

Land use change detection and impact assessment in Anzali international coastal wetland using multi-temporal satellite images

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Abstract Anzali is one of the 18 Iranian wetlands of international importance listed in Ramsar Convention. This unique ecosystem in the world with high ecological diversity is highly threatened by various factors such as pollutants, sedimentation, unauthorized development of urban infrastructure, over-harvesting of wetland resources, land use changes, and invasive species. Among which, one of the most challenging destructive factors, land use change, was scrutinized in this study. For this, remotely sensed data and Geographical Information System (GIS) were used to detect land changes and corresponding impacts on the study area over a 38-year period from 1975 to 2013. Changes in the study area were traced in five dominant land-use classes at four time intervals of 1975, 1989, 2007, and

2013. Accordingly, changes in different categories were quantified using satellite images. The methodology adopted in this study includes an integrated approach of supervised classification, zonal and object-oriented image analyses. According to the Kappa coefficient of 0.84 for the land use map of 2013, the overall accuracy of the method was estimated at 89 %, which indicated that this method can be useful for monitoring and behavior analysis of other Iranian wetlands. The obtained results revealed extensive land use changes over the study period. As the results suggest, between the years 1975 to 2013, approximately 6500 ha (~69 %) rangeland area degraded. Further, urban and agricultural areas have been extended by 2982 ha (~74 %) and 2228 ha (~6 %), respectively. This could leave a negative impact on water quality of the wetland.

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Introduction

In 1975, Anzali Wetland was registered in Ramsar Convention as a wetland of international importance (www.ramsar.org). The main goals of Ramsar Convention, signed by all contracting parties including Iran, are conservation and wise use of wetlands to achieve sustainable development (Jones et al. 2009). Unfortunately, Iran with having a total number of six endangered wetlands, including Anzali Wetland, stands

first in the Montreux Record. Among the main reasons that led Anzali placed on the Montreux list are high sedimentation rate due to erosion of upstream forest and rangeland areas, discharge of industrial and domestic wastewater, release of pesticides and chemical fertilizers, and land use changes as a whole. All these factors cause eutrophication phenomenon in the wetland, resulting in abnormal growth of aquatic plant species and reduced depth of water as major threats to the life of the wetland. Other important threats include excessive growth of *Azolla filiculoides*, change of wetland surrounding lands to farmlands and orchards, water pump into the paddy fields and fish-farming ponds, and return of wastewater enriched with nitrogen- and phosphate-based fertilizers and pesticides into the wetland (Ashoori and Abdoos 2013). The total sediment transport to the wetland is estimated at approximately 400,000 t/year, 30 % (about 110,000 t/year) of which is deposited in the wetland and the remaining (nearly 290,000 t/years) is discharged into the Caspian Sea (JICA and DOE 2005). During the last 50 years, the average water depth of the wetland has reduced significantly from 10 to 2 m. This would mainly due to river in sediments and deposition. Urban development and population growth surrounding exacerbate the situation by the release of municipal wastewater and agricultural effluents containing chemical fertilizers and pesticides as well as the dump of solid waste (Kiani Saba and Pourjahan 2013).

Welfare of human societies depends on ecosystem services provided by the nature (Teeb 2010). Wetlands cover about 6 % of the Earth's surface and play a key role in global carbon cycle (Erwin 2009). In 2012, around 28 % of the state parties confirmed deterioration of wetlands in their countries while the improvement of wetlands was reported by only 19 % of them (Ramsar Convention 2012). Increased pollutants induced by population growth around the wetlands can threaten the coastal areas (Kennish 2002). In other words, increased population and human activities causes an increased demand on limited land resources for farming. It is necessary to have information about the rate and type of land use changes for sustainable planning and management of land resources (Phukan et al. 2013).

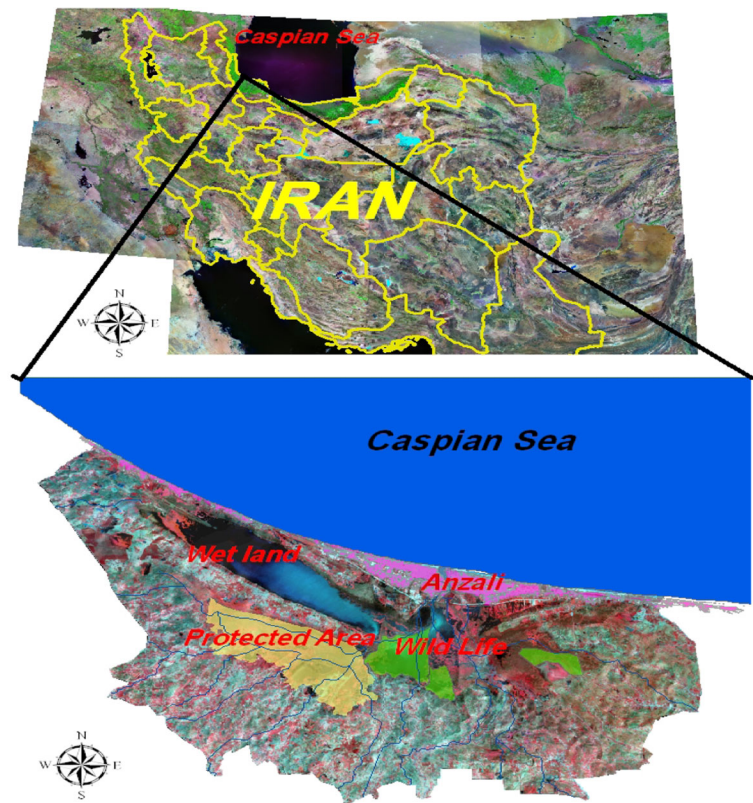
Sheikh in 2001 suggested remote sensing to detect land use changes over time. He declared that remotely sensed data can easily be integrated with GIS software (Adam et al. 2010). Remote sensing techniques make it possible to study land use changes in less time and with less cost and better accuracy. Remote sensing

and GIS provide effective tools for land use planning and modeling. Land use is an indicator of human interaction with nature. Therefore, it is necessary to discover and monitor land use changes in order to either protect the environment or ensure sustainable development (Pandian et al. 2014). Remote sensing techniques are widely accepted as one of the most appropriate and accurate tools of land use monitoring. Detecting the changing trend of land uses in the wetlands and surroundings can be useful in management and planning of such valuable ecosystems. Remote sensing offers many advantages in situation analysis and monitoring of the wetlands. It can also verify changes in different land use classes over time (Ozesmi and bauer 2002).

In a relevant study by Qulin in China in 2003, biomass levels of a Chinese wetland were studied by non-automatic interpretation of remote sensing images with 4.3.2 virtual color composition. In another study by Zhaoning et al. (2007), relationship between the spatial pattern of landscape and changes in water quality of main wetlands of Beijing was studied using satellite images and point samples. Zhang et al. (2011) detected the changing trend of Hanshiqiao Wetland during a 16-year period using supervised classification method. They concluded that the wetland area has been declined due to conversion of wetland area into the cultivated, forest, and grass lands. Chen et al. (2014) developed a method to classify wetland cover types based on timing of inundation with time series of 16-day MODIS NDVI from 2000 to 2012. Their findings showed that MODIS 250-m resolution based on timing inundation was useful for mapping general land cover patterns of Poyang Lake. Dronova et al. (2011) used object-based image analysis and supervised classification to four 32-m Beijing-1 micro-satellite images to study broad-scale surface cover composition and its change during November 2007–March 2008 low-water season at Poyang Lake. They reported that the “fuzziest” mudflat class declined in classification accuracy by March 2008.

Wetlands have a significant role in hydrological and geochemical (carbon sequestration) cycles, nitrogen absorption, and conservation of biodiversity and water resources. In large areas, it is so difficult to map wetlands by common field surveying methods. This problem can be solved by remote sensing techniques. However, spectral interference with other land cover

Fig. 1 Location of the study area in the Caspian Sea and in Iran



types makes it difficult to verify different land uses and to determine the boundary of wetlands automatically. By integrated use of multi-source remote sensing data and DEM, the present study offers a composite method for automated delimitation of lakes and wetlands. The overall accuracy of the classification by this method exceeds 85 %, which is within the acceptable range (Zhu et al. 2011). Kindu et al. (2013) used an object-based image classification technique to classify the satellite images. Accuracy assessment was performed for each reference year. Change detection analysis was also done using post classification in GIS. A total number of nine land use land cover classes (LULC) were successfully captured with the overall accuracy values varying

from 85.7 to 93.25 % and the kappa coefficient range of 0.822 to 0.924 (Kindu et al. 2013). Comparative assessment of local needs, costs, and benefits was also carried out by proper planning and management. To support the results, spatially explicit, synoptic land cover change data was provided by satellite remote sensing. Nielsen et al. (2008) produced a 30-m resolution wetland change probability map for the US mid-Atlantic region by applying an outlier detection technique to a base classification provided by the National Wetlands Inventory (NWI). The accuracy of a regional change/no-change map produced from the change probabilities was estimated at 89.6 % with a Kappa of 0.779 (Nielsen et al. 2008).

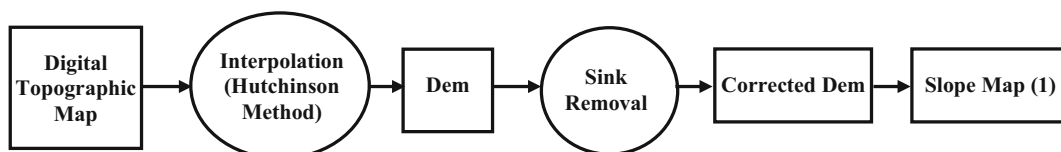


Fig. 2 Flow diagram of creating DEM and slope map of Anzali Wetland

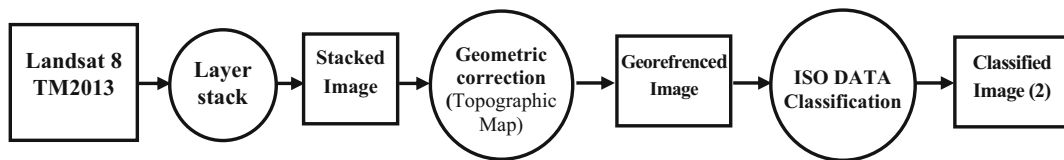


Fig. 3 Flow diagram of unsupervised classification method

In Iran, Zebardast and Jafari in 2011 prepared an environmental management for Anzali Wetland by detection of environmental changes during a 10-year period using remote sensing and GIS. They classified the wetland into five land use classes with an overall accuracy of 80.83. Their findings suggested that Anzali Wetland has been deteriorated over the 10-year period, and the resulting impacts on vegetation type and water body have resulted in eutrophication of the wetland (Zebardast and Jafari 2011).

Jamalzade in 1998 delimited Anzali Wetland using satellite images. He also mapped sensitivity of different zones in the wetland by sampling and entering the data to GIS software. Nouri et al. (2013) used supervised classification method to detect land use changes in Anzali Wetland. The overall accuracy in their study was 82 %.

Land use change detection would be necessary to understand the existing condition of a wetland and to prepare future management plans. In this study, it was attempted to detect the changes occurred in Anzali Wetland and the resulting impacts during a 38-year period using remote sensing and GIS. Land use maps of different time intervals were prepared using post-classification analyses and a combination of supervised and segmentation. Objectives of the current paper can be summarized as follows: (1) identification and quantification of different land uses in the wetland during four periods using remote sensing, (2) analysis of the impacts of land use changes, and (3) determination of main challenges and the need for further researches.

Materials and methods

Study area

The study area covers a part of Anzali Wetland, in the southwest of the Caspian Sea, between the latitudes of 37° 15' and 37° 35' N and the longitudes of 49° 10' and 49° 40' E. Anzali Wetland is located in Anzali towns in the vicinity of Rasht and Some'esara Cities. Changes in the area of the wetland are strongly influenced by fluctuations in the Caspian Sea level and annual rainfall. Since the sea level rise in 1991, the wetland area has also been expanding. The water level of the wetland is 26 m below the open sea level (Ashoori and Abdoos 2013). Anzali Wetland with several large freshwater lagoons including extensive reed beds and seasonally flooded meadows at the southwest Caspian Sea provides a good place for spawning and nursery of fish species and for breeding, staging and wintering of a wide variety of waterfowls.

Anzali City in the north is a highly developed urban area (JICA and DOE 2012). There could be found four distinct parts in the wetland as follows:

- (1) The shallowest part in the east where the growth of aquatic plants is very high.

Compared with other parts of the wetland, it is more polluted due to industrial, agricultural, and municipal wastewater discharge.

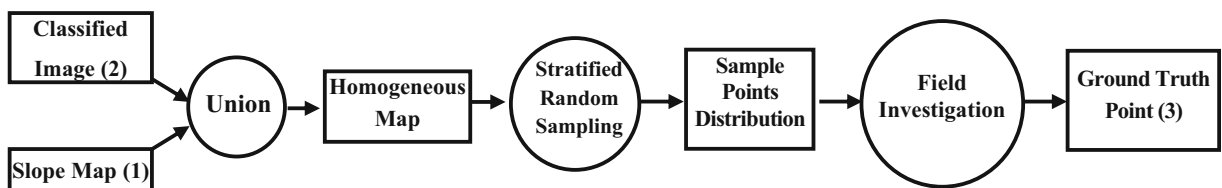
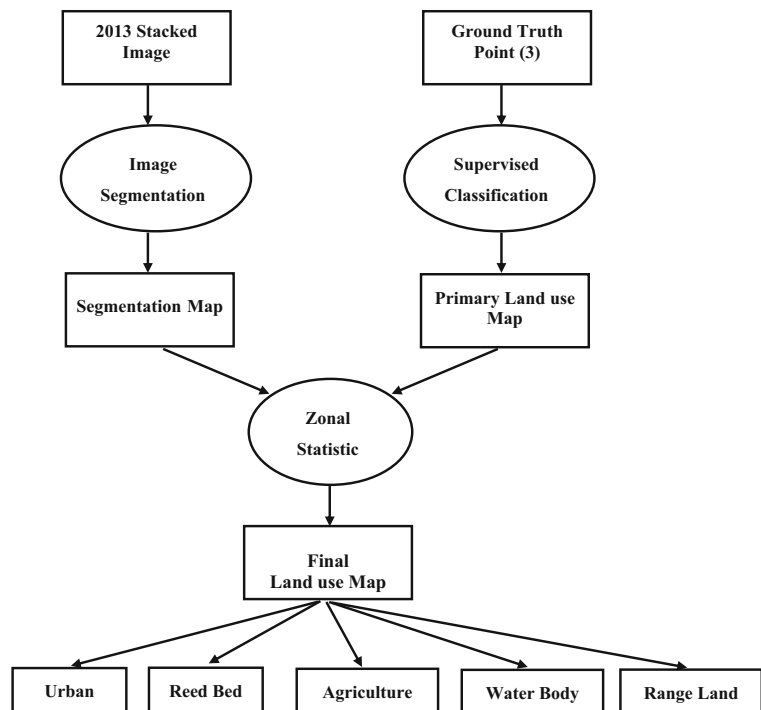


Fig. 4 Flow diagram of positioning training sample points

Fig. 5 Supervised classification and image segmentation processes



- (2) Terrestrial part in the center. The enormous growth of floating and emergent such as *Phragmites Australis*, has dried a vast area in the central wetland.
- (3) Siahkeshim area in the southwest of the wetland.
- (4) Deepest part in the west where the water table is at its peak (Kiani Saba and Pourjahan 2013).

Including the water body and reed beds; the current area of the wetland reaches by about 19,095 ha with a surface area of 65,553 ha. Anzali Wetland encompasses one protected area called Siahkeshim (3935 ha) and three wildlife refuges, namely Selkeh (360 ha), Sorkhnkol (1209 ha), and Choukam (443 ha), all of which are rich in biodiversity and required to be protected. Figure 1 depicts location of the study area in the Caspian Sea and in Iran.

Materials

The following materials were used in the present study:

- (i) Landsat TM 8 image (2013), Aster (2007), TM 5 (1989), MSS (1975).

- (ii) 1:25,000-scale digital topographic maps with 10-m contour lines prepared by the National Cartographic Center of Iran based on aerial photos of 1993. The maps were mainly used for geo-referencing of satellite images, ground truthing, and generating of Digital Elevation Model (DEM) and slope map.
- (iii) Ground truth points for supervised classification and accuracy assessment.
- (iv) ERDAS Imagine (version 9.2) and ArcInfo (version 9.3) software to process the images..

Land use classification and mapping

General description

The research procedure could be divided into five phases (Figs. 2, 3, 4, and 5.): (i) preprocessing of the images, (ii) selection of training points in a random manner, (iii) supervised classification of the image into different land use classes (iv) the use of image segmentation and zonal statistics to enhance the land use classification, and (v) accuracy assessment.

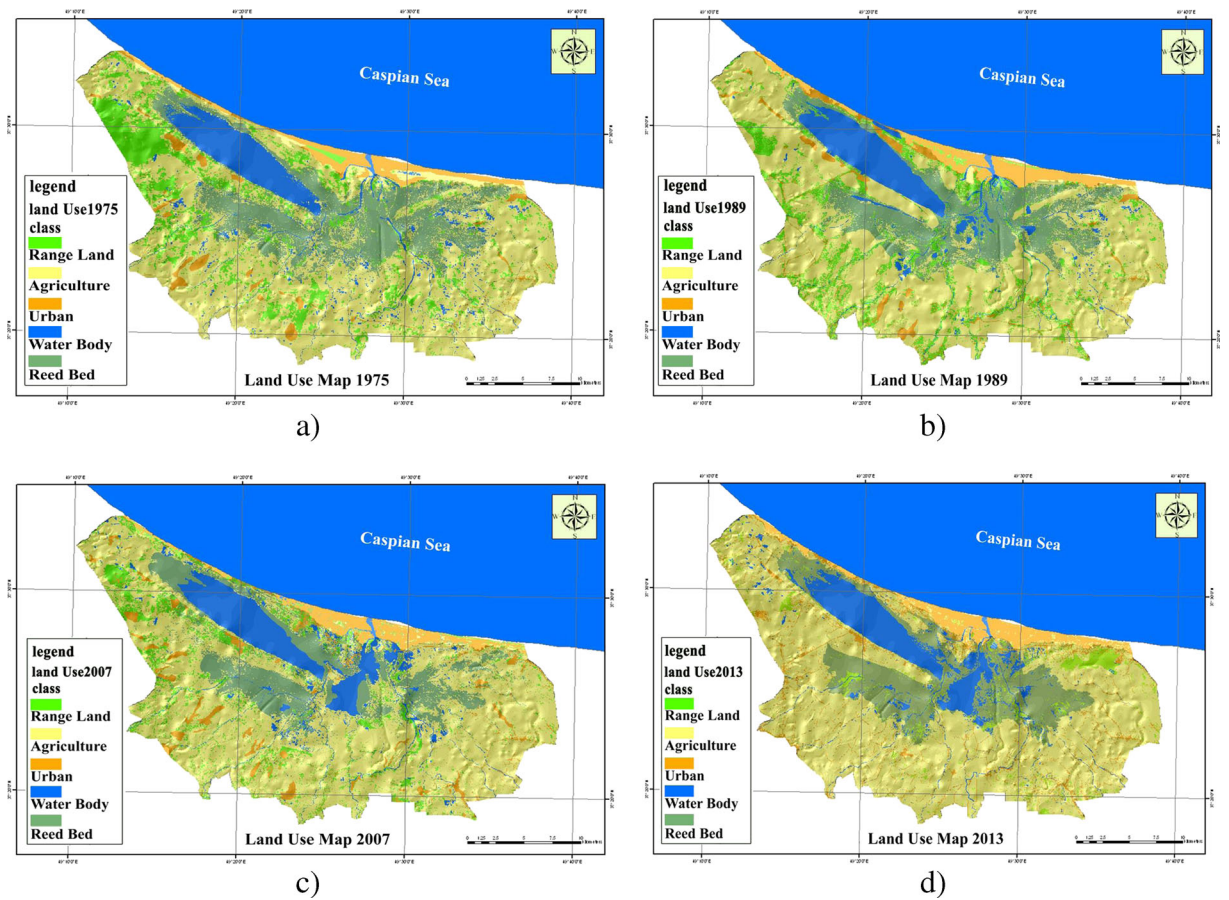


Fig. 6 Land use map of Anzali Wetland in 1975, 1989, 2007, and 2013

Step i: preprocessing of the images

At first, the Landsat TM 8 image of the study area was geo-referenced. The image includes a total number of 11 individual bands, each for a single layer of continuous imagery. Due to the low spatial resolution of the thermal bands (bands 10 and 11), they were excluded from the preprocessing. The visible and infrared bands (bands 2, 3, 4, 5, 6, and 7) were stacked to create a multilayer image. The image was then clipped to the boundary of the study area together with a buffer of 300 m.

The geo-referencing operation was performed by using 20 ground control points taken from 1:25,000 topographic maps (Fig. 2). The coordinate system of the topographic maps was set on Universal Transverse Mercator (UTM) zone 39 North WGS84. The images were re-sampled using first-degree polynomial and nearest neighborhood methods. The resultant RMS error was estimated at 0.85 pixels. Therefore, this image was chosen as the reference image.

Step ii: training points

Creating DEM and slope map For preparing DEM, the map layers of main streams, elevation points, and contour lines were derived from topographic map of the study area at a scale of 1:25,000. The resultant DEM had

Table 1 Overall accuracy and Kappa coefficients for the land use map of 2013

Land use type	Test result	
	Accuracy matrix (%)	Kappa coefficient
Agricultural lands	83.3	0.82
Rangeland	90.9	0.90
Reed Bed	79	0.75
Urban areas	92.9	0.85
Water body	88.9	0.87
Total	89	0.84

Table 2 Overall accuracy of land use maps of the four time periods

Land use map	Overall accuracy (%)
MSS 1975	72.4
TM 1989	86.9
Aster 2007	83.2
TM 2013	89.1

a pixel size of 10 m. To avoid mis-interpolation of borders, a 300-m buffer zone was also considered. Virtual sinks estimated at 513 were filled out based on neighborhood analysis using a 3 × 3 filter. Accordingly, the slope map (in percent) of the study area was produced (Fig. 2).

Unsupervised classification and homogenous polygons Training sample points were distributed throughout the study area in a way to include different kinds of land use classes. In this phase, the land use classes were classified using unsupervised classification method as depicted in Fig. 3. According to which, nine land use classes were detected on Landsat TM 8 image. Convergence threshold and maximum iterations were 95 % and 14, respectively. Subsequently, the classified land use map was overlaid with the classified slope map to generate a total number of 30 homogeneous units. The homogeneous unit map was used as a basis for positioning training sample point. These points were later used to support supervised classification of land uses in the study area. As illustrated in Fig. 4, a total number of 220 training sample points were specified using stratified random sampling method as explained by Stehman (1999).

Step iii: supervised classification

Supervised classification classified the study area into five land use classes including agricultural areas (AG), reed beds (RB), rangelands (R), urban areas (U), and water bodies (W). The classification was done using maximum likelihood method and ground-truth points. Based on which, the land use map of the study area including five land use classes was prepared for each of the four images (Fig. 5). Therefore, confidence level was repeatedly by 90 %. About 1 % of all pixels were recognized as “unknown,” which was remained unclassified.

Step IV: image segmentation and zonal statistics

The accuracy of the Landsat TM8 images was enhanced by image segmentation algorithm, namely Bonnie Ruefenacht (Fig. 5) (Ruefenacht et al. 2002). Image segmentation parameters in this phase include minimal value difference of 10 and variance factor of 2, as well as edge detection settings comprising threshold of 9 and minimal length of 5.

The segmented image was then overlaid with the “primary classified map,” as seen in Fig. 5, to distinguish the size, shape, and homogeneity of different objects. The raster to vector format of this algorithm could just merge pixel groups into polygon objects without classifying them. So, it is required to integrate the segmented image and the classified map with zonal statistical analysis (Fig. 5) to generate a new classified polygon map in which the error of mixed pixels is eliminated. Zonal statistics clarifies distribution of each land use in each segmented polygon.

It was revealed that the majority distribution for the five land use classes within any one segmented

Table 3 Total estimated area of each land use category (ha, %) in Anzali Wetland

Land use category	1975		1989		2007		2013	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agriculture	35,357	53.94	36,070	55.02	37,317	56.93	37,585	57.34
Range land	9479	14.46	8197	12.50	6178	9.42	2979	4.54
Urban area	4038	6.16	5502	8.39	6005	9.16	7020	10.71
Water body	6001	9.15	6048	9.23	6971	10.63	7257	11.07
Reed bed	10,678	16.29	9736	14.85	9082	13.85	10,712	16.34
Total	65,553	100.00	65,553	100	65,553	100	65,553	100

Table 4 Land use changes during the periods of 1975–1989, 1989–2007, 2007–2013, and 1975–2013

Land use type	Land use change							
	1975–1989		1989–2007		2007–2013		1975–2013	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Agricultural lands	713	2.02	1247	3.46	268	0.72	2228	6.30
Rangeland	-1282	-13.52	-2019	-24.63	-3199	-51.78	-6500	-68.57
Urban area	1464	36.26	503	9.14	1015	16.9	2982	73.85
Water body	47	0.78	923	15.26	286	4.1	1256	20.93
Reed bed	-942	-8.82	-654	-6.72	1630	17.95	34	0.32

polygon was always more than 90 %. Therefore, each segmented polygon was fully classified to the 90 % majority, by which one layer was prepared for each of the five Land use categories (Fig. 5). Figure 6a–d) compares land use changes of Anzali Wetland at different time intervals.

Table 5 Trend of changes in population, water consumption, wastewater and solid waste production, and amount of nitrogen fertilizer used in agricultural lands in various time series

Indicators	1975	1989	2007	2013
Population of Anzali City	55,481	94,697	110,643	116,664
Changes (%)	0	70.7	16.8	5.4
Water consumption (million liters/day)	6.24 ^a	10.65	12.45	13.12
Changes (%)	0	70.7	16.8	5.4
Wastewater production (million liters/day)	5.60 ^b	9.56	11.17	11.78
Changes (%)	0	70.7	16.8	5.4
Solid waste production (ton/day)	44.38 ^c	75.76	88.51	93.33
Changes (%)	0.00	70.70	16.80	5.40
Amount of nitrogen fertilizer used in agricultural lands (ton/day)	4419.63 ^d	4508.75	4664.63	4698.13
Changes (%)	0	2.02	3.46	0.72

^a National per capita water consumption is 112.5 L/day

^b Average per capita of wastewater production for urban areas is 101 L/day (Sadatiyan Abkenar, M. 2012)

^c Per capita of solid wastes production in Gilan Province is estimated to be 800 g/person (Municipality of Anzali 2009)

^d The amount of nitrogen-based fertilizers used in paddy fields is 125 kg/ha on average (AREEO 2015).

Map accuracy assessment

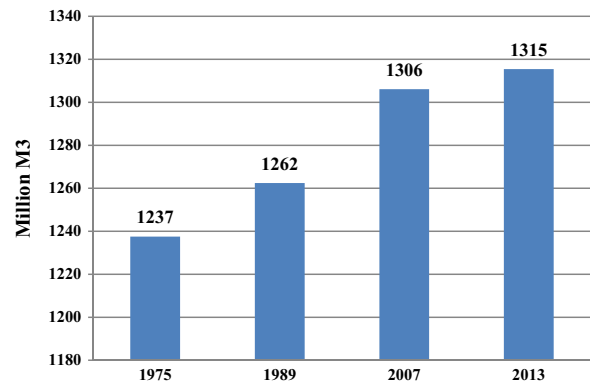
Based upon a total number of 110 training points extracted from TM images, the accuracy of the land use map of the year 2013 was estimated (Table 1). The overall accuracy was also estimated for other land use maps prepared from different satellite images (Table 2).

Results and discussion

Multi-temporal land use statistics reveal extensive land use changes in the study area from 1975 to 2013. Findings of this study suggest that the water body area of Anzali wetland has expanded during 38 years. The obtained results indicate an increased extent of water bodies from 6001 ha in 1975 to 7257 ha in 2013, which is attributed to deposition of 110,000 t/year of sediments. This decreased the wetland depth from 10 to 2 m.

During which, the wetland has been under the influence of either anthropogenic or natural threatening factors including a considerable land use loss due to urban expansion and development of farmlands. As a result, a large volume of fertilizers, silt, solid waste, and pesticides are released into the wetland. These in turn cause other problems such as decreased water depth, poor water quality, and destructed natural ecosystem. Interpretation of the satellite images, the largest proportion of the study area was covered by water body in 2013 while this proportion reduced to the lowest level in 1975. The increased water body is an indication of decreased water depth of the wetland in the last 40 years due to high rate sedimentation in the basin. To detect land use changes in the study area during the period of 1975–2013, land use maps of the four time intervals were compared with each other (Table 3).

Fig. 7 Comparison of changes in agricultural water demand in various time intervals



As Table 4 suggests, the declining trend of rangeland areas has been accelerated from 2007 to 2013. In contrast, urban areas had a highest growth rate from 1975 to 1989. Furthermore, water body underwent the greatest changes from 1989 to 2007.

According to Table 4, the area of residential land use and water bodies increased respectively by 74 and 21 % during the 38-year period from 1975 to 2013. In other words, these land uses experienced the greatest increase over the study period. The largest decrease of 68 % is related to the rangeland area. Such an extensive land use change in a short period of time could be alarming. Moreover, the area of agricultural lands has shown an increase of 6 % in the study period. During which, the area of wetland vegetation cover (reed beds) had no significant changes. Satellite images demonstrate a significant reduction in rangeland area from 14.6 % in 1975 to 4.54 % in 2013. This can be attributed to overgrazing, conversion of forests and rangelands to urban and agricultural land uses as a result of population growth.

The method used in the present study has an acceptable accuracy compared to the relevant studies previously conducted in the study area. The main advantage of this research compared to similar studies is the use of image segmentation as an object-oriented method along with zonal statistics. For instance, in a study by Zebardast and Jafari in 2011 in the same study area, an overall accuracy of 80 % was attained by visual interpretation while the accuracy was enhanced by 89 % in this research by filed investigations and considering a large number of control points. Large number of training points scrutinized the accuracy of detecting different land uses at borders. Furthermore, this study sought to discuss the effects of land use changes on the wetland environment.

Farming is recognized as the main threat to freshwater of the wetland ecosystems in northern Iran. Change

detection of different land use classes in the last 38 years confirms an increase in the farmland areas as a result of population growth (Table 5). The wetland is bordered on the south by cultivated lands (mainly paddy farms) with a water demand of 30,000–35,000 million m³/ha on average. An increase of 2500 ha in cultivated lands increased the water demand from 1237 million m³ in 1975 to 1315 million m³ in 2013 (Fig. 7). In addition to intensified water consumption, pollution of wetland water by fertilizers and pesticides could clearly be observed in Anzali Wetland so that the use of nitrate-based fertilizers increased from a total of 4400 t in 1975 to 4700 t in 2013. The increase of farmlands demonstrates the expansion of residential areas by 3000 ha during 1975 to 2013. During this period, development of built-up areas expanded the area of impermeable surfaces and in consequent increased the annual runoff. The impact of land use change on water balance was also confirmed by Hosseini et al. (2012). They attributed an increase of 7.3 % in surface runoff and 11.3 and 11 % decrease in the lateral flow and groundwater flow in Taleghan Basin to the land use changes within the period of 1987–2007. The adverse effects of land use change have been approved by many researchers such as Wagner et al. (2013) in India, Gustard and Wesselink (1993) in Balquhiddier catchment in Scotland, and Li et al. (2013).

According to the latest consensus in 2011 by Iranian Center of Statistics, population of Anzali City, as the greatest residential area in the study area, increased from 55,000 inhabitants in 1975 to approximately 110,000 inhabitants in 2013, a growth rate of 110 %. Consequently, the per capita water consumption rose from 6 to 13 million liters. Further, per capita wastewater increased from 5.6 to 11 million liters. An increase of per capita municipal waste was also reported from 44 to 93 t during 1975–2013.

Fallah et al. (2014) measured nitrate level in water of Anzali Wetland. They found a dramatic increase in nitrate level from spring 2007 to spring 2013.

Majority of inhabitants in the study area are farmers and rancher. They use grasses and other small plants to feed livestock. Accordingly, natural vegetation cover is rapidly being decreased. A large part of rangeland areas is degraded by farmers as land use changes for farming purposes. Furthermore, high population growth rate as a result of unsustainable urban development in the study area has caused large-scale land degradation. This is also confirmed by the findings of Sun and Zhou (2016) which reported rapid farmland expansion and the subsequent abandonment of the farms as predominant land use changes in arid zone of western China. Further, Okta Pribadi and Pauleit (2015) introduced rapid urbanization as a main factor in large-scale loss of farmland and increased land fragmentation in Jabodetabek Metropolitan Area, Jakarta.

Increased area of water body as well as declined water depth during the years 1975 and 2013 urge implementation of advanced watershed management strategies in the adjacent basins in order to reduce transport of sediment into the wetland. It is worth mentioning that those wetlands listed in Montreux Record are faced with the risk of increased pollutants from expansion of the surrounding farmlands, increased use of chemical fertilizers, and skyrocketing water consumption. According to which, proper use of agricultural fertilizers and modification of cultivation and irrigation patterns would be among the highly recommended strategies. It is also strongly suggested to reduce the area of farmlands around the wetland. Another strategy to overcome the problem of wetland over pollution and sedimentation can be implementation of sustainable rangeland and forestry plans in the study area.

Conclusion

This study shows application of remote sensing techniques in spatiotemporal analysis of land use changes. Precise monitoring of land use changes is necessary for the achievement of sustainable development goals. In conclusion, reclamation of land uses should be based on accurate analyses of environmental consequences.

Considering the increasing trend of population growth and expansion of residential areas around the wetland, management of wastewater and solid waste

released by industries into the wetland is quite essential. The obtained results suggest that urban areas and farmlands have gradually been expanded in the study area from 1975 to 2013. This can cause a negative impact on water quality of Anzali Wetland. Therefore, it would be of utmost importance to prepare a comprehensive management plan to avoid extensive land use changes. This requires the cooperation of all stakeholders. Otherwise, the ecological properties of the wetland will be subject to destruction, and the concept of the rational use outlined in Ramsar Convention will be violated.

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References

- Adam, E., Mutanga, O., & Rugege, D. (2010). Multispectral and hyperspectral remote sensing for identification and mapping of wetland vegetation: a review. *Wetlands Ecology and Management*, 18, 281–296.
- Agricultural Research, Education & Extension Organization (AREEO) (2015). Rice research institute of Iran, deputy of Mazandaran. Available at: berenjamol.areo.ir. Accessed date 19 Feb 2015
- Ashoori, A., & Abdoos, A. (2013). *Important wetland habitats for waterbirds of Gilan*. Tehran: Katibeh Gyll Publication (In Persian).
- Chen, L., Jin, Z., Michishita, R., Cai, J., Yue, T., Chen, B., & Xu B. (2014). Dynamic monitoring of wetland cover changes using time-series remote sensing imagery. *Ecological Informatics*, 24, 17–26.
- Dronova, I., Gong, P., & Wang, L. (2011). Object-based analysis and change detection of major wetland cover types and their classification uncertainty during the low water period at Poyang Lake, China. *Remote Sensing of Environment*, 115(12), 3220–3236.
- Erwin, K. L. (2009). Wetlands and global climate change: The role of wetland restoration in a changing world. *Wetlands Ecology and Management*, 17(1), 71–84.
- Fallah, M., Fakheran Esfahani, S., Piralizadeh, A., Farhadian, A. (2014). Investigation of physical and chemical properties of water in Anzali international wetland. The 2nd National and Professional Conference on the Environmental Researches, Iran. (In Persian)
- Gustard, A., & Wesselink, A. J. (1993). Impact of land-use change on water resources: Balquhider catchments. *Journal of Hydrology*, 145(3–4), 389–401.
- Hosseini, M., Ghafouri, A. M., Amin, M. S. M., Tabatabaei, M. R., Goodarzi, M., & Abde Kolahchi, A. (2012). Effects of land use changes on water balance in Taleghan catchment, Iran. *Journal of Agricultural Science and Technology*, 14, 1159–1172.

- Japan International Cooperation Agency and Department of Environment the Islamic Republic of Iran (JICA and DOE) (2005). *The study on Integrated management for ecosystem conservation of the Anzali Wetland*.
- Japan International Cooperation Agency and Department of Environment the Islamic Republic of Iran (JICA and DOE) (2012). *Anzali Wetland ecological management project in the Islamic Republic of Iran - Zoning Plan in the Anzali Wetland*, p. 1.
- Jones, K., Lanthier, Y., Voet, P., Valkengoed, E., Taylor, D., & Fernández-Prieto, D. (2009). Monitoring and assessment of wetlands using Earth Observation: The GlobWetland project. *Journal of Environmental Management*, *90*, 2154–2169.
- Kennish, M. J. (2002). Environmental threats and environmental future of estuaries. *Environmental Conservation*, *29*, 78–107.
- Kiani Saba, M., & Pourjahan, S. (2013). Environmental condition of Anzali wetland, The 1st National Conference on Tourism and Ecotourism in Iran. (In Persian).
- Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2013). Land use/land cover change analysis using object-based classification approach in Munessa-Shashemene landscape of the Ethiopian highlands. *Remote Sensing*, *5*, 2411–2435.
- Li, Q., Cai, T., Yu, M., Lu, G., Xie, W., & Bai, X. (2013). Investigation into the impacts of land-use change on runoff generation characteristics in the upper Huaihe River Basin, China. *Journal of Hydrologic Engineering*, *18*(11), 1464–1470.
- Municipality of Anzali (2009). <http://anzali.ir/and www.shomalnews.com> (In Persian).
- Nielsen, E. M., Prince, S. D., & Koeln, G. T. (2008). Wetland change mapping for the U.S. mid- Atlantic using an outlier detection technique. *Journal of Remote Sensing of Environment*, *112*, 4061–4074.
- Nouri, J., Gharagozlou, A., Arjmandi, R., Faryadi, S. V., & Adl M. (2013). Monitoring of land use changes in Anzali city to achieve the goals of sustainable urban development. The 3rd International Conference on Environmental Planning and Management. (In Persian).
- Okta Pribadi, D., & Pauleit, S. (2015). The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek Metropolitan Area. *Land Use Policy*, *48*, 13–24.
- Ozesmi, S. L., & Bauer, M. E. (2002). Satellite remote sensing of wetlands. *Wetlands Ecology and Management*, *10*, 381–402.
- Pandian, M., Rajagopal, N., Sakthivel, G., & Amrutha, D. E. (2014). Land use and land cover change detection using remote sensing and GIS in parts of Coimbatore and Tiruppur districts, Tamil Nadu, India. *International Journal of Remote Sensing & Geoscience (IJRSG)*, *3*(1), 15–20.
- Phukan, P., Thakuria, G., & Saikia, R. (2013). Land use land cover change detection using remote sensing and GIS techniques—a case study of Golaghat district of Assam, India. *International Research Journal of Earth Sciences*, *1*(1), 11–15.
- Ramsar Convention, (2012). Report of the Secretary General on the implementation of the Convention at the global level. Ramsar COP11 DOC. 7. <http://www.ramsar.org/pdf/cop11/doc/cop11-doc07-e-sg.pdf>.
- Ruefenacht, B., Vanderzanden, D., & Morrison, M. (2002). New technique for segmenting images. An image segmentation algorithm developed by the USDA Forest service, Remote Sensing Application Center. <http://www.fs.fed.us/Sadatiyan>
- Abkenar, M. (2012). Guide to Water and Wastewater Engineering, Maks e Nazar Publication. (In Persian).
- Stehman, S. V. (1999). Basic probability sampling designs for thematic map accuracy assessment. *International Journal of Remote Sensing*, *20*, 2423–2441.
- Sun, B., & Zhou, Q. (2016). Expressing the spatio-temporal pattern of farmland change in arid lands using landscape metrics. *Journal of Arid Environments*, *124*, 118–127.
- TEEB, (2010). The economics of ecosystems and biodiversity: ecological and economic foundations. Editor: Kumar P. Earthscan, London and Washington.
- Zebardast, L., & Jafari, R. (2011). Assessment of changes in Anzali wetland using remote sensing and management solutions. *Journal of Ecology*, *37*(57), 57–64 (In Persian).
- Zhang, W. W., Yao, L., Li, H., Sun, D. F., & Zhou, L. D. (2011). Research on land use change in Beijing hanshiqiao wetland nature reserve using remote sensing and GIS. *Procedia Environmental Sciences*, *10*, 583–588.
- Zhu, C., Luo, J., Shen, Z., & Huang, C. (2011). Wetland mapping in the Balqash Lake Basin using multi-source remote sensing data and topographic features synergic retrieval. *Procedia Environmental Sciences*, *10*, 2718–2724.
- Wagner, P. D., Kumar, S., & Schneider, K. (2013). An assessment of land use change impacts on the water resources of the Mula and Mutha Rivers catchment upstream of Pune, India. *Hydrology and Earth System Sciences*, *17*, 2233–2246 www.ramsar.org/country-profiles.x.
- Zhaoning, G., Huili, G., Wenji, Z., Xiaojuan, L., & Zhuowei, H. (2007). Using RS and GIS to monitoring Beijing wetland resources evolution. *IEEE International*, 4596 – 4599.