The Use of Remote Sensing and GIS Technologies for Comprehensive Wastewater Management

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Abstract: In the present study, it was aimed at combining remote sensing technology, geographic information system and statistical data in order to provide a rather rapid, sensitive and comprehensive overview of current situation of Turkish river basins in terms of existing spatial data. For the aim of the study, all statistical information gathered from the national authorities on regional basis was overlapped with the geometric data of Turkish river basins using maps being established in a GIS environment. As a result of GIS studies on 26 Turkish basins, Marmara Basin served as a model sensitive region and was studied in more detail by using 2000 dated Landsat 7 ETM image.

Keywords: Remote Sensing, GIS, water management, river basin

1. INTRODUCTION

The limited capacity of available natural water resources cannot meet the ever increasing demands of the socioeconomic system without a sustainable management strategy that requires the integration of economic and environmental balances. The establishment of a sustainable environmental management program depends upon the development of an efficient, reliable database considering both available water resources and wastewater production.

Remote Sensing Technology (RST) and Geographical Information Systems (GIS) have often been used by decision makers as an effective and powerful method. These informative and visual analytical tools have been widely applied to improve monitoring and conservation of water resources and evaluate changes in environmental conditions in a more global and far-reaching manner.

This study consists of two main parts. The first part covers the all of the 26 river basins in Turkey. Those basins were analyzed in a GIS by using concerning spatial data and considering water pollution parameters, population density, capacity and number of treatment plants, and etc. As a result of GIS analyzes The Marmara Basin was selected as the study area based on population density, generated wastewater, distribution and type of wastewater treatment plants, population served, treatment capacity and treated wastewater, which are obtained as the study area as a result of GIS queries and analysis, was examined by using remote sensing technology.

In this study investigation of prevailing situation of Turkish river basins in terms of spatial data were performed. Therefore, relationship between land cover and land use categories and water quality parameters were interpreted by using remote sensing and GIS technologies.

2. STUDY AREA

Turkey is a country located between the two continents, Europe and Asia. It has an approximate area of 770 000 km^2, total population of around 68 million with an average population density of 87 capita/km^2 (SIS, 2003). The State Hydraulic Works (SHW) categorizes Turkey into 26 main hydrological basins as presented in Figure 1. Turkey possesses 177 714 km of river, 203 599 ha of natural lakes and 179 920 ha of constructed dams and artificial lakes, the latter area being continuously increasing (SIS, 2003).

In the second part of the study, Marmara Basin, which is shown in Figure 2, was examined by using remote sensing technology. The major criteria for selecting this basin were: 1) Marmara Basin is the leader with an approximate value of 12.5 million inhabitants among the other basins of Turkey. 2) The basin governs the industrial development, has the highest share in the economical power of the country. Istanbul, being the most crowded province of the country, is located in this basin that houses 45% of the industries in its vicinity. While the average population density of the country is calculated as 87 capita/km^2, this value in the Marmara Region is 518 capita/km^2 (SIS, 2003). 3) Study region consists of a wide range of land use/land cover categories that is including industrial, urban, water bodies, wetlands, and agricultural.

Wastewater production values basically depend on the population and industrialization load. The Marmara Basin that is ranked as over-populated and highly industrialized generates the maximum amount of wastewater.

Figure 1: River Basins of Turkey

Figure 2: Study Area

3. DATA AND METHODOLOGY

3.1 Evaluation of Turkish River Basins

Today, environmental issues are not only considered as laboratory problems or statistical concepts but also new technologies -such as GIS and remote sensing-, which introduce current methods by combining statistical data and world reality, are used to obtain better results. A watershed is a structural and functional unit of a landscape consisting of various physical environments (Fujihara and Kikuchi, 2005). Remote sensing technologies and geographic information systems are major tools in order to find suitable environments and decide on action plans for watershed conservation. GIS and Remote Sensing integration is one of the most important methods used to apply geo-information in management of hydrological structures (Goksel, 1998).

GIS can be defined as an organized collection of computer, hardware, software, geographic data and personnel to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Clarke, 2002). Its capabilities on manipulation and analysis of spatial information make GIS an indispensable vector and raster based solution for assessing environmental problems. On the other hand, maps as presentation tools, which are used for communication of the information obtained as a result of the analysis in GIS, add another dimension to this technology for being so popular.

GIS technology was used in the first part of this study to introduce the general situation of the river basins in Turkey. First of all, statistical data including, population density, generated wastewater, distribution and type of wastewater treatment plants, population served, treatment capacity and treated wastewater, water quality parameters such as pH, BOD5 (five day biological oxygen demand), COD (chemical oxygen demand), TSS (total solidated sediment), and TP (total phosphorous) and attribute data about 26 river basins of Turkey (EC, 2004) were organized by using a relational data base. The relational data model consists of the following three parts: (1) a structural part that represents information in the form of a table; (2) an integrity part that applies the constraints on the table and (3) a manipulative part that operates on the table (Hirao, 1990). Although it is said that relational database model has not sufficient capacity to be used in nationwide applications, it is preferred in our study with its basic and easy structure for especially manipulation of the data. Then organized attribute and statistical data were combined with their geometric data by using Arcview GIS 8.3 software. All data types used in this study are presented in Figure 3. Moreover maps are used as the basic communication tool for better understanding of the theme. In this concept, thematic maps were created by considering cartographic issues and showed in following figures (Ulugtekin and Dogru, 2004).

In the figure 4, population density of the river basins was shown according to final census of year 2000. Basins that have high population density in the figure (Marmara, Kucuk Menderes, and Asi) are attractive for tourism, trade, and location of the major industries.

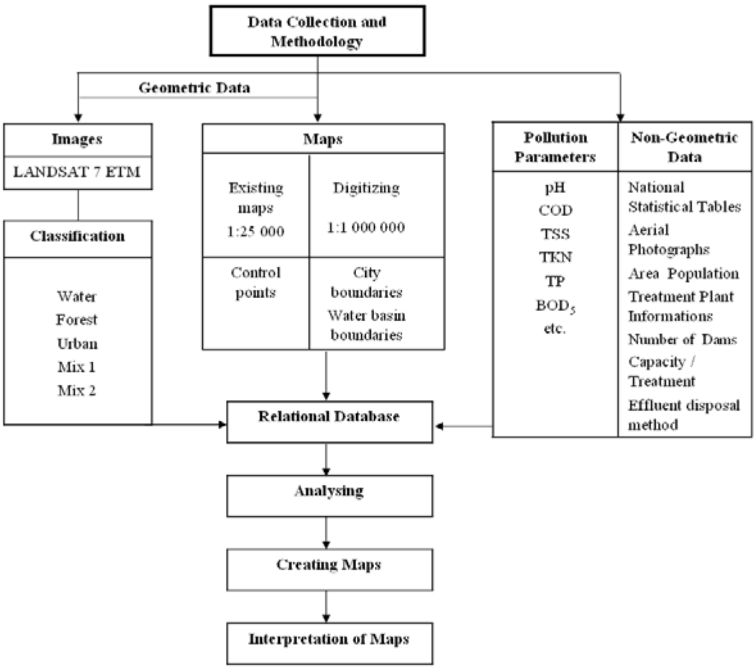

Figure 3: Workflow

Figure 4: Population density of the river basins

Figure 5 shows that The Marmara and Kucuk Menderes Basins have the highest amount of generated wastewater because of population and industry. On the other hand it should be stated that The Marmara and Sakarya Basins account to one third of total wastewater generated, to emphasize the importance of the highly industrialized regions on wastewater generation (EC, 2004).

Figure 5: Generated waste water of River Basins

As it is visualized in Figure 6, total number of the treatment plants in the west part of the Turkey is higher than the eastern part. Especially The Marmara Basin stands out with its total 22 treatment plants, of which 13 plants are physical, 7 are biological, and 2 are advanced, between the other basins. Advanced treatment facilities are only being operated in river basins of Marmara and Kucuk Menderes. Biological treatment facilities are located in the south part of Turkey (Mediterranean Region) which is quite sensitive as tourism area. The treatment facilities performed in north part of Turkey (Black Sea Region) are preliminary treatment systems with only physical treatment units. Sea outfall discharges are preferred at the Black Sea Coast of the country due to the topographic structure of the region and to the suitability of the sea to receive preliminary treated wastewater.

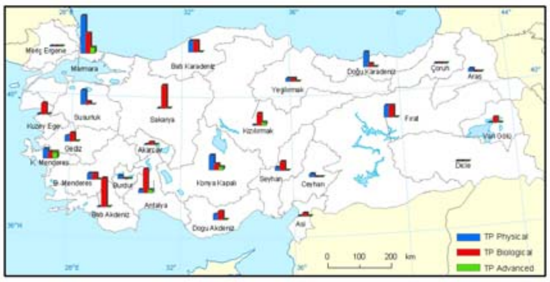

Figure 6: Distribution of treatment plants

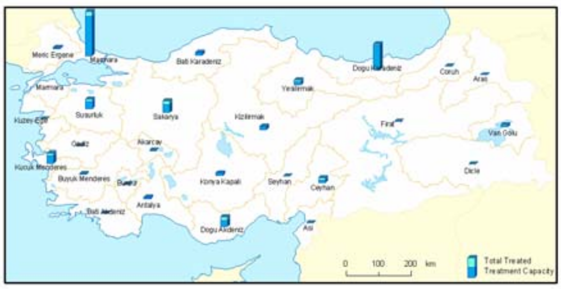

Figure 7: Treatment capacity and total treated water

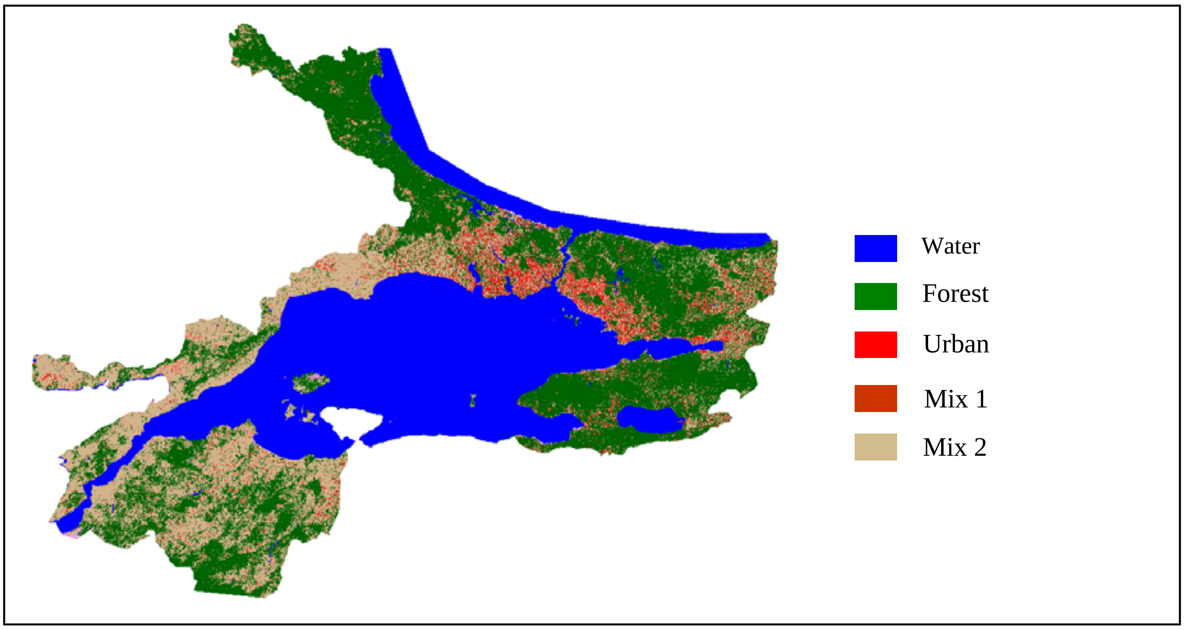

Figure 8: Classified image of 2000 dated Landsat 7 ETM

Although The Marmara Basin is highly developed region the amount of total treated waste water is not enough as compared with its treatment capacity (See Figure 7). It means that treatment plants in this region should be operated better. The number of the treatment plants distributed eastern part of Turkey is not sufficient for obtaining accurate and reliable values. Moreover, the existing ones do not work properly.

3.2 Evaluation of the Marmara Basin

Remote sensing has traditionally concentrated on rural or natural areas when looking at land use of environment. There has however been a recent trend toward the analysis of urban and regional environments (Arthur et al., 2000; Chen et al., 2000; de Jong et al., 2000; Masek et al., 2000; Yeh and Li, 2001).

In the second part of this study remote sensing technology was used for monitoring the Marmara Basin. For this purpose, 2000 dated Landsat 7 ETM satellite image were used to provide land use and land cover classes of Marmara Basin to analyze relationship between wastewater treatment plant data and land cover/use of Istanbul. Together with these satellite image, 1/25000 scale topographic maps, aerial photographs and existing maps were used (See Figure 3). In order to extract land use/cover classes, digital image processing techniques were performed including, geometric correction and classification from the remotely sensed data.

In the first step of image processing, geometric correction of Landsat 7 ETM image was performed. 2000 dated Landsat TM image covering five frames (each 117x117 km) was rectified to UTM projection system based on 1/25000 scale topographic maps of the region using first order polynomial method. During image registration nearest neighbor resampling algorithm was used root mean square error (RMSE) with 0.47 pixels.

ISODATA unsupervised classification were applied in the second stage of processing work flow to classify the Landsat images of the Marmara Basin. Six land cover types for study region are identified and used in this study, including: water, urban, forest, green areas, mix 1 and mix 2. Category of mix 1 including agricultural, bare and range land category, of mix 2 including open mining areas, road and industrial region of study area. Figure 8 shows the visual results of classified image in 2000 and Table 1 shows the statistical results of classification.

Statistical results of land use/cover classification were used as a reference data in order to support the way of selecting sensitive study region. It was found that % 36. 19 of total area were covered with urban class. Mix1 and mix 2 classes were % 1.32 and % 5.2 of the study region. The classification results showed clearly that the Marmara Basin has to be worked on urgently in detail by means of wastewater management to represent relationship between land cover/land use and water management.

Table 1: Statistical results of classification

Class Name	**Area (ha)**	**% Area**
Water	76851,54	% 3,28
Forest	1265913	% 54,01
Urban	121845,8	% 36.19
Mix 1	848055,9	% 1.32
Mix 2	30840,04	% 5.20
Total Area	2343506,18	

4. CONCLUSION

This study aims forming a database for basin management for prevailing situation of whole Turkey according to EC, 2004. In this context, watersheds are by far the most logical scales on which integrated water management should be undertaken.

As a result of the study, the characteristics of each basin are found to be very different from each other which is mainly due to the variations in geographical structure, and to the extend of industrial activities, and population. As a developing country, Turkey faces certain difficulties in having a well organized and systematic database concerning especially infrastructure facilities. Lack of information and/or reliance on available data together with data scattered among various governmental organizations make the task of partly improving and reestablishing a sustainable water and wastewater management strategy for the country. On the other hand, the administrative boundaries of provinces do not usually coincide with river basin boundaries, and other institutional constraints can make the management at the watershed scale difficult, as is accepted universally. All of these problems affect the later stages of the study such as analyzes step of GIS and map production.

Most of the treatment plants are located in the more industrialized regions with high population density. Istanbul, which is the best example for this situation, should be considered as the sensitive area for future environmental works.

Water quality is highly related with land use and land cover parameters. Thus, remote sensing technology is used in order to produce reliable and efficient land use/cover maps fast and economically. Landsat 7 ETM image is used in this study. The spatial resolution of the Landsat images is sufficient for mapping regional urban land use. Landsat satellite imagery can be used to produce accurate estimates of urban growth and effects of environment. These estimates can be related to census and economic data that are available from traditional data sources. One of the main advantages of this technique is its low cost as compared to traditional mapping techniques. However, Landsat data is suitable for regional studies, high resolution images should be used for more detailed works such as monitoring the impacts of the treatment plants on environment.

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