SAZLIDERE WATERSHED, ISTANBUL, TURKEY: LAND USE CHANGE AND WATER QUALITY

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Abstract

Increased urbanization is a global problem and a form of environmental change that impacts directly on the day-to-day lives of people. The City of Istanbul is one of the top 25 crowded metropolitan cities in the world and Sazlidere Dam is one of the major drinking water reservoirs of the Istanbul Metropolitan City. In this study, remote sensing (RS) with computer-based Geographic Information Systems (GIS) techniques are used as a tool for monitoring the water basin area and water quality of the catchment of the metropolis drinking water dam reservoir named Sazlıdere. For this aim, the satellite data of IRS-LISS of 2000 and Landsat-5 TM of 2004 are used for urban analysis and water quality. RS data were converted into UTM coordinate system and image enhancement and classification techniques were used. To analyze the study area on protected water basin zones by using GIS raster data was converted to vector data. Finally land use change of the watershed and water quality of the lake is analyzed and presented in this paper.

Keywords: Sazlidere Watershed; remote sensing; GIS; land use; water quality.

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1.Introduction

The area of the province of Istanbul is 5750 km^2 and it covers 0.97% of Turkey (Baz&Geymen,2009). The population living in Istanbul is approximately 13.7 million according to the Address Based Population Registration System in 2012 (TUIK, 2013). It has been increasing rapidly with the pressure on the natural sources, social and environmental infrastructure of the city. The most vital need for life is clean drinking water. The main water basins in Istanbul are Ömerli, Elmali, Küçükçekmece, Büyükçekmece, Alibeyköy, Terkos, Sazlıdere and Darlık. They cover approximately 60% of the city. Some industrial organizations use the riverbeds in the basins as their water resources. In recent years new industrial areas have increased. Organized Industrial Zones (OIZ) around the basins offer great potentials for employment, and have also encouraged population increase and new settlements around their locations (BazandGeymen, 2009)

The Istanbul Water and Sewerage Administration (abbreviated as ISKI in Turkish) are responsible for maintaining the water quality of the supply from all catchment areas of Istanbul. Therefore it needs to protect the drinking water quality and periodically perform total field inventories for it. Protection zones around the drinking water resources are established by Turkish Water Pollution Control Federation (TWPCF) to restrict or to permit residential, industrial and agricultural activities (Coskun etal., 2006). In Istanbul, four types of protection zones are established: absolute (0-300 m), short (300-1000 m), medium (1000-2000) and long distance (2000 m-Water Basin Border) protection zones (Coskun, 2009).

This study is valuable research work for Istanbul using RS/GIS as a tool. RS and GIS are conceded all around the world as effective and useful tools for evaluation, management and analysis of natural resources and water. The field of RS/GIS has become exciting and glamorous with rapidly expanding opportunities (Coskun et al., 2010)

In the world, increasingly, many regions are exposed to natural hazards. To reduce disaster losses, hazard and risk assessments are carried out at multiple scales, ranging from global to community levels. Multi-hazard risk assessment is a complicated procedure and requires a multi-disciplinary approach. RS and GIS have become an integrated approach in natural hazards assessment and disaster risk management (Westen, 2013). (Haq et al., 2012) develops the techniques for mapping flood extent and assessing flood damages by using RS/GIS to improve the efficiency of flood disaster monitoring and management. Besides hazards analysis and risk assessment (Alexakis et al., 2013; Siddiqui et al., 2004; Pradhan, 2010; Pradhan, 2007; El Broudy, 2011); land cover and land use changes (AbdEl_Kawy et al., 2011; Lytwyn, 2010; Obade, 2013; Nandy, 2011), urban growth (Belal, 2011), habitat potential (Choi et al., 2011), water quality (Basnyat et al., 2000; Ju et al., 2010,) are some main subjects of RS/GIS research field.

As in the world quite a lot of studies exist on recent applications of RS/GIS technologies on environmental issues in Turkey. For example, the potential sources and levels of arsenic in geothermal resources of western Turkey are investigated (Baba, 2012). Archaeological features in Hisar (southwest Turkey) are researched (De Laet et al., 2007,). Land use and land cover characteristics of Elmali Water Basin Area in Istanbul (Goksel, 1998), urbanization, either legal or illegal housing, deterioration of agricultural land and green areas in Istanbul (Maktavand Erbek,2005), land use changes for Sazlıdere Dam, Kilyos-KaraburunCoasline, Haliç Bay in Istanbul for urban planning (Erbek at al.,2005), urban sprawl in the surface water resource basins of Istanbul (Kucukmehmetoglu and Geymen, 2009), water quality determination of Küçükçekmece Lake (Alparslan et al., 2009) are researched, analyzed and evaluated. Omerli Watershed (Coskun, 2009), Terkos Watershed (Coskun et al., 2006), Küçükçekmece Watershed (Alpaslan et al., 2009; Coskun et al., 2008a) and Ömerli Watershed (Coskunet al.,2008b4; Coskun and Alparslan, 2009) are examples on RS/GIS studies for the watersheds in Istanbul.

In this paper it is aimed to monitor and analyze land use change of Sazlıdere Watershed and its water quality by using RS and GIS techniques.

2.Data and Methodology

Istanbul is one of the most populated metropolitan cities in the world, spreading over two continents (Asia and Europe) with a population of about 14 millions. One of the major drinking water reservoirs of Istanbul is Sazlıdere Dam Lake, located on European side, as shown in Figure 1.The study area of Sazlıdere Water Basin and Dam is presented as geo-referenced vector data with streams, including whole Istanbul Water basin Area. It has a total drainage area of 168,42 km^2 and provides 50 hm^3 drinking waterannually.

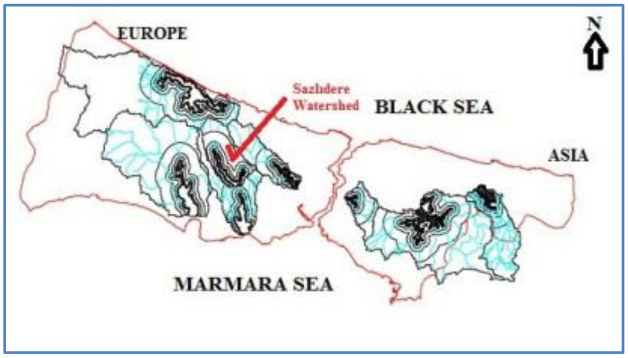


Figure 1:Study area.

2.1. Data

During the analysis of urban changes and water quality in Sazlidere Watershed, IRS-LISS and Landsat-5 TM satellite data were used, respectively, for the years of 2000 and 2004. The spatial resolutions are 23.5 m and 30 m, respectively for IRS-LISS and Landsat-5 TM.

1:25,000 and 1:5,000 scaled digital maps that cover the study area and orthophotos formed of 1:5,000 air photos were used as ground truth.

Digitized vector data of Istanbul Reservoir (Dam) Basins and creeks that feed the basins from ISKI (Istanbul Water and Sewerage Administration) is used to analyze urban sprawl and land use changes.

For the rectification of the satellite imageries IRS-multispectral imagery and Landsat-panchromatic imagery for 1998 were used.

2.2.Image Rectification

Image processing of the satellite data on Sazlidere Watershed was performed by using Erdas Imagine Software. Erdas Imagine is a remote sensing application with raster graphics editor abilities for geospatial applications. It aims the geospatial raster data processing and allows the users to prepare, display and enhance digital images for mapping use in GIS.

First, the digital satellite data set was transformed into UTM coordinate system using IRS-multispectral and Landsat-panchromatic imageries in order to achieve the necessary geometric registration. Taking 8 ground control points (GCPs) from reference image and raw image, the images were registered and then geometrically corrected (Figure 2 and Figure 3). From a test of the registration accuracy, the resulting root mean square error (RMSE) amounted to ±0.5 pixels.

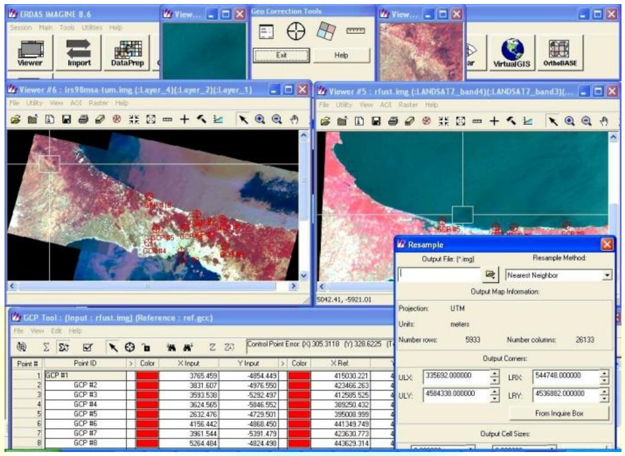


Figure 2:Geometric registration of image of Landsat-5 TM by referencing the image of IRS 98.

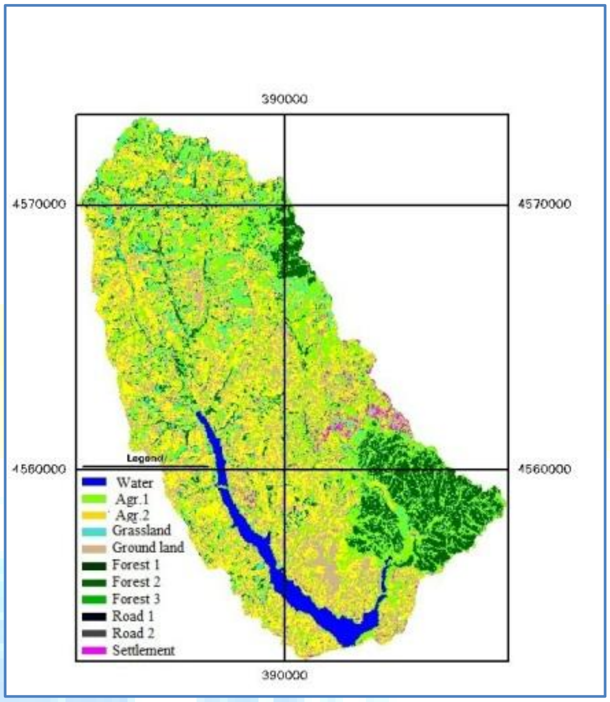
Figure 3:The geo-rectified image of Landsat-5 TM.

2.3.Classification

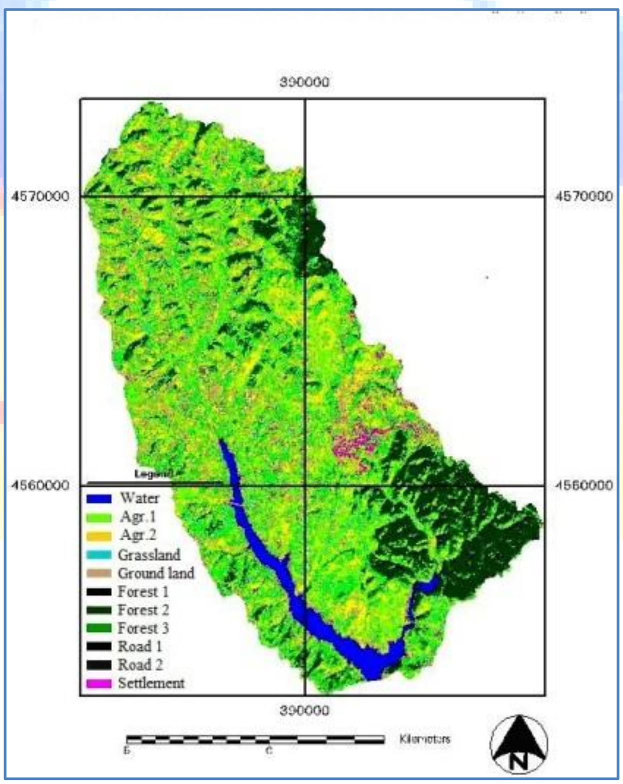
2.3.1. Land Use Analysis

The rectified and merged images were subject to a classification procedure with 11 classes, using the Supervised Maximum Likelihood Classification Method, including water, forest, agricultural land, road, settlement (Figure 4). The study was performed for all protection zones of Sazlidere Watershed. Geo-rectified image was merged with the digitized vector data of Sazlidere Watershed and its creeks to present the land use change in areal units (Figure 5).

In this analysis GIS techniques are applied to illustrate the changes of land use in the protection zones and the water quality. The graphical representations and numerical values of the results are visualized.



(a)



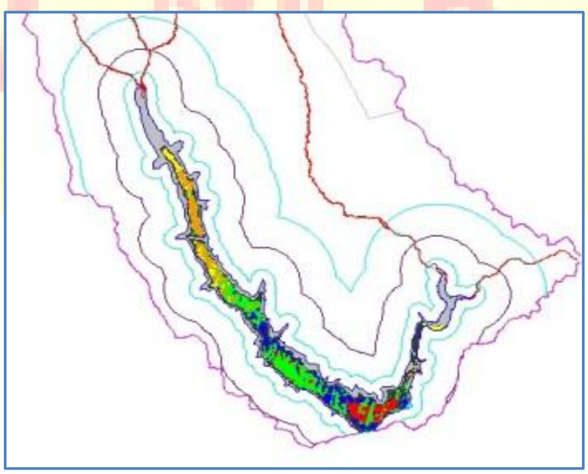
(b)

Figure 4: Classified images of water basin area **a)** IRS LISS of 2000 **b)** Landsat-5 TM of 2004.

Figure 5:Geo-rectified image that is merged with the digitized vector data of Sazlidere Watershed and its creeks.

2.3.2. Water Quality Analysis

The images of IRS-LISS in 2000 and Landsat-5 TM in 2004 are overlaid (merged) with vector data of the protection zones and four creeks that feed the reservoir. The same classification method, Supervised Maximum Likelihood Classification Method which is used in the land use change analysis, was used for the water quality analysis (Figure 6).



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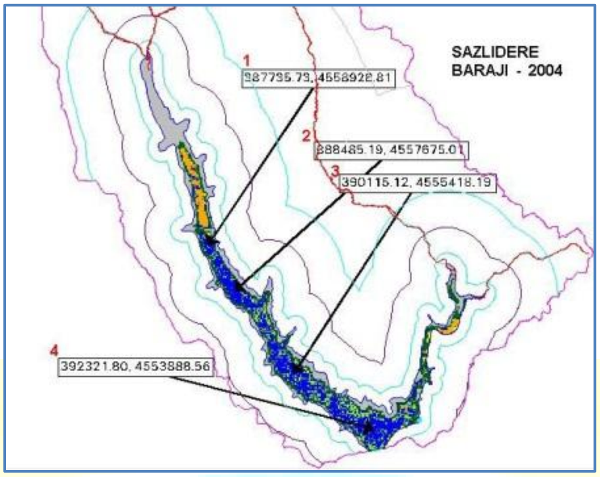

(b)

Figure 6:Classified images of water quality a) the image of IRS LISS of 2000 b) the image of Landsat-5 TM of 2004.

3. Results and Discussion

The land use classification results were evaluated as area of protection zones for urban units in hectares and the difference between 2000 and 2004 (Table 1). It is seen from the table that urban area increased in total from 2000 to 2004.

For water quality analysis, the colors in the classified images mean as following: red and yellow mean that the water has pollutants, green is reeds or reed-bed, grey is soil or clay, black is swamp, blue is reservoir water. The colors of red, yellow, green and blue are dominant.

Especially on the north side there is no significant change of the pollutants that the creeks carry. When this region is investigated with field works and ground data, it is observed that the settlements and industrial facilities increased around the arms of the creeks, and these creeks carry the wastewater and sewage. The IRS-LISS image of 2000 shows the effects of the different quality waters which the left and rights creeks and their arms carry, and also the wastewater discharge system that that comes through the main body of the reservoir. The different qualities are determined from the left side of the reservoir and it is estimated that the pollutants come from the discharge system in the main body. However the water is quite clean in the Landsat-5 TM image of 2004 because of the season and weather. This image is taken on 12 December 2004. On that date the amount of the water is more than usual and the cold environment is not suitable for the development of the micro-organisms. Figure 6b also illustrates the coordinates of the measurement points of the high rated clean water on image of 2004 as in Table 2.

Table 1: Area of the protection zones of Sazlidere Watershed for years 2000 and 2004 (Ha).

	Settlement (2000)	Settlement (2004)	Total watershed area	2004-2000 Difference
Total	229,18	317,64	16842,96	88,46
Long	109,79	149,21	5412,32	39,42
Medium	19,05	39,45	3165,32	20,40
Short	34,29	32,46	3914,85	-1,83
Absolute	28,33	24,99	2350,74	-3,34

Table 2: The points having high rate.

Point No	X	Y
1	4558922,81	387735,73
2	4557675,01	388485,19
3	4555418,19	390115,12
4	4553888,56	392321,80

When the findings are compared with the previous works on drinking water quality analysis of Istanbul watersheds the same pressure is seen on the water quality. As a consequence of rapid population growth and industrial development, the wastewater discharges from the residential areas and industrial plants highly affect the watersheds. The results of Omerli Watershed analysis show that the current environmental problems faced are highly based on the establishment of illegal residential areas and lack of sufficient infrastructure (Coskunand Alparslan,2009; Coskun et al., 2008b). After the analyze of Küçükçekmece Lake it is determined that the main pollutant sources are domestic discharges dumped directly into creeks, industrial discharges and irrigation water remains enriched in nitrogen and phosphorous compounds swept away from agricultural areas (Alparslan et al., 2009). Water quality of Terkos Lake is acceptable in comparison with other main watersheds in Istanbul, most probably because of low population and limited industrial activities (Coskun et al., 2006).

4. Conclusions

Istanbul is one of the provinces of Turkey with the highest population. The high rate of population increase in Istanbul affects the natural resources such as water basins and drinking water. This study forms an example of how RS and GIS tools are integrated in the determination of large scale watershed land uses within years and how the

water quality measurements are coupled with RS reflectance values for Sazlıdere Watershed in Istanbul. This integrated technology permits large regions of the environment to be studied, and thus it enables to determine the problems faster and precisely. The technology provides an opportunity for decision-makers to understand the main causes of remarkable changes.

Land use and water quality analysis are carried out for each of the images using Maximum Likelihood Classification. When two images are compared, it can be observed that the settlements and the industrial organizations increased, and the polluted water carried by the creeks from the settlements and industrial plants is displayed on the satellite imagery.

To monitor land use change and water quality quickly and correctly RS/GIS techniques are adequate tools to obtain necessary information. Because the water quality is an interdisciplinary problem with urban sprawl, infrastructure, population, settlement and industry all related organizations such as local governments, municipalities, planning and environmental protection agencies, universities, scientific organizations. They must work in harmony under a good coordination. Land use plans should be prepared in accordance with a protection strategy.

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