Journal of the Persian Gulf
(Marine Science)/Vol. 3/No. 10/December 2012/10/47-56

Monitoring Land Cover Changes of Forests and Coastal Areas of Northern Iran (1988-2010): A Remote Sensing Approach

Gholamalifard, Mehdi[1*]; Zare Maivan, Hassan[2];
Joorabian Shooshtari, Sharif[1]; Mirzaei, Mohsen[1]

1- Dept. of Environment, Faculty of Natural Resources, Tarbiat Modares University, Noor, Mazandaran, IR Iran.
2- Dept. of Plant Biology, Faculty of Biological Sciences, Tarbiat Modares University, Tehran, IR Iran.

Received: September 2012 *Accepted: November 2012*

Abstract
Caspian Sea coastline in the Mazandaran province has been altered as a result of activities of developers attracted to aesthetic and coastal recreational aspects of forest ecosystems. Advances in GIS and RS techniques, has made it possible to study the coastal areas for better management. Hence, the present study was undertaken to determine land cover changes via applying cross classification and tabulation analysis. Landsat satellite images of 1988, 2001, 2006 and 2010 were evaluated pixel by pixel. Results showed 33487 ha of forest areas had decreased and about 21367 and 13155 ha of agricultural and residential lands had increased, respectively. The greatest change in forest areas were pertaining to agricultural and residential lands (30424 and 1265 ha, respectively). In addition, 10984 ha of agricultural lands were transformed to residential areas. Extensive land use changes, inevitably contributed to increasing of soil erosion and sedimentation in the Caspian Sea watersheds, decreasing of water quality and limiting access to clean water for recreation, fishing and industry. Results of this research could be applied to better land use managing of the Caspian Sea coastline and its watersheds, impact assessment of development projects, identifying of vulnerable areas and monitoring Reducing Emissions from Deforestation and Forest Degradation (REDD).

Keywords: *Change Detection, Remote Sensing, Cross Classification and Tabulation, Caspian Forests, Mazandaran Province coastline*

1. Introduction

Coastal areas are of great importance to man because of their significant effects on social, cultural, economic and political activities, as well as values of coastal ecosystems. Recent literature showed that above 40% of world human population live in coastal or nearby areas (Carter, 1998). However, in spite of their importance for human societies, coastal areas have been faced with pollution, altered coastlines and ecosystem attributes as well as with multitude of complex problems for marine biota. In many cases, GIS has been providing many different methods in order to analyze and evaluate the coastal zones and closed territories by coastal managers (Bakr et al., 2010; Mendoza et al., 2011). These methods have further been extended by applying the Remote Sensing (RS) and image processing techniques. For example, Ayad (2005) applied remote sensing data, aerial photographs and GIS raster modeling to evaluate the visual changes of landscape in the coastal

* *E-mail: gholamalifard@gmail.com*

regions of Egypt and gained the composite index based on four visual indicators, plant diversity, function intensity, proximity to the coast and topographic changes and, as such, identified three groups on the basis of normal visual resources. Wu et al. (2006) used combination of GIS and remote sensing to detect land cover changes in the Beijing, China and found significant growth in urban areas and decline in pastures from 1986 to 2001. Shalaby and Tateishi (2007) surveyed monitoring land cover changes in the northwestern coastal region of Egypt from 1987 to 2001, used post-classification technique and maximum likelihood method to generate land cover maps, detect land use changes and report on the effects of development projects in agriculture and tourism on vegetation coverage area. Abd El-Kawy et al. (2011) used Post-classification comparisons to study changes in land cover in the west of Nile River.

Many researchers have studied channges in ecosystem status of Northern Iran. For example, Salman Mahini et al. (2009) investigated land cover changes through Artificial Neural Network classification and post-classification comparison methods using Landsat TM and ETM+ images in Golestan province. Sheikh Goodarzi et al (2011) generated land use/cover maps using satellite images from Landsat (MSS), IRS/P6 (LISS III) and applied landscape metrics to changes analysis (during 1975-2007), in Gorganrud watershed (in the Gilan province). Vakili et al. (2010) analyzed the trend of land use/cover and vegetation changes in Neka region (in the Mazandaran province), during 1977-2003 and concluded that forest, agricultural and bare land areas had reduced but conversely, areas of urban and degraded regions had expanded as much as (25%). Kelarestaghi et al. (2007) prepared three landcover maps 1967, 1994 and 2004 by using digital topographic maps and ETM^+ satellite images. Change detection of these periods have shown that forest and dry farming areas had reduced and irrigated farming areas had expanded. Rahmani et al. (2011) used multi-temporal images to investigate landcover changes in Kasilian watershed (in the Mazandaran province). They generated different false color composites of images and classified with maximum likelihood algorithm, which showed that about 251.94 hectare of forest areas had reduced during 1977-2007. In a similar study, Naimi nezamabad et al. (2010) assessed land cover changes in the coastal of Asalooiyye region (in south of Iran), which reported drastic increase in soil erosion and degradation.

Despite mosaic satellite investigation of Mazenderan coatal areas, research for southern coastal areas is lacking. Accordingly, in this study, supervised classification method was used to compare new and old land cover maps from four series (1988, 2001, 2006 and 2010) of Landsat satellite images.

2. Materials and Methods

2.1. Study Area

Mazandaran is a province in the north of Iran and borders southern coastline of the Caspian Sea. Because of its location being surrounded with Turkmenistan, Kazakhstan, Russia and Azerbaijan as well as its biodiversity and effect on regional climate, the Caspian Sea has high economic and commercial values. Mazandaran Province as such, has established many infrastructures and developed extensive facilities such as roads, railroads and transportations and communication hobs to facilitate commerce and tourism. The study site, located between 50º23′16″to 53 º 13′25″ eastern longitudes and 36º 23′13″ to 36 º44′52 ″northern latitudes (about 982033 ha) has been exposed to side effects of development and as such, merits investigation (Figure 1).

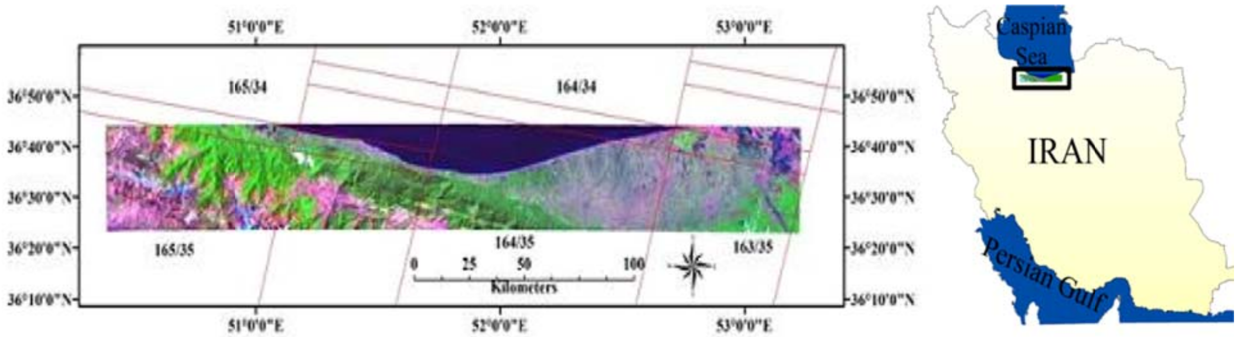

Fig. 1: Study area (coastal regions of Mazandaran province) and applied satellite frames

2.2. Data

Remote sensing data including TM and ETM^+ sensor images from the Landsat satellite and 1:25000 topographic maps were used in this study. According to qualitative nature of the land cover data in the present study and because of no change in the land cover in short periods, the nearest available images were selected and used for the intended time periods (Table 1).

Table 1. Data and frames of Landsat Satellite images

Year	Date	Number of frames
	1978,07,14	163.35
	1988,09,19	164.34
1988	1988,09,19	164.35
	1989,05,08	165.34
	1987,06,28	165.35
	2001,07,30	136.35
	2000,06,16	164.34
2001	2000,07,18	164.35
	2000,07,25	165.34
	2000,07,25	165.35
	2006,08,29	136.35
	2004,03,23	164.34
2006	2006,07,19	164.35
	2006,07,10	165.34
	2006,08,11	165.35
	2011,10,06	163.35
	2011,09,11	164.34
2010	2010,06,04	164.35
	2010,07,29	165.34
	2010,10,01	165.35

2.3. Data Pre-processing Operation

Satellite data were corrected in geometric correction phase (Geometric Correction) by using 1:25000 and 1:50000 topographic maps. Atmospheric correction was performed and images were orthorectified.

2.4. Land Cover Mapping for Years 1988, 2001, 2006 and 2010

Landsat satellite images from TM and ETM^+ Sensors (1988, 2001, 2006 and 2010) were used to generate land cover maps of the study area. To better separate and identify phenomena, false-color images were produced by combining bands 432 (Khoi and Murayama., 2010). These images helped to recognize different types of land cover in the region. Supervised classification method was used for mapping land cover. The first step in performing a supervised classification method was to define areas used as training samples for each class (Eastman, 2006). For this step, with visual interpretation of false color composite images, training samples were defined for each class using 1:25000 topographic maps provided by Geological Survey of Iran. Seven land cover classes were determined in the region as follows: forest, agricultural fields, residential areas, shallow sea, deep sea, wetlands and water resources and open lands. Next, the training samples were separated and produced by on screen digitization method. Then, classification of satellite images was implemented (Eastman, 2006) through maximum likelihood classification method (Schulz et al., 2010). Finally, mode filter was used to remove scattered pixels and simplify the classified maps.

2.5. Classification Accuracy Assessment

In order to determine accuracy of the classified maps the following steps were employed: first, using a GPS, 331 points was assigned for image of 2010 and after that the actual ground points were compared with the classified maps. Then, Kappa coefficients were calculated for each class. Finally, using visual interpretation and ground control points, the overall accuracy assessment of the classified maps of 1988, 2001 and 2006 were calculated (317, 321 and 337 points, respectively), which had not been changed during these years (Schulz et al., 2010).

2.6. Change Detection

Using classification analysis and cross tabulations, maps of land cover classes (1988, 2001, 2006 and 2010) were compared with each other, as the maps of 1988 and 2001, 2001 and 2006, 2006 and 2010 and also maps of 1988 and 2010 were crossed. Finally, aspects of changes were extracted (Figure 2).

3. Results

Classified images showed that there were seven land cover classes in the study area by using the maximum likelihood classifier. In Figure 3, land cover maps of 1988, 2001, 2006, and 2010 are shown. Generally, the Kappa coefficient for 1988, 2001, 2006 and 2010 were 89.67%, 88.70%, 90.29% and 83.41%, respectively (table 2).

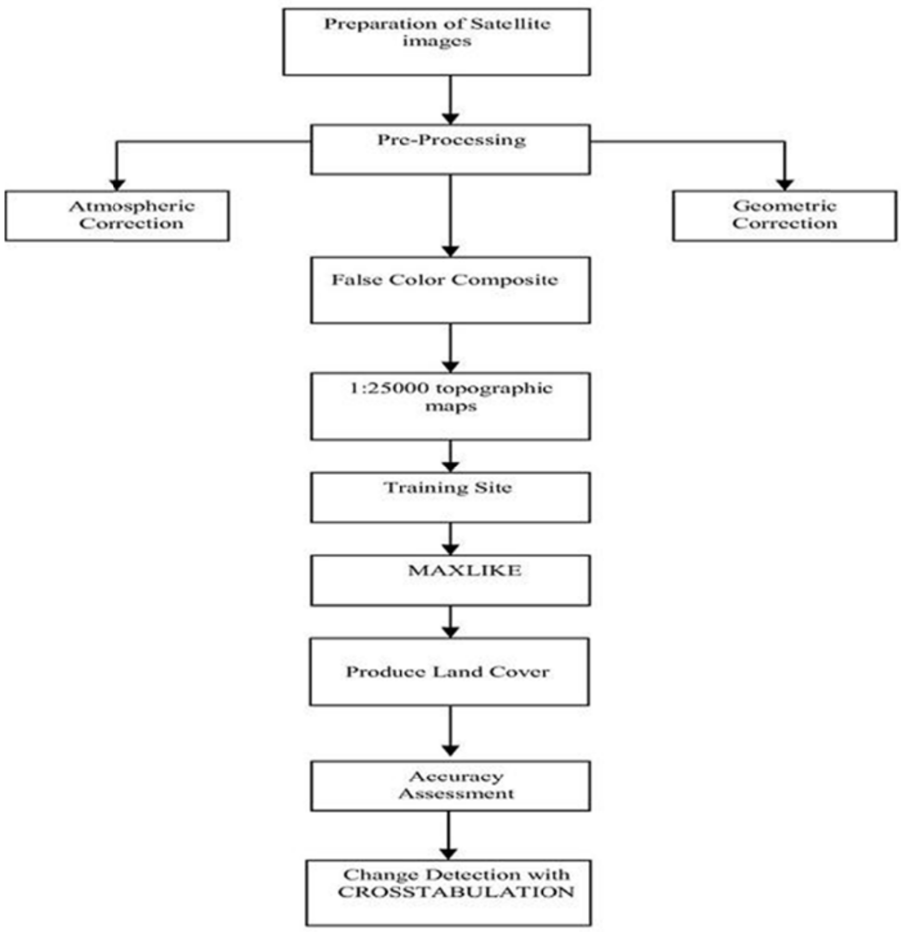

Fig. 2: Flowchart method (change detection)

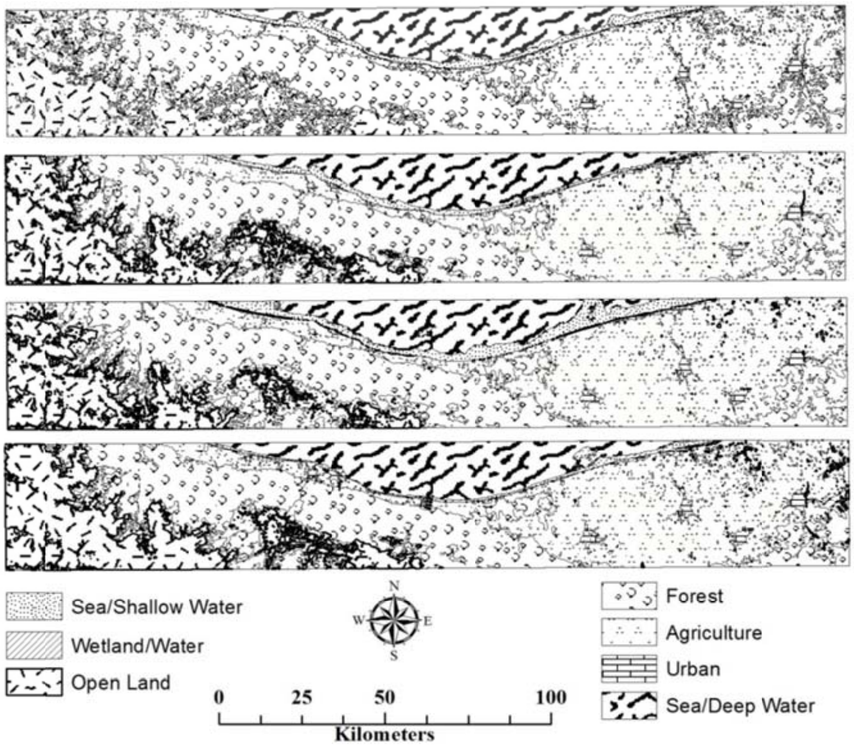

Fig. 3: Regional land cover maps (from top to bottom 1988, 2001, 2006 and 2010, respectively)

Table 2. Accuracy evaluate matrix of classification maps

Land use classes		Ground truth data						
		Forest	Agriculture	Residential	Sea/deep	Sea/shallow	Wetland/water	Openland
1988 classified map	Forest	42	7	0	0	0	0	0
	Agriculture	4	44	0	0	0	0	0
	Residential	0	0	48	0	0	0	0
	Sea/deep	0	0	0	42	0	0	0
	Sea/shallow	0	0	0	2	41	0	0
	Wetland/water	0	5	0	0	3	27	0
	Open land	0	22	0	0	5	0	45
2001 classified map	Forest	47	3	0	0	0	0	0
	Agriculture	2	48	5	0	0	4	8
	Residential	0	0	38	0	2	0	0
	Sea/deep	0	0	0	46	0	0	0
	Sea/shallow	0	0	0	0	44	0	0
	Wetland/water	0	0	0	0	0	31	0
	Open land	0	0	0	0	2	5	36
2006 classified map	Forest	53	0	0	0	0	0	0
	Agriculture	0	50	4	0	0	12	7
	Residential	0	0	44	0	0	0	0
	Sea/deep	0	0	0	41	0	0	0
	Sea/shallow	0	0	0	0	47	0	0
	Wetland/water	0	0	0	0	0	31	0
	Open land	0	0	0	0	2	3	43
2010 classified map	Forest	47	2	0	0	0	0	0
	Agriculture	14	43	5	0	0	7	0
	Residential	0	0	46	0	0	0	5
	Sea/deep	0	0	0	41	4	0	0
	Sea/shallow	0	0	0	0	35	7	0
	Wetland/water	0	0	0	0	0	37	0
	Open land	0	3	0	0	0	0	35

3.1. Change Detection

Results of change detection revealed that during the study period (1988 -2010) 33487 ha of forests had reduced and 21367 ha of agricultural lands expanded. Furthermore, development of urban and residential areas had increased as much as 13155 ha.

Over the study period, the rates of changes were not uniform. For example, between 1988-2001 and 2001-2006, 37727 and 5451 ha of forest area had declined, respectively, while in the last period (2006-2010) 9691 ha had increased on this class. Agricultural land comprised most of the area as 49838 and 29963 ha in the first and second periods had been added, respectively. However, 58433 ha of these areas were later reduced during 2006-2010 period. In residential lands, an increase of 2865, 151 and 10140 ha was observed during 1988-2001, 2001-2006 and 2006-2010 periods, respectively (Table 3 and Figure 4).

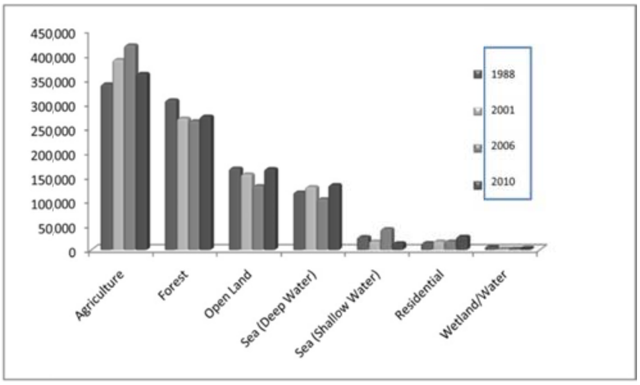

Fig. 4: Land cover changes over the study period

Table 3. Land cover transfer matrix during the study periods (ha)

1988-2001	Forest	Agriculture	Residential	Sea/deep	Sea/shallow	Wetland/water	Open land
Forest	263540.43	42541.38	286.11	0	11.43	147.33	1375.11
Agriculture	5575.68	320920.11	5112.45	0	267.66	685.71	8020.44
Residential	0.36	2779.20	11110.50	2.97	502.65	4.59	115.56
Sea/deep	0	0	0	117551.34	1266.93	0	0.63
Sea/shallow	0	2.16	157.86	11944.71	14248.35	1.80	155.88
Wetland/water	46.89	3799.44	92.61	213.66	935.64	420.84	161.46
Open land	101.51	20377.44	621	3.51	333.09	13.77	14673.64
2001-2006	Forest	Agriculture	Residential	Sea/deep	Sea/shallow	Wetland/water	Open land
Forest	255878.46	13962.15	3.33	0	22.32	13.14	295.47
Agriculture	8784.9	374413.5	3908.52	0	20.52	389.07	2903.22
Residential	19.98	3170.88	13316.49	0	317.07	26.73	529.38
2006-2010	Forest	Agriculture	Residential	Sea/deep	Sea/shallow	Wetland/water	Open land
Forest	257165.64	6719.22	20.97	0	12.06	24.03	782.19
Agriculture	16925.40	350228.34	11831.76	41.04	370.8	1629.9	39355.29
Residential	0.27	1982.25	14925.69	0	52.65	13.5	556.92
Sea/deep	0	0	0	103660.74	214.47	0	0
Sea/shallow	22.23	53.28	53.28	29998.62	12315.15	118.26	86.85
Wetland/water	1.89	0	0	0	108.09	692.37	0
Open land	299.52	839.34	839.34	282.15	1115.19	848.43	12720.01

3.2. Net Changes and Transition between Land Cover Classes

Conversion of the forest area to agricultural lands (30424 ha) and residential areas (1265 ha) was significant. Meanwhile, the net change of agricultural lands to residential areas was 10984 ha. The largest increment occurring between 1988-2001, as 36966 ha of forests had been converted to agricultural land. Furthermore, 2333 ha of changes occurred from agricultural to residential and developed areas. In the second, period (2001-2006), conversion of forest to agricultural land and agricultural land to residential areas were 5177 and 738 ha, respectively. In addition, during the last period, converted forest to agricultural land and agricultural to residential areas were 10206 and 9850 ha, respectively. During each of the three study periods, in total, 364, 256 and 483 ha of the forests had been transformed to open lands, respectively. Over 1988-2001 and 2001-2006 periods, furthermore, the net changes of open lands to agricultural areas were 12357 and 25400 ha, respectively. It was also estimated that 36616 ha of agricultural land was converted to open lands in 2006-2010.

3.3. Change Maps

The land cover demonstrated significant changes during 1988-2001, 2001-2006 and 2006-2010 periods (Figures 5, 6 and 7).

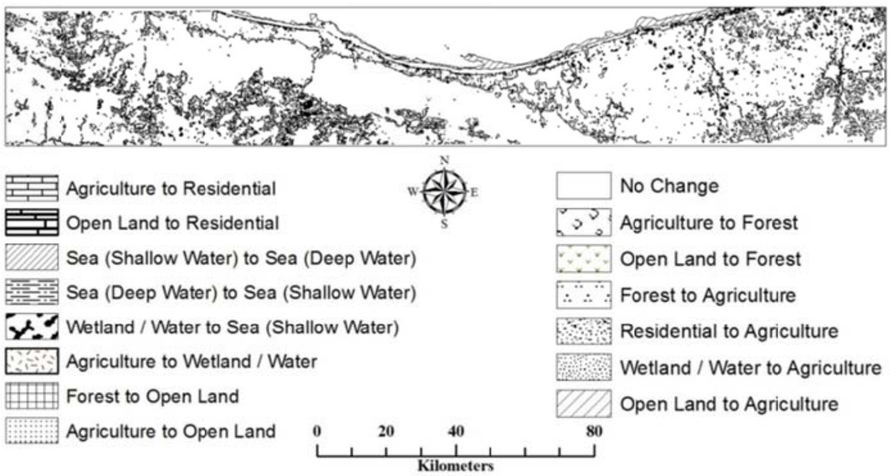

Fig. 5: Spatial distribution map for the land cover changes between 1988 and 2001.

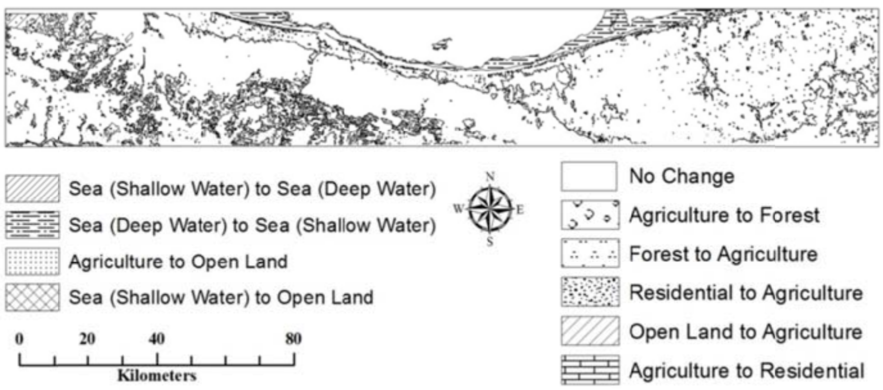

Fig. 6: Spatial distribution map for the land cover changes between 2001 and 2006.

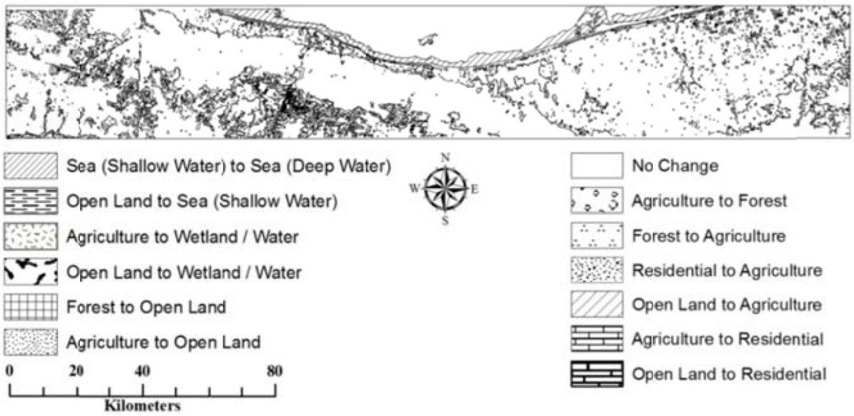

Fig. 7: Spatial distribution map for the land cover changes between 2006 and 2010.

4. Discussion and Conclusions

Accurate assessing of land cover changes in Southern Caspian Sea was investigated using cost effective remote sensing via applying cross classification and tabulation analysis method. Change detection maps were prepared by pixel by pixel analysis. Coppin et al. (2004), images of two separate dates were classified to minimize radiometric corrections. Results illustrated significant changes in land cover of Mazandaran Province coastline during the past twenty-two years. Overall, 33487 ha of the forest areas were converted from 1988 to 2010.

Undoubtedly, degraded or converted forests provide circumstances for increased soild erosion and water runoffs. This consequently adds to sedimentation in rivers and eventually in coastal areas, contributing to eutrophication, harmful algal blooms (HABs) (Anderson et al., 2002) deteriorating water quality (Shahidul Islam and Tanaka., 2004), turbidity increases (Orpin et al., 2004) and changes in dissolved oxygen (Sanchez et al., 2007). Extensive land use changes in Mazendaran province land classes could have potentially contributed to increasing of soil erosion and sedimentation in Caspian Sea Coastline probably affecting water quality adversely and limiting access to clean water for recreation, fishing and industry. Results of this research could be applied to better land use managing of the Caspian Sea coastline and its watersheds, impact assessment of development projects, identifying of vulnerable areas and monitoring Reducing Emissions from Deforestation and Forest Degradation (REDD).

Acknowledgements

This research was funded by the Deputy for the Marine Environment, Iran Department of Environment (Contract Number: 34/71380 Dated February 7, 2010). Special thanks are due to Dr. S. M. B. Nabavi, Deputy Head of Marine Environment for funding. Authors thank Mr. Omid Sedighi, Mr. Bagher Teimouri and Mr. Arash Nikouian for their support and cooperation throughout the research period. Special thanks are due to vice-chancellor for Research at Kharazmi University.

References

Abd El-Kawy, O.R., Rød, J.K., Ismail, H.A. and Suliman, A.S., 2011. Land use and land cover change detection in the western Nile delta of Egypt using remote sensing data. Applied Geography. 31(2): 483-494.

Anderson, D.M., Glibert, P.M. and Burkholder, J.M., 2002. Harmful algal blooms and eutrophication: nutrient sources, composition and consequences. Estuaries. 25(4b): 704–726.

Ayad, Y.M., 2005. Remote sensing and GIS in modeling visual landscape change: A case study of the northwestern arid coast of Egypt. Landscape and Urbanlanning. 73(4): 307-325.

Bakr, N., Weindorf, D.C., Bahnassy, M.H., Marei, S.M. and El-Badawi, M.M., 2010. Monitoring land cover changes in a newly reclaimed area of

Egypt using multi-temporal Landsat data. Applied Geography. 30(4): 592-605.

Bierman P., Lewis M., Ostendorf B. and Tanner J., 2011.A review of methods for analyzing spatial and temporal patterns in coastal water quality. Ecological Indicators. 11(1): 103-114.

Carter, R.W.G., 1988. Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastline, London Academic Press. 617P.

Chavez, P.S: 1996. Image-Based Atmospheric Corrections – Revisited and Improved. Photogrammetric Engineering and Remote Sensing. 62 (9): 1025 - 1036.

Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B. and Lambin, E., 2004. Digital change detection methods in ecosystem monitoring: a review. International Journal of Remote Sensing. 25(9): 1565-1596.

De Leeuw, A., Veugen, L., & Van Stokkom, H. 1988. Geometric correction of remotely-sensed imagery using ground control points and orthogonal polynomials. International Journal of Remote Sensing, 9(10-11): 1751-1759.

Eastman, J.R., 2006. IDRISI Andes. Guide to GIS and Image Processing. Clark Labs, Clark University, Worcester, MA. 212P.

Kelarestaghi, A., Ahmadi, H., Jafari, M., Ghodosi, J., 2007. Probabilistic prediction of land use change from forest to dry farming using Bayesian Theorem modeling in Farim Drainage Basin. Pajouhesh & Sazandegi. 1(1): 52-62, (in Persian).

Khoi, D.D. and Murayama, Y., 2010. Forecasting Areas Vulnerable to Forest Conversion in the Tam Dao National Park Region, Vietnam. Remote Sensing. 2(5): 1249–1272.

Mallinis, G: Emmanoloudis, D: Giannakopoulos, V: Maris, F: Koutsias, N: 2011. Mapping and interpreting historical land cover/land use changes in a Natura 2000 site using earth observational data: The case of Nestos delta, Greece. Applied Geography. 31(1): 312–320.

Mendoza, M.E., Granados, E.L., Geneletti, D., Pérez-Salicrup, D.R. and Salinas, V., 2011.Analysing land cover and land use change processes at watershed level: A multi temporal study in the Lake Cuitzeo Watershed, Mexico (1975-2003). Applied Geography. 31(1): 237-250.

Naiminezamabad, A., Ghahrooditali, M. and Servati, M., 2010. Monitoring of Persian Gulf coastline changes and geomorphologic Landform using GIS and RS technical (Case Study of Asalooyeh coastline). Journal of Geographical, space, 10(30): 35-61, (in Persian).

Orpin, A.R., Ridd, P.V., Thomas, S., Anthony, K.R.N., Marshall, P. and Oliver, J., 2004. Natural turbidity variability and weather forecasts in risk management of anthropogenic sediment discharge near sensitive environments. Marine Pollution Bulletin. 49(7–8): 602–612.

Qasim, M: Hubacek, K: Termansen, M: Khan, A: 2011. Spatial and temporal dynamics of land use pattern in District Swat, Hindu Kush Himalayan region of Pakistan. Applied Geography. 31(1): 820-828.

Rahmani, N., Shahedi, K., Soleimani, K., Miryaghoobzadeh, M, H., 2011. Investigation of Land use Change in KasilianWatershedUsing Multi-Temporal Images. Journal of Range and Watershed Management. 65(1): 35-47, (in Persian).

Salman Mahini, A., Feghhi, J., Nadali, A., Riazi, B., 2009. Tree cover change detection through Artificial Neural Network classification using Landsat TM and ETM+ images (case study: Golestan Province, Iran). Iranian Journal of Forest and Poplar Research. 16(3): 495-505, (in Persian).

Sanchez, E., Colmenarejo, M.F., Vicente, J., Rubio, A., Garcia, M.G., Travieso, L. and Borja, R., 2007. Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecological Indicators. 7(2): 315–328.

Schulz, J.J., Cayuela, L., Echeverria, C., Salas, J. and Rey Benayas, J.M., 2010. Monitoring land cover change of the dryland forest landscape of Central Chile (1975–2008). Applied Geography. 30(3): 436–447.

Shahidul Islam, M. and Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. Marine Pollution Bulletin. 48(7–8): 624–649.

Shalaby, A. and Tateishi, A., 2007. Remote sensing and GIS for Mapping and Monitoring Land Cover and Landuse changes in the northwestern coastal zone of Egypt. Applied Geography. 27(1): 28-41.

Sheikh Goodarzi, M., Sheikh Goodarzi, A., Salman Mahini, A., Feghhi, J., 2011.Landscape Ecological Metrics-based Investigation of Land Cover/Use Changes in Korganrud Watershed. Journal of Natural Environmental. 64 (4): 431-441, (in Persian).

Vakili, M., Mousavi, R., Shokri, M., Safaian, N., Shamlu, R., 2010.Analyzing the trend of land use and vegetation changes in Neka region using remote sensing techniques. Rangeland. 4(4)580-587, (in Persian).

Van Oort, P.A.J., 2007. Interpreting the change detection error matrix. Remote Sensing of Environment. 108(1): 1-8.

Wu, Q., Li, H., Wang, R., Paulussen, J., He, Y., Wang, M., Wang, B. and Wang, Z., 2006. Monitoring and predicting land use change in Beijing using remote sensing and GIS. Landscape and Urban Planning. 78(4): 322-333.