LAND USE/COVER CHANGE DETECTION THROUGH REMOTE SENSING AND GIS TECHNIQUES: A CASE STUDY OF ASTRAKHAN, RUSSIA

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The present study illustrates the spatial-temporal dynamics of Land use/cover change in Astrakhan city, Russia. Landsat satellite imageries of three different time periods of 2000, 2007 and 2015 were acquired by earth explorer website and quantify the changes in the Astrakhan. In this study maximum-likelihood supervised classification along with post-classification change detection was applied to satellite images for 2000, 2007 and 2015 in order to map land use/cover changes. The land use/cover study was classified into five major class's viz. agriculture, bare-land, settlements, vegetation and water body. The classification results were then further refined using ancillary data, visual interpretation and expert knowledge of the area along with GIS. After post-classification change detection a change image form the cross-tabulations were generated. The result shows extensive vegetation degradation and water logging in different parts of the study area.

Keywords: Landscape classification, change trajectories, satellite data, remote sensing, GIS.

Introduction

Changes on the earth's surface can be related to the natural dynamics of human activities. Timely and accurate change detection of the earth's surface features provides a better understanding of the interactions between human and natural phenomena to better management. Over the last 15 years in southern Russia has been subjected to a series of major disturbances both natural and manmade such as droughts, civil disturbances leading to migration, large population increases and cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, geology, water and other physical features of the land, including settlements [1-2]. Today earth resource satellites data are very applicable and useful for land use/cover change detection studies [2], with the invent of remote sensing and Geographical Information System (GIS) techniques, land use/cover mapping has given a useful and detailed way to improve the selection of areas designed to water, urban, settlements and industrial areas of a region [3-4].

Encroachment of urban settlements upon agricultural land may pose dire results such as land degradation. The ever increasing population produces growing pressure on areas that are causes a decrease in area per capita [5-6]. The government of Russia adopted policies aimed at maximization of production on the existing agricultural land.

The study area was selected for change detection because of being subjected to settlements, water body and soil erosion, over grazing and cutting of any cooperative communal structure and reduced income opportunities. The fast urban development taking a place in the study area has led to environmental problems [7-8]. Therefore, the main objective of the present research was to utilize GIS and remote sensing applications to discern the extent of changes occurred in Astrakhan, Russia, over 15 year time period [9-10].

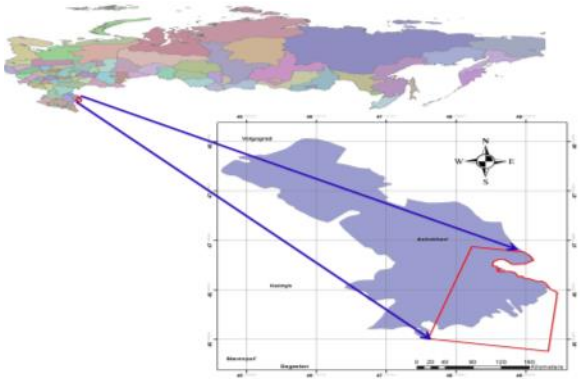

Fig. 1. Location map of the study area in Astrakhan, Russia.

The objectives of this study were to:

1. To identify and perspective different land use/cover categories.
2. To monitoring 2000 to 2015 land-cover changes using GIS and then classification.
3. To describe problems and make brief suggestions for improved management of natural resources.

Study area, data and methodology

Astrakhan is a city in southern Russia and the administrative center of Astrakhan Oblast (fig. 1). The city lies on two banks of the Volga River, close to where it discharges into the Caspian Sea. The latitude of the city is 46°20' N and longitude 48°1' E and average elevation is -12 meters (-39 feet). There are many techniques available for detecting and recording differences, ratios and correlation. The data used in this paper were divided into two categories first satellite data and second ancillary data. Satellite data for the other hand consisted of multi- spectral data acquired by Landsat satellite provided by USGS gloves. Ancillary data include ground truth data for the land use/cover classes and topographic maps.

Any study of land use changes will involve the analysis of both conventional and remotely sensed data. Conventional data is more accurate and site specific, but its collection is time consuming, manpower hungry and difficult to extrapolate over a larger area. Remotely sensed data, on the other hand, has several advantages due to its repetitive and synoptic coverage of large and inaccessible areas in a quick and economical fashion. In the present study both conventional and remotely sensed data were used. The specific satellite images used were Landsat ETM+ (Enhanced Thematic Mapper plus) for 2000 and 2007, Landsat OLI (Operational Land Imager) for 2015, an image captured by a different type of sensors at a resolution of 30m were used for land use/cover classification. These data sets were imported in ArcGIS 10.2 software. Satellite images were making by processing software to create composites [11-12]. A Trimble hand-held GPS with an accuracy of 10 meters was used to map and collect the coordinates of important land use features during pre- and post-classification field visits to the study area in order to prepare land-use and land-cover maps. Supervised classification was performed here using ground checkpoints and digital topographic maps. The area was classified into eight main classes:

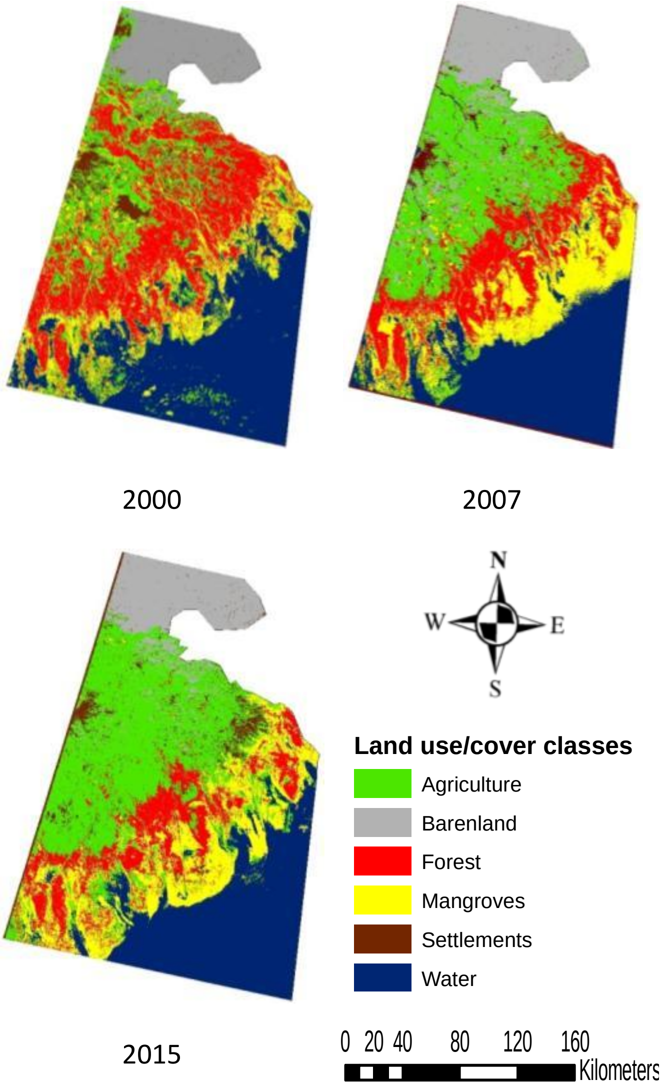

Fig. 2. Land use/cover status of the Astrakhan, Russia; (a) in 2000, (b) in 2007 and (c) 2015 (based on Landsat ETM+ and OLI Satellite Imagery).

1. Agriculture - areas cultivated with annual crops,
2. vegetables or fruit.
3. Forest - small trees and shrub vegetation area except for vegetation.
4. Bare soil - land areas of exposed soil surface influenced by human impacts and/or natural causes, containing sparse vegetation with very low plant cover due to overgrazing and woodcutting.
5. Dunes – with or without vegetation.
6. Mangroves - small trees and shrubs grow near the saline coast line and river.
7. Ocean & river – the Volga River and its mouth in the Caspian Sea.
8. Urban - includes construction activities along the coastal dunes (summer resorts) as well as sporadic houses within the local villages and some governmental buildings in the main city of Astrakhan.
9. Costal Trays- accurse or close to sea area.

Results

Land use/cover status

Figure 2 shows land use/cover image after supervised classification. These images provide pattern of land use/cover of the study area. The brown color represent settlements, green color vegetation, blue color water/ice, gray color shows the bare land and yellow color shows mangroves. All land cover class maps were compared with reference data, which was prepared by ground truth, sample points and google earth. Over all classification accuracy of the study area was more than 90% for all three dates.

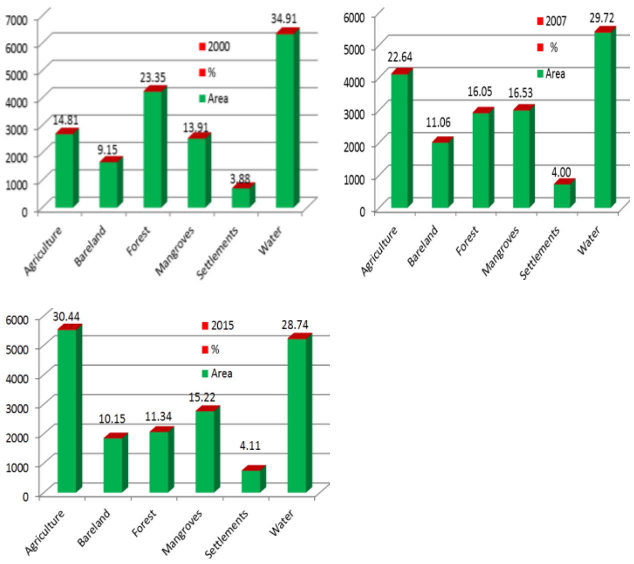

Fig. 3. Land use/cover for Astrakhan, Russia in 2000, 2007 and 2015.

Classification maps were generated for all of the fifteen years shown in figure 2 and the individual class area and change statistics are summarized in table 1. In 2000 the urban area covered 703.78 km² (3.88%), but by 2007 it had increased to approximately 725.65 km² (4.00%) and in 2015 had increased to 745.23 km² (4.11%). The agricultural area initially increased from 2685.32 km² (14.81%) in 2000 to 4104.88 km² (22.64%) by 2007 and then had increased to 5519.75 km² (30.44%) by 2015. The forested area decreased from 2000, 4233.45 km² (23.35%) to 2910.94 km² (16.05%) by 2007 and then it again decreased from 2015 to 2055.95 km² (11.34%). The mangroves area was 2521.43 km² (13.91%) in 2000, in 2007 had increased 2996.45 km² (16.53%) and then it had decreased 2758.90 km² (15.22%) by 2015. Although the extent of mangroves may change from year to year due to varying precipitation and temperature and although variation is also likely due to classification errors, because of the high classification accuracy for water small fluctuations in water are believed to be related to different water levels.

The vegetation (forest, agriculture and mangroves) has been most dominant class in the study are for all three dates (fig. 3). Settlements of the study area were less than 2 percent of the total study due to extreme cold and severe climatic conditions. Since 2000 to 2015 water/ice, settlements and mangroves area were little bit variate (fig. 3). These land use/cover change variables from 2000 to 2015 were mainly caused by natural and manmade activities and climatic conditions.

Table 2. Area and amount of change in different land use/cover categories in the study area during 2000 to 2015.

	2000		2007		2015		2000-07		2007-15	
Class	Area	%	Area	%	Area	%	Diff.	%	Diff.	%
Agriculture	2685.32	14.81	4104.88	22.64	5519.75	30.44	1419.56	7.83	1414.87	7.80
Bareland	1658.17	9.15	2005.68	11.06	1841.04	10.15	347.51	1.92	164.64	0.91
Forest	4233.95	23.35	2910.94	16.05	2055.95	11.34	1323.01	7.30	854.99	4.72
Mangroves	2521.43	13.91	2996.45	16.53	2758.90	15.22	475.02	2.62	237.55	1.31
Settlements	703.78	3.88	725.65	4.00	745.23	4.11	21.87	0.12	19.58	0.11
Water	6329.08	34.91	5388.13	29.72	5210.86	28.74	940.95	5.19	177.27	0.98
Total	18131.73	100.00	18131.73	100.00	18131.73	100.00				

Table 1 shows both positive and negative land use/cove changes in the study area. Since last 15 years only 2007 area has been decrease from 1323.01 km^2 in 2000 to 854.99 km^2 in 2015 which accounts for 4.72% of the total study area (table 2). In the same time other classes such as settlements, vegetation, water/ice increase respectively. In first half from 2000 to 2007, the major change was in bare land and mangroves. Bare land was increase 1.92% (347.51km^2) and forest was decrease 7.30% (1323.01km^2) of the total study area. From 2000 to 2007 total settlement area was increase from 21.87km^2, which is 0.12% of the whole area. Water was reduced approximately 5.19% from 2000 to 2007. From 2007 to 2015 only water body was reduced around 0.98% (177.27km^2) and other classes settlement, vegetation were increased 0.11% (19.58 km^2 and 7.80% (1414.87km^2). Bare land, forest and mangroves were decrease 0.91% (164.64km^2), 4.72% (854.99 km^2) and 1.31% (237.55km^2).

Table 2. Land use/cover change matrix showing land encroachment of the study area

2000-2007	AGRICULTUR	BARENLAND	FOREST	MANGROVES	SETTLEMENT	WATER	Total
Agriculture	1490.07	320.37	120.10	487.35	116.22	148.12	2682.24
Bareland	38.83	1612.52	0.00	0.00	17.75	0.00	1669.10
Forest	1657.33	77.39	2081.44	383.89	39.66	5.82	4245.53
Mangroves	552.81	13.04	681.79	988.57	53.53	205.81	2495.56
Settlements	296.52	206.37	13.87	16.64	170.32	7.21	710.93
Water	72.40	0.00	6.10	1123.65	102.35	5023.86	6328.36
Total	4107.96	2229.68	2903.31	3000.11	499.84	5390.83	18131.73
2007-2015	AGRICULTUR	BARENLAND	FOREST	MANGROVES	SETTLEMENT	WATER	Total
Agriculture	3341.47	104.01	145.34	208.30	302.06	10.82	4112.00
Bareland	354.76	1736.33	0.55	0.00	85.71	0.00	2177.35
Forest	732.81	0.83	1518.69	566.39	87.65	0.00	2906.37
Mangroves	594.96	0.28	383.32	1500.57	37.72	477.91	2994.76
Settlements	147.01	12.76	11.37	31.07	218.29	77.66	498.16
Water	336.17	0.00	1.39	448.23	16.09	4641.22	5443.10
Total	5507.17	1854.21	2060.67	2754.56	747.51	5207.61	18131.73

The results indicate that from 2000 to 2007, 1490.07 km2 agriculture areas was stable but 1657 km^2 area converted from forest to agriculture. In the same time period 988.57 km^2 mangroves area was stable but 1123.65 km^2 water body area was encroached by mangroves. Maximum extension of settlements was in agriculture area around 116.22 km^2 agriculture area was converted into settlements. Maximum stable class was water body, where 5023.86 km^2 areas were stable from 2000 to 2007.

In second half 3341.47 km^2 agriculture area was stable and 354.76 km^2 bare land, 594.96 km^2 mangroves and 732.81 km^2 forest area converted into agriculture land due to increase of demand. In this time period there is not a big change in bare land and maximum bare land area (1736.33 km^2) was stable. From 2007 to 2014 383.32 km^2 mangroves and 145.34 km^2 agriculture area was converted into forest area, which show governmental protection. For mangroves 566.39 km^2 forest area and 448.23 km^2 water body area was converted into mangroves area. In this time period 218.29 km^2 settlement areas was stable but 302.06 km^2 agriculture area was converted into settlements. Its shows very high pressure on surrounding agriculture area of city, where urban area has been extended. In the second half again water body area was highly stable area around 4641.22 km^2.

As shown by our study, land-cover change is mainly driven by the expansion of socio-economic activities. The increase of agricultural areas, if poorly managed, has impacts above those previously mentioned - changes in the soil water cycle, nutrient depletion and an increased risk of soil erosion and land degradation, even though the expansion of croplands leads to a growth in agricultural outputs like food and fibers to positively impact on the country's economy and human well-being. As well as the huge increase in agricultural land there has also been a considerable increase in urban settlements, with the area of natural vegetation decreasing considerably and the main causes of land degradation have been removal of vegetation and water logging. Such changes require rapid adjustments to land management in order to avoid crises in food [13]. From a socio-economic point of view this means not only a loss of ecosystem services, but also a decline of earn money and cultural values, not to mention a subsequent reduction of income from tourism. A consequence of this is to make protected areas some of the few remaining zones where fuel wood, rich pastures and game resources are left and so they attract more and more legal activities.

Conclusion

Over the last 15 years unprecedented land cover and land use changes have occurred within the Volga region. The area has undergone very severe land-cover change as a result of development projects of the agricultural, settlements and tourist kinds. The main drivers of such changes have been both human and natural. A high rate of population increase, economic development and globalization on one side and natural harmful such as floods, drought and climate change on the other side. Present study shows the importance of land use/cover study for resource management and planning and their sustainable development. The results of this research work is helpful for proper utilization of land, there accurate strategical development and conversion in specific timeframe. Here remote sensing and GIS data provide extensive opportunity for this type of land use/cover change study, which is not possible with conventional methods in inaccessible area. The results of this research have direct relevance to land management and nature conservation and can help to elaborate recommendations for a rational land-use strategy in Russia. The mapping, monitoring and modelling of land use/cover in such Astrakhan city could also contribute to the study of global environmental change.

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