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Monitoring land use/cover changes using remotely sensed imagery in Isfahan, Iran

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Present study studies land use/cover changes in Isfahan urban area located in the center of Iran from 1985 to 2010 using multi temporal Landsat TM images. Overall accuracy and kappa of was more than 85% for all maps. Land use/cover maps of 1985, 1998 and 2010 were compared using the post-classification comparison method for detecting changes. The results showed that the urban lands faced the maximum of 16.4% incremental changes from 1985 to 1998 and this change was 9.03% in vegetation. Decreasing changes related to the barren lands was equal to -13.05%. Trend of the changes from 1998 to 2010 was 33.38% incremental in urban lands as well as, the decreasing changes occurred in the vegetation by -9.42% and in the barren lands equal to -0.74%.

[**Keywords:** Change detection, Landsat TM, Land use, Post-classification comparison]

Introduction

Land use and land cover of the earth is changing dramatically because of human activities and natural disasters[1]. Land use and land cover changes, apart from changing the physical dimension of the spatial extent of the land use and land cover classes, also influence many of the secondary processes which lead to the eventual degradation of the ecosystems of the earth[2]. Urbanization has been a universal and important social and economic phenomenon taking place all around the world. This process, with no sign of slowing down, may be the most powerful and visible anthropogenic force that has brought about fundamental changes in land use and landscape pattern around the world. Rapid urbanization, especially in the developing world, will continue to be one of the crucial issues of global change in the 21st century affecting the human dimensions[3]. Continual, historical, and precise information about the land use and land cover (LULC) changes of the Earth’s surface is extremely important for any kind of sustainable development program, in which LULC serves as one of the major input criteria[4].

Nowadays, it is widely-known that land-use changes can be accurately monitored at a global, regional and local scale using satellite remote sensing imagery. One of the most commonly used satellite sensors for such purposes is the Thematic Mapper (TM) on board of Landsat series satellite platforms. The spatial and temporal resolution, the availability, the coverage and the overall quality of the Landsat data, provide a useful informational background for detailed land-use change studies (e.g. Güler et al., 2007; Julien et al., 2011; Liying et al., 2009; Mahmoodzadeh, 2007; Petropoulos et al., 2011; Yuan et al., 2005)[5-10] .

Change detection is the process of identifying differences in the state of a feature or phenomenon by observing it at different times[11]. Change detection is useful in many applications related to land use and land cover (LULC) changes, such as shifting cultivation and landscape changes [12-13], land degradation and desertification [14-15], coastal change and urban sprawl [16], urban landscape pattern change [17-19]. Change detection involves the analysis of two co-registered multi-spectral images acquired in the same geographical area at two different times; it can be performed both by an unsupervised and a supervised approach [11]. The supervised approach to detection of land cover change, often indicated as the

Post Classification Comparison (PCC) approach, shows some advantages over the unsupervised approach because of its capacity to detect land cover transitions. It is based on comparison between the classification maps obtained by classifying the two considered images independently [20].

Fichera et al. (2012) used Remote Sensing data in combination with GIS to characterize land cover changes in Avellino located in Southern Italy. The results of the study indicated that the urbanization has considerably modified the Land cover of the study area, with significant land conversions [21].

Alqurashi & Kumar (2014) assessed land use/cover change in Makkah and Al-Taif, Saudi Arabia from 1986 to 2013 using Landsat images. Maximum likelihood and object-oriented classification were used to generate land use/cover maps. The change detection was executed using post-classification comparison and GIS. The results showed that urban areas have increased over the period. Object-based classification provided slightly greater accuracy than maximum likelihood classification[22].

Hamed Saeifar & Mohammadnia (2015) used Landsat5 TM and Landsat 8 (Operational Land Imager (OLI) sensor) to map the spatiotemporal changes of LULC in Tehran city. Supervised maximum likelihood method was used to map the Land use/cover in the study area. Changes in land use/cover were detected using post-classification comparison technique. The results indicate that from 2010 to 2014, the area of green spaces decreased and the area of built-up class increased[23].

In this study, the proposed approach was applied to identify and detect the Land Use/Land Cover (LULC) changes in Isfahan city located in the center of Iran. The study area is characterized by rapid urban development and consequently LULC changes. The main scope of the present study was to detect land-use and land cover changes and highlight the spatial conversion tendencies of the different land types using remote sensing imagery and GIS. This study intended to contribute as an informative background to future studies, influencing policies and strategies, leading to a sustainable management in the specific and rapidly changing geographic region. For this purpose, three Landsat images (1985, 1998 and 2010) were used and classified into five classes (including agricultural lands, urban lands, Barren lands, mountains and rivers) and the changes was calculated using post-classification comparison method.

Materials and Methods

The city of Isfahan is located between the latitudes 51° 30' 15" and 51° 47' 10"N and the longitudes 32° 30’ 20” and 32° 48’ 10" E (Fig.1). In the northern and southern parts leads to desert lands. Isfahan has an elevation from 1550 to 1650 above sea level and average annual rainfall is 121.1 mm. Mean annual temperature is 16.2°C. In recent years, this historic city exposed to the population increase due to the existence of multiple industrial centers. Indiscriminate destruction of agricultural lands caused by the significant growth of the urban areas.

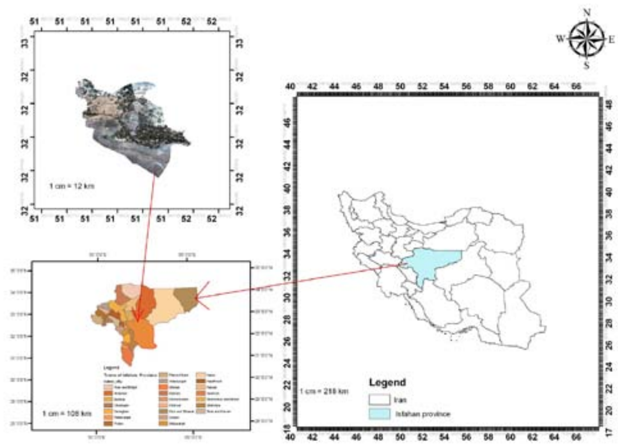

Fig. 1— The study area

Remotely sensed data were used as the primary data source to provide input for land use/cover mapping and change detection. A time series of remote sensing imagery including satellite images spanning 25 years was used to generate land use/cover maps. Landsat TM images (path 164, row 37) for the years 1985, 1998 and 2010 were used in this study. Topographic maps at a scale of 1:25,000 were used as reference maps. Land use/cover maps were generated by the processing of satellite images with Idrisi Kilimanjaro software.

Remotely sensed data has probably the errors or noises. The errors are two types of geometric and radiometric. Noise in the satellite time series may be the result of varying atmospheric conditions, sun-sensor-surface viewing geometry, sensor disturbances, geometric errors, misregistration, mixed pixels, surface anisotropy, and clouds or cloud shadows [24-25].

In this study, geometric correction of the Landsat TM image of 2010 was performed using topographic maps at a scale of 1:25000. Thirty ground control points were selected with appropriate distribution on the image and map. Image-to-image registration is the matching of one image to another so the same geographic area is positioned coincident with respect to the other. Landsat TM satellite image of 1998 was registered to the Landsat TM satellite image of 2010. For this purpose, 28 ground control points were selected with the appropriate distribution, the common points between the images was selected mainly of the streets, roads and buildings intersection. For geometric correction of Landsat TM image of 1985, the rectified image of 1998 was used. 32 ground control points were used with the appropriate distribution which was mainly located at the intersection of streets and buildings. The root mean square error (RMSe) of the 1985, 1998 and 2010 images was estimated to be 0.48, 0.51 and 0.53, respectively. A first-order polynomial model was applied and all data were resampled to a 30 m pixel size using the nearest neighbor method.

In the study area, five categories of land use/cover including vegetation, urban areas, Barren lands, mountains and rivers were identified based on field studies. On this basis, satellite images were classified to prepare land use/land cover maps of 1985, 1998 and 2010. Supervised maximum likelihood classifier was employed to generate land use/land cover maps within different periods.

Accuracy assessment gives information on map quality and identifies possible sources of errors. The overall accuracy of land use/cover maps was calculated from error matrices. The Ground truth data were derived from topographic maps and an error matrix was generated for each land use/cover map. Table 1 shows the overall accuracy and overall kappa of land use/cover maps. Acceptable total accuracy for land use and land cover maps was over 85 %.

Results

Land use/cover changes were examined in three time periods using land use/cover maps and post classification comparison method and tables of changes were generated. To study the process of land use/cover change using satellite images in three periods (1985-1998, 1985-2010 and 1998-2010), land use/cover maps for the years 1985, 1998 and 2010 were produced. The vegetation, urban lands, Barren lands, mountains and rivers are the most important types of the land use/cover in the study area. The area of different classes of the land use/cover was determined and the change of land use/cover for each time period was quantified using post-classification comparison method. Table 2 and Figure 2 shows the area and percent area of land use/cover classes in 1985. The most dominant area was related to barren lands with an area of 62 387 ha (40.2% of the total area). In the second place located the vegetation with area of the 59,513 ha (38.4% of the total area).

Table 1. Classification accuracy

Land use / cover map	Overall accuracy	Overall kappa
1985	0.92	0.91
1998	0.91	0.90
2010	0.88	0.87

Table 2. The area of Land use/cover classes for 1985

Land use/cover class	Area (ha)	% Area of total
Agriculture	59513	38.4
Urban lands	16722	10.8
Barren lands	62387	40.2
Mountains	16081	10.4
Rivers	424	0.2
Total	155127	100

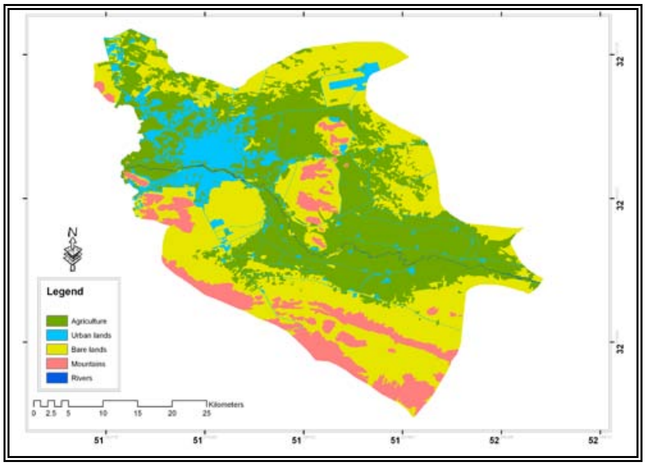

Fig. 2— Land use/cover map in 1985

Figure 2 shows the land use/cover map for 1998 and Table 3 indicates the area of land use/cover types in 1998. The most area of land covering was allocated to the vegetation with the area of 64,890 ha (41.8% of the total area). The Barren lands area was about 54,240 ha (35% of the total area) in 1998.

Table 3.The area of land use/cover classes for 1998

Land use/cover class	Area (ha)	% Area of total
Agriculture	64890	41.8
Urban lands	19470	12.6
Barren lands	54240	35
Mountains	16087	10.4
Rivers	440	0.2
Total	155127	100

Table 4 and Figure 4 show the land use/cover classification in 2010. The most area of land cover was allocated to the vegetation with an area of 58773 ha (37.9% of the total area). The area of Barren lands was about 53,834 ha (34.7% of the total area) in 2010.

To determine the changes in land use/cover, the land use/cover of the 1985 and 1998 were compared using cross-tabulation matrix (Table 5). The maximum incremental change was related to the vegetation up to 5377 ha. Urban land increased from 16722 ha in 1985 to 19470 in 1998. Decreasing changes equal to -8147 ha was observed in the Barren lands.

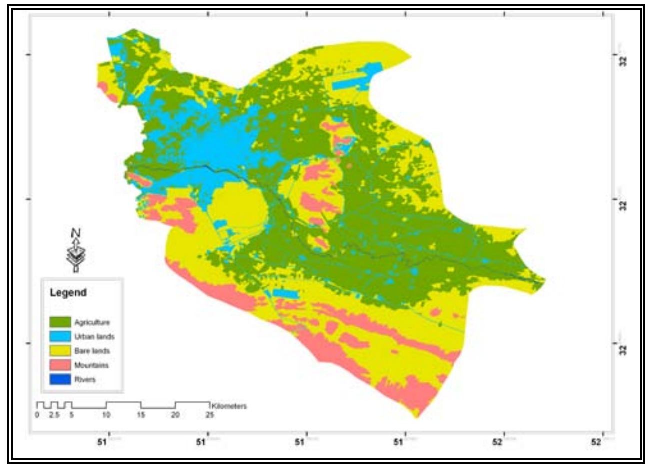

Fig. 3— Land use/cover map in 1998

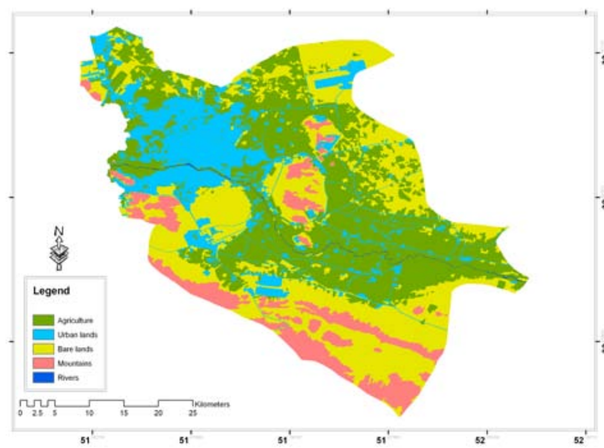

Fig. 4— Land use/cover map in 2010

Land use/cover maps of 1985 and 2010 were compared to determine the changes of land use/cover from 1985 to 2010. As can be seen in Table 6, the maximum incremental change was

Table 4.The area of land use/cover types for 2010

Land use/cover class	Area (ha)	% Area of total
Agriculture	58773	37.9
Urban lands	25970	16.7
Barren lands	53834	34.7
Mountains	16096	10.4
Rivers	454	0.2
Total	155127	100

related to the urban lands with changes up to 9248 ha. The incremental change equal to 30 ha was assigned to rivers. The Barren lands decreased from 62387 to 53834 ha between 1985 and 2010. In this time period, the decreasing change of the vegetation up to -740 ha was observed.

Table 6. Land use/cover change matrix for 1985-2010 (ha)

Land use/cover class	Area (ha) 1985	Area (ha) 2010	Area of Changes (ha)	Changes area%	Type of changes
Agriculture	59513	58773	-740	-1.24	Decreasing
Urban lands	16722	25970	9248	55.3	Incremental
Barren lands	62387	53834	-8553	-13.7	Decreasing
Mountains	16081	16096	15	0.09	Incremental
Rivers	424	454	30	7.07	Incremental
Total	155127	155127	-	-	Incremental

The comparison of the land use/cover areas between 1998 and 2010 (Table 7) showed that the maximum of incremental changes equal to 6,500 ha has occurred in urban lands, these changes were 406 ha in the Barren lands. The decreasing changes equal to -6117 ha observed for the vegetation.

Table 7. Land use/cover change matrix for 1998-2010 (ha)

Land use/cover class	Area (ha) 1998	Area (ha) 2010	Area of Changes (ha)	Changes area%	Type of changes
Agriculture	64890	58773	-6117	-9.42	Decreasing
Urban lands	19470	25970	6500	33.38	Incremental
Barren lands	54240	53834	-406	-0.74	Decreasing
Mountains	16087	16096	9	0.05	Incremental
Rivers	440	454	14	3.18	Incremental
Total	155127	155127	-	-	Incremental

Discussion

The change process from 1985 to 1998 implies incremental and decreasing changes for different categories of land use/cover. The most incremental changes were assigned to urban land with increasing up to 16.4% and the change of vegetation class was 9.03%. In this period, bare land was experienced decreasing changes equal to 13.3%. The most incremental changes of the 1985-2010 periods was related to the urban lands equal to 55.3% while, vegetation changes was decreasing by -1.24%. Maximum decreasing change was related to bare lands to -13.7%. During 1998-2010, the most incremental changes equal to 33.38% was observed for the urban lands. The maximum decreasing change was -9.42% and was related to vegetation. Moreover, the decreasing change of barren lands was equal to -0.74%.

Therefore urban expansion during the 25 years from 1985 to 2010 was more than 55%. Acceleration of urbanization from 1998 to 2010 was more than double what observed between 1985 and 1998. In contrast, the vegetation with incremental changes from 1985 to 1998 was placed in first position of decreasing changes in 1998 to 2010. Bare land was faced with a decrease in all three studied periods, however, decreasing changes of the -13.05 reached to -0.74% in the second period from 1998 to 2010. This indicates that a substantial area of fertile agricultural lands have been destroyed at the expense of urban growth. Urban development in Isfahan city was associated with an increase in arid lands. The major driving forces of land use/cover changes of the Isfahan city were population growth, rapid urbanization and industrialization. Yuan et al (2005) used TM Landsat-derived change maps and showed that increase in urban areas mainly derived from conversion of agricultural land to urban uses during the sixteen years period from 1986 to 2002, So that of the 70,000 ha of total growth in urban land use from 1986 to 2002, 75.1% was derived from agricultural lands and 11.3% from forest.

Conclusion

In this study, the land use/cover maps were derived from multi temporal Landsat TM images for 1985, 1998 and 2010 based on maximum likelihood classification. The results indicated that information from satellite remote sensing could play a significant role in quantifying and understanding the nature of changes in land use/cover and where they are occurring. The outcomes of this research showed that Landsat TM images could be effectively used for generating accurate land use/cover maps as the overall accuracies of all generated land use/cover maps were found to be over 85%.

In the present study, the post-classification comparison method was successfully used for detecting and monitoring land use/cover changes. Analysis of changes occurred from 1985 to 2010 revealed that vegetation was particularly vulnerable to urban expansion. The major causes of land use/cover changes of the Isfahan metropolitan area were population growth, rapid urbanization and industrialization. Information on land use/cover changes due to urban expansion is essential to planning for Isfahan urban growth and development. Our results suggest a framework for using multi-temporal images with supervised classification that is broadly applicable to urban areas. The results indicated the importance and effectiveness of integrating change detection method and remote sensing images to generate knowledge on the land use/cover change and its driving forces.

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