the magnitude and the direction of changes in the landscape are considered to be the most important factors relating to landscape evolution. Therefore, the comparison of the changes of each forest cover types from 1977, 1987 to 2001 and 2006 was analyzed by means of the transition from one forest cover to other forest cover. The forest cover polygon themes for 1977, 1987 to 2001 and 2006 were overlaid using Arc GIS 9.3 and the areas which changed from each of classes to any of the other classes was computed.

Accuracy assessment: Prior to accuracy assessment for visual classification of different classes, data fusion was done using ETM$^+$ 2001 and 2006 with 8 band ETM data adopting resolution merge technique as shown in the Fig. 3 Similarly, the Google image was used to enhance visual clarity as shown in the Fig. 4.

Accuracy assessment means identifying a set of sample locations (ground verification points) that are visited in the field. In order to do accuracy assessment, the forest cover found in the field is compared to the cover mapped in the image for the same location by means of error or confusion matrices. As far as this study is concerned, Accuracy Assessment was assessed by using an error matrix for the years 1977, 1987 to 2001 and 2006 and accordingly the classification was supervised by using four measures of accuracy including overall accuracy, user's accuracy, producer's accuracy and Kappa coefficient. A total of 40 random points for each class were taken to determine the accuracy of the classification method. Accuracy was assessed in terms of errors of omission (producer's accuracy) and commission (user's accuracy) and Kappa coefficient. The overall map accuracy was calculated by dividing the total correct classified pixels, (major diagonal of the error matrix) by the total number of pixels in the error matrix. Overall accuracy did not take into account the proportion of agreement between

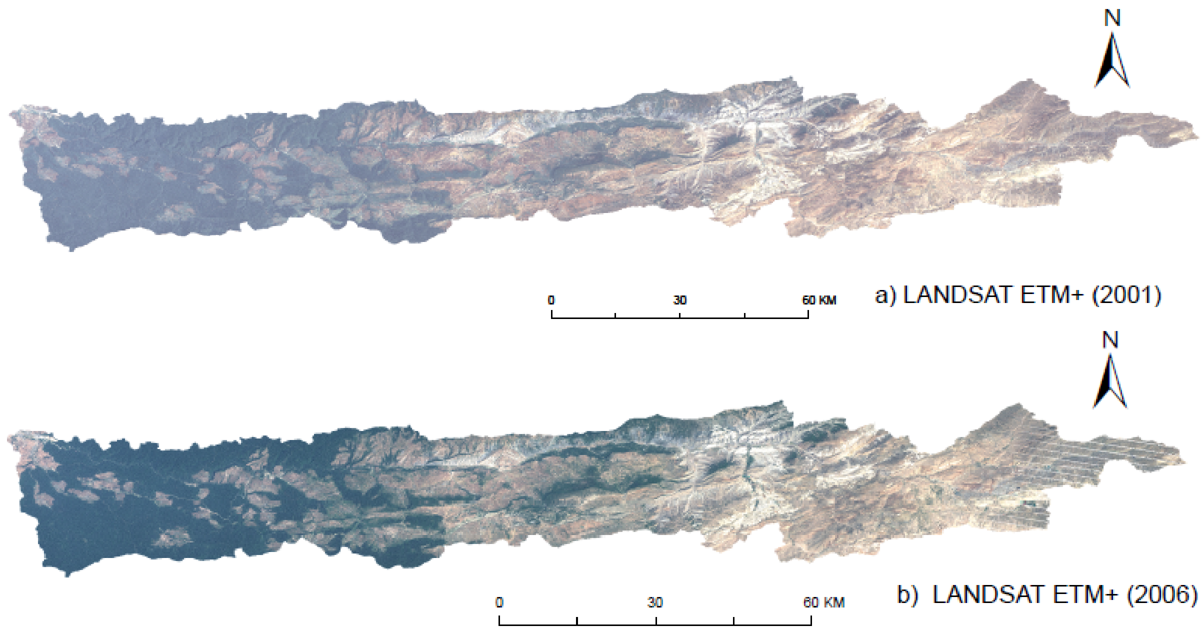

Fig. 3: Data fusion for Neka river basin (ETM 2001-2006)

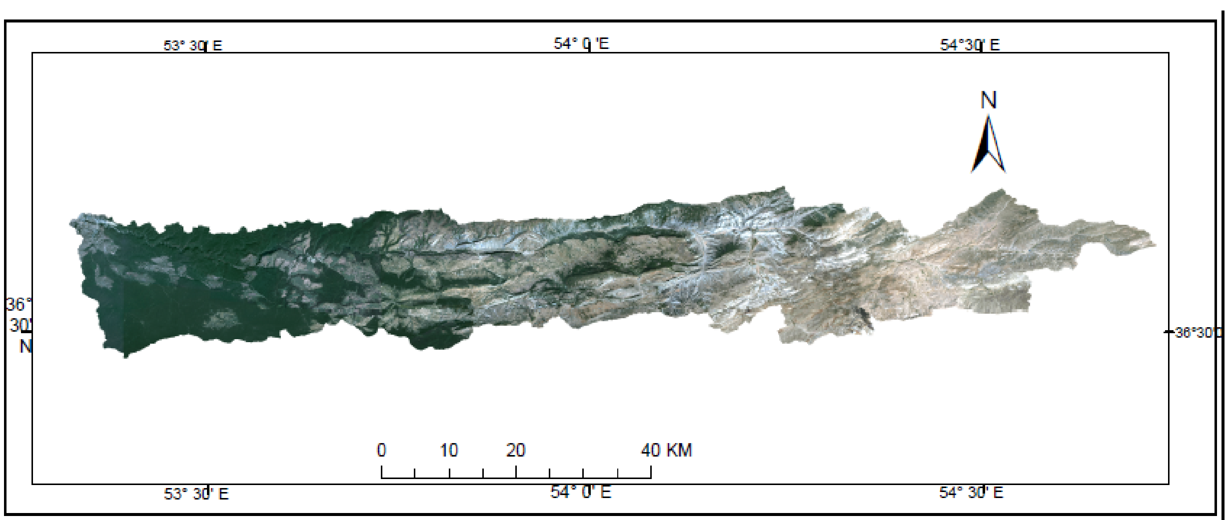

Fig. 4: Visual enrichment of Google image for Neka river basin

Table 3: Confusion matrix for the Land Sat MSS (1977) image supervised classification

User. Acc.	Total	BS	LV	DV	Forest	
83.33	40	-	-	5	35	Forest
93.33	40	-	1	38	1	Dense vegetation
93.33	40	2	38	-	-	Low vegetation
93.33	40	38	2	-	-	Bare soil area
-	160	40	41	43	36	Total
-	-	100.00	90.71	96.55	96.55	Prod Acc.
-	-	0.8962	0.88000	0.9005	0.9105	Kappa

datasets and it tends to overestimate classification accuracy (Congalton and Mead, 1983; Congalton *et al.*, 1983). Producer's accuracy indicates the probability of reference pixel being correctly classified and it is a measure of omission error. User's accuracy is the probability of classified pixel actually represents that category on the ground. User's accuracy is a measure of commission error (Im *et al.*, 2008). The Kappa Coefficient measures the proportional improvement of classification over purely random assignment to classes. This accuracy measure attempts to control for a chance agreement by incorporating the off-diagonal

Table 4: Confusion matrix for the Land sat TM (1987) image supervised classification

User. Acc.	Total	SA	LV	DV	Forest	
93.33	40	-	1	1	38	Forest
93.33	40	-	1	38	1	Dense vegetation
93.33	40	-	39	1	-	low vegetation
100.00	40	40	-	-	-	Sand area
-	160	40	41	41	39	Total
-	-	100.00	85.71	96.55	96.55	Prod Acc
-	-	1.0000	1.0000	0.9205	0.9205	Kappa

Table 5: Confusion matrix for the Land sat ETM (2001) image supervised classification

User. Acc.	Total	SA	LV	DV	Forest	
93.33	40	-	2	-	38	Forest
93.33	40	-	1	38	1	Dense vegetation
100.00	40	-	40	-	-	low vegetation
100.00	40	40		-	-	Sand area
-	160	40	43	38	39	Total
-	-	100.00	85.71	96.55	96.55	Prod Acc
-	-	1.0000	1.0000	0.9205	0.9205	Kappa

Table 6: Confusion matrixes for the Land sat ETM (2006) image supervised classification

User. Acc.	Total	SA	LV	DV	Forest	
93.33	40	-	2	-	38	Forest
93.33	40	-	1	38	1	Dense vegetation
93.33	40	-	38	2	-	low vegetation
100	40	40	-	-	-	Sand area
-	160	40	43	40	39	Total
-	-	100.00	85.71	96.55	96.55	Prod Acc
-	-	1.0000	1.0000	0.9205	0.9205	Kappa

elements as a product of the row and column of the error matrix (Cohen, 1960). After accuracy assessment, all images were clumped, eliminated 2×1 pixels and vector zed in Erdas Imagine 9.3™ programme.

In addition, a standard overall accuracy for land-cover and land-use maps is set between 85% (Anderson *et al*., 1976) and 90% (Lins and Kleckner, 1996; Smits *et al*., 1999). In this study, the overall accuracy of classification was 89.00% for the 1977 MSS, 92.35% for 1987 TM image, 92.67% for the 2001 ETM^+ and 93.33% for 2006 ETM^+ image, (Table 3 to 6).

RESULTS

Neka Watershed region experiences temperate climate with temperate rainforest vegetation. The luxuriant vegetation with dense forest cover forms the major part of the watershed area. The forests cover dominates outside the settlements, which practice shifting cultivation. As the shifting cultivation areas are abandoned by the settlers/farmers, dense scrub occupies the cultivated hill slopes changing the spatial-temporal patterns. In addition to shifting cultivation practice, other activities such as legal felling, clear felling, encroachment, etc. plays a vital role in deforestation shaping the forest cover. While analyzing temporal changes in forest cover, the results showed that there is a drastic reduction in the total forest cover in the North of watershed region. The Table 7 and Fig. 5 explains the changing scenario of forest cover in the region.

Interval forest change: 1977-1987: The total area under forest was 69871.37 hectares in 1977 and in the year 1987 the total area decreased to 62774.74 hectares, which resulted in -10.16 percent growth rate of forest between 977-1987. The loss of forest during this period was due to the agreement between Iranian government and the Government of Romania. The Iranian Government exported Neka Watershed forest to Romania.

In case of dense vegetation, the total area in the watershed was 38921.40 which increased to 43052.09 placing a positive growth of rate of 10.61. Similarly, the low vegetation cover increased from 55498.44 ha to 59010.37 ha at a rate of 6.33 growth rate. During the same period bare soil had a negative growth of -3.63. This clearly indicates the cutting of trees resulted to decline in the forest area which has been converted into agriculture land. The impact is observed in terms of substantial increase of growth rate (10.61) in the Dense Vegetation. There is also an increase of Low vegetation from 55498.44 to 59010.37 with a heaping positive growth rate to 6.33. The decrease in the bare soil area is a positive impact on the agriculture and on pasture landas well. The scrubs increased reducing the bare soil area in the northern and north eastern parts of the Neka river watershed. The overall change in forest cover transformation can be envisaged as the policy of the government in using the forest land for agriculture purpose.

Table 7: Forest cover change in the Neka river watershed (Iran), 1977–2006

Class name	1977	1987	1977 -87 Change(ha)	Growth rate(ha)	2001	1998-2001 Change(ha)	Groth rate (ha)	2006	2012006 Change (ha)	Growth rate (ha)
Forest	69871.4	62774.6	-7096.73	-10.15	65193.5	2418.82	3.85	66049.5	856.08	1.31
Dense vegetation	38921.4	43053	4131.6	10.61	32217	-10836.01	-25.17	35164.2	2947.19	9.14
Low vegetation	55398.4	58810.4	3411.93	6.33	60178.3	1367.92	2.06	56249.1	-3929.22	-2.96
Bare soil	25868.8	25422	-4406.081	-3.63	32471.2	7049.23	28.23	32597.2	125.9494	3.09

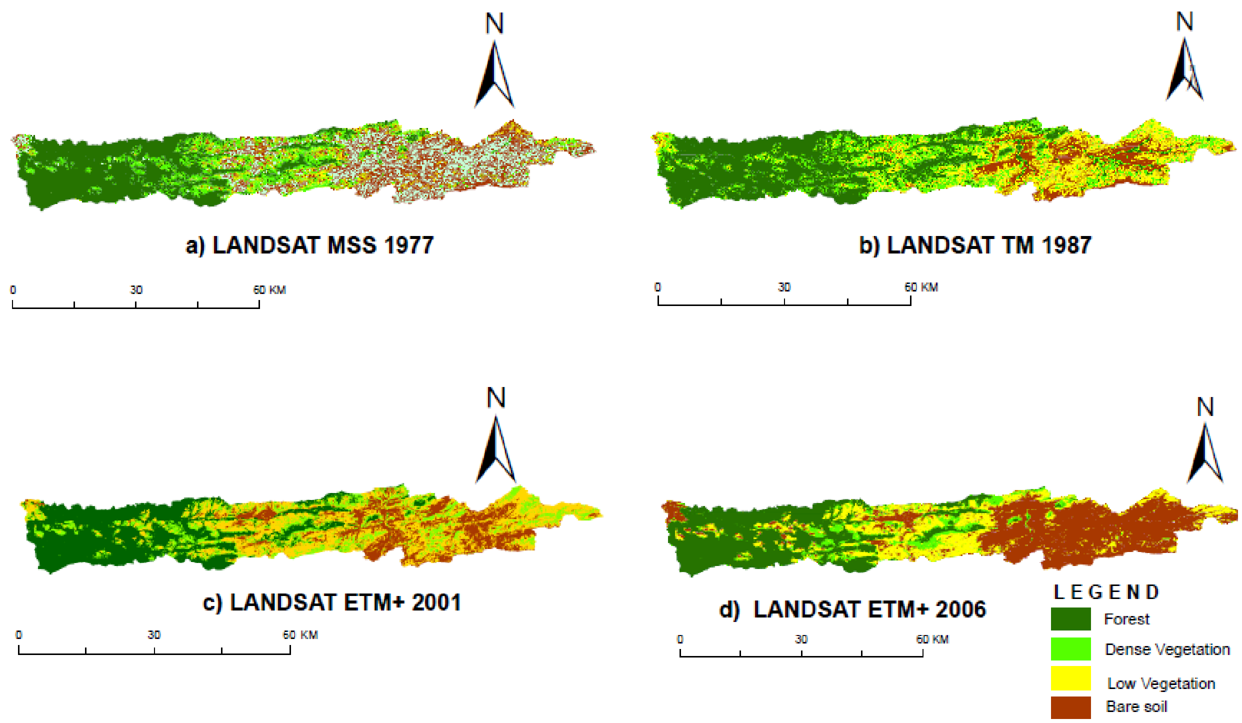

Fig. 5: Forest cover change in the Neka river water shed (Iran) 1977-2006

Interval forest change (1987-2001): During this period, the growth rate of forest land (FL) increased by 3.85. The reforestation policy brought by the government in this period resulted to increase in the forest land between 1987 -2001. There was steep decrease (-25.17) of dense vegetation (DV) as the government policy of exporting timber introduced. Subsequently the Government again changed the policy and reforestation of tree was introduced in the deforested and encroached land. The forest land left abandoned led to the growth of the Low vegetation land which increased to 2.06 growth rate of LV area. The bare soil region during this period increased as there was soil erosion due to intensive agriculture and over grazing of animals.

Interval forest change (2001-2006): The forest growth rate in this period was 1.31 due to reforestation program carried out by the Government of Iran. The changed policy resulted in the increase of DV to 10.70. This had a negative impact on the LV which experienced negative growth with-2.96 and the bare soil increased to 3.09 with the result of the abuse of land for agriculture purpose.

CONCLUSION

The total area under forest was 69871.37 hectares in 1977 and in the year 1987 the total area decreased to 62774.74 hectares, which resulted in -10.16 percent growth rate of forest between 977-1987 due to utilization of forests. During this period the growth rate of forest land (FL) increased by 3.85. The reforestation policy brought by the government in this period resulted to increase in the forest land between1987-2001 and the next period of study (2001–2006) the growth rate was 1.31 with the same reason of previous period.

It is evident from the above facts that the loss of forest land has resulted in an increase in bare soil in Golestan province and Semnan province of due to soil erosion in the Neka river basin. Therefore, it is recommended that soil conservation and top soil runoff preventions are required to retain regional sustainability in this province. The Mazandaran province, which is covered with forest, has less soil erosion. The regional sustainability in this province is better than other province.

Proper land use planning in future can be helpful to reduce the soil erosion and also scientific approach in the Neka watershed regions can revert the environmental condition to the previous state of condition. As this study is the first of its kind in Iran utilizing the satellite images to assess, monitor and plan this form of study need to be adapted to estimate the loss in other regions of Iran.

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