Investigation Of Coastal Morphological Changes Due To River Basin Characteristics By Means Of Remote Sensing And GIS Techniques

D.Z. Seker*, C. Goksel*, S. Kabdasli*, N. Musaoglu* and S. Kaya*

* ITU, Istanbul Technical University, Civil Engineering Faculty, 80626, Maslak, Istanbul Turkey
(E-mail: dzseker@ins.itu.edu.tr)

Abstract
Riva River is located on the Anatolian (Asian) side by the Black Sea coast, with a wonderful sandy beach and delta formation has been selected as study area. The Riva is the largest river in this region, which flows into the Black Sea and also gives it names to the area. The river carries some amount of sediments to the Black Sea. These particles cause considerable changes not only in the bed bathymetry and coastal boundaries of the river but also along the coastline of Black Sea. The aim of this study is to determine these variations by means of satellite data and GIS. In the study, satellite images dated 1975, 1984, 1992 and 2001 have been used. At the end of the study possibility of observing bathymetric changes in front of the coastline by means of satellite data have been investigated and results were evaluated and visualised by means of GIS.

Keywords
Remote Sensing, Morphological Changes, Coastline, GIS

INTRODUCTION

Life sources such as water basins, rivers, forests and green areas of Istanbul, are located in the green belt, which surrounds the city to the north. Although the preservation of this belt has been taken into consideration in the planning studies carried out in Istanbul, the city has continued to grow northwards. Information about changes in land use and environment is important for the management and planning of these areas. Remote Sensing Technology provides a method for acquiring regular, current information about environment for monitoring these kinds of changes.

Monitoring the temporal hydrological changes is very difficult with the conventional methods. Using remote sensing data and GIS help find solutions to the potential hydrological and environmental problems on time. Furthermore, accurate, fast and low coast data/information can be obtained in the studies aimed at determining the potentials in hydrological and environmental changes and updating relevant information.

When the general evaluation of the natural balance irregularities arising at a global scale is made, it can be seen the affecting parameters, which are subject to change, are the hydraulic and hydrological ones due to their activities in the river basin. In some areas almost all the waters of the rivers are used up within the basin, primarily for the purpose of irrigation.
It is a generally accepted fact that especially the dams constructed at a point very close to the shoreline destroy the natural balance of the shoreline by totally changing the flow regimen and therefore the sediment load in the rivers. This point, according to one point of view, constitutes the crossing point of the shorelines management and the basin management; according to another point view it constitutes the intersection between the two. Basic purpose of both approaches is to watch the natural balance and maintain development, that is to say, the problem could easily be solved in

case there is sustainable growth. In order to achieve joint management, it is obvious that a good monitoring study has to be done and healthy data must be obtained.

Estuaries that form the intersection of the inland water resources and the coastal water resources are among the parts of nature, which are hardest to preserve because of the extremely sensitive natural balance, they have. In addition to the hydrodynamic effects such as wave, flow and ebb tide of the coastal areas, hydrodynamic characteristics arising out of the river constitute the complex hydrodynamic structure of the river estuaries. With the sediments they carry, rivers flowing into the sandy coasts make up the basic factor of the morphological structure before the river estuaries and on the adjacent shores. Therefore, changes that may arise in the sediment load of the river cause direct and very significant changes in the structure of the river estuaries. At present in Turkey, it has been revealed as a result of the researches, effects caused by the dams constructed in the basins of the rivers which discharge into the sea constitute the problems such as chronicle sand accumulation or erosion in the coastal areas where the river is discharged into the sea. Although radical solution to this problem is impossible, it can be considered to prevent or minimize these problems by means of measures to be taken beforehand. Studies showed that some of the morphological parameters of the coastline area have dramatically been changed.

Especially the hydrodynamic and morphological characteristics of the shorelines depend heavily on the freshwater and sediment flow speed of the rivers they have. The sediment load of the rivers in particular directly controls sediment budgets of the sandy coasts. On the other hand, the dynamic natural balance of the shoreline and the base bathymetry is formed as a result of the cross interaction between not only the wave effects but also the hydraulic and hydrological characteristics of the river. Within this complex interaction, any change in one of the affecting parameters due to natural or unnatural reasons leads to changes in the natural balance of the coast.

In this study, morphological changes in the estuary of the Riva River along the Black Sea in Istanbul and the sand formation, which is the most significant example of such changes, are analysed by means of satellite images of different dates and the results have been examined. Also standard topographic maps related to same area, amount of particles carried by the river, flow rates in the past and today are evaluated in Geographic Information Systems to obtain reliable information and estimated morphological changes in different phases.

USING REMOTE SENSING FOR RIVER BASIN MANAGEMENT

Remote sensing provides synoptic view of the terrestrial landscape and is used for inventorying, monitoring, and change detection analysis of environmental and natural resources (Narumalani et al. 1997). Remotely sensed data can be especially valuable in studying phenomena over large areas, and satellite sensors provide the opportunity for regular observation of even very remote regions. Although remotely sensed images seldom replace the usual sources of information concerning water resources, they can provide valuable supplements to field data by revealing broad scale patterns not recognizable at the surface, recording changes over time, and providing data for inaccessible regions (Campbell, 1996). The recently developed remote sensing and GIS technologies and availability of better resolution data, has revolutionised the mapping of wastelands and other natural resources. Hydrological models and remote sensing techniques are advanced tools that are better suited to estimate the evaporation and the related hydrological processes at the regional scale (Beven et al., 1988). Remote Sensing technology has been recognized as a useful means of supplying up to date information on activities within the urban environment (Treitz et all, 1992; Ehlers et all., 1990; Forster., 1985). Several studies have also demonstrated the utility of remote sensing for examining

about hydrology and river basin (Curranand Novo, 1988, Nellis et al, 1998, Zhou, 1998, Narumalani et al., 1997)

STUDY AREA

The Riva River is regulated by the Omerli Dam built for the purpose of providing drinking water to Istanbul. This dam retains the sediment coming from the upper basin. In addition to this effect disrupting the natural balance, no water is released to upstream from the sluiceways and spillways of the dam due to recent cases of drought. Due to such unfavourable impacts, dynamic balance condition of the coastal section where the river is discharged into the sea is spoiled. Because of the waves due to the effect of the wind coming from the opposite direction and the sand movements on the shore, the mouth of the river is face to face with full blockade. Figure 1 shows the study area and the bathymetry of the area where the river is discharged into the sea.

Figure 1. Study area.

METHODOLOGY

Changes in the coastal morphology have been examined between standard topographic maps of the study area and satellite images related to different dates. Also desktop GIS software has been used to show temporal changes in 3D view and using the same data digital terrain model has been produced.

Used Data

In this research, multitemporal Landsat Images, 1/5 000 scaled Standard Topographic Maps and Bathymetric maps have been used for analysing of the study area. Table 1 shows parameters of used satellite images. Sandy areas have been digitised on the image using on screen digitising methods. In the last step these data have been combined and visualised by means of ArcView GIS software.

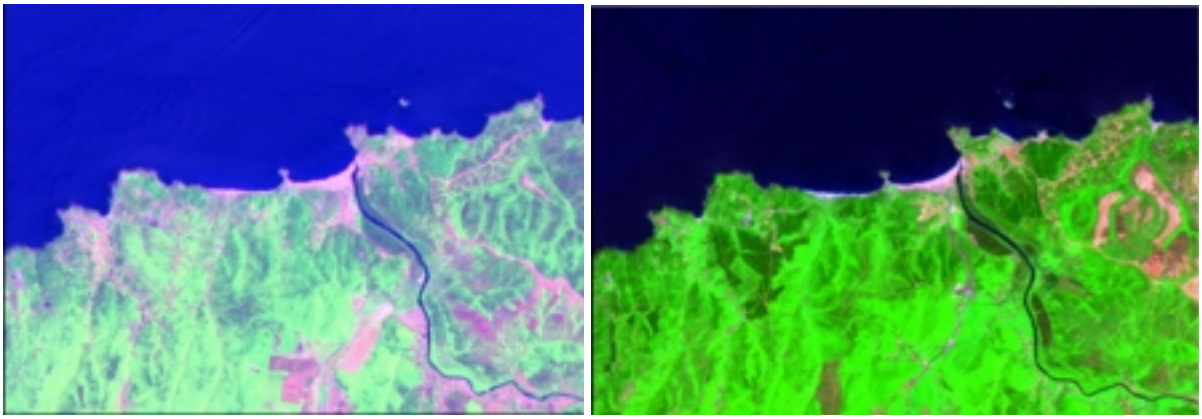
Table 1 Properties of used images

Sensor	Date	Spatial Resolution
Landsat MSS	June 1975	80 m
Landsat 5 TM	June 1984	30 m, 120 m – Thermal Band
Landsat 5 TM	September 1992	30 m, 120 m – Thermal Band
Landsat 7 TM	May 2001	30 m, 60 m – Thermal Band, 15 m – Panchromatic

Classification

Different feature types in digital images constitute combinations, which contain different digital values depending on the natural spectral reflection and emission features. The aim of the classification is to group the objects carrying same spectral features. In classification stage, Maximum Likelihood supervised classification algorithm was performed on this data sets. Before the classification, preliminary information was required of the region in order to determine statistical limits. Various maps (orthophoto maps and land use maps) and photographs were used to select classes and ground truth studies have been done. Classification result is given in Table 2.

It can be ascertained from the satellite images that there was virtually no change in the course of the Riva River in the period from 1975 to 2001. Despite heavy rainfall in winters of 1986, 1987 and 2000 in the area, the river maintained its stability near the shore thanks to the regulation of the dam. However, it can be seen that a very significant change both in terms of the shoreline and bathymetrically is in the process of occurrence at a small bay where the estuary of the River Riva is located. Images dated 1984 and 2001 are given in Figure 1 as a and b respectively.



a) 1984 b) 2001

Figure 2 Landsat TM Data dated 1984 and 2001 (Band 7,4,1)

In Figure 3, images taken in the year of 1975, 1984 and 1992 are given in 3D view before and after classification process. Similar view is given in Figure 4 for the image dated 2001. Classified images dated 1984 and 2001 are given in Figure 5, to show the changes between these periods. Several classes have been chosen and given as legend in the same figure. To evaluate changes in the river and coastline classes have been masked and several classes related to water and sand were selected. Result of masking process are given for the year of 1984, 1992 and 2001 in figure 6.

Digital Elevation Model (DEM)

In general sense, digital elevation model is the digital and three-dimensional expression of the surface of the land. As the digital elevation models bear elevation information, they are used in obtaining resolutions, which cannot be obtained by two-dimensional analysis. By means of the interpolation methods applied to the elevation values which have been digitised from topographic maps, ground measurements, photogrammetry or remote sensing data and them transferred to computer media; brightness values at raster data at the desired pixel size and radiometric resolution can be obtained from the elevation values. Selection of the data sources, frequency of the points

selected on the land and the mathematical method used in conversion are important for the quality and accuracy of the digital elevation model. Therefore, before the digital elevation model is formed, a method has to be established according to the purpose of the study and the desired accuracy (Musaoğlu, 1999).

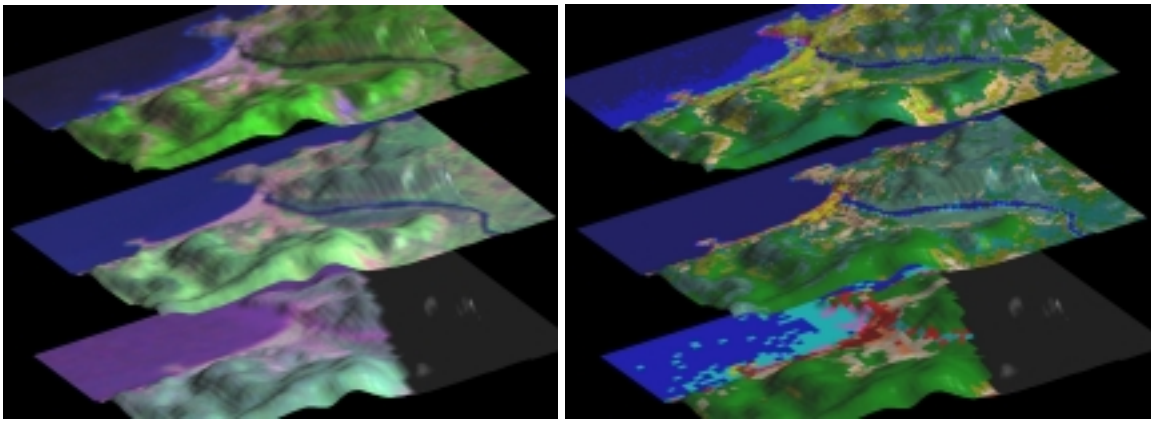


Figure 3 Satellite Data and classified images - 3D (1975,1984,1992)

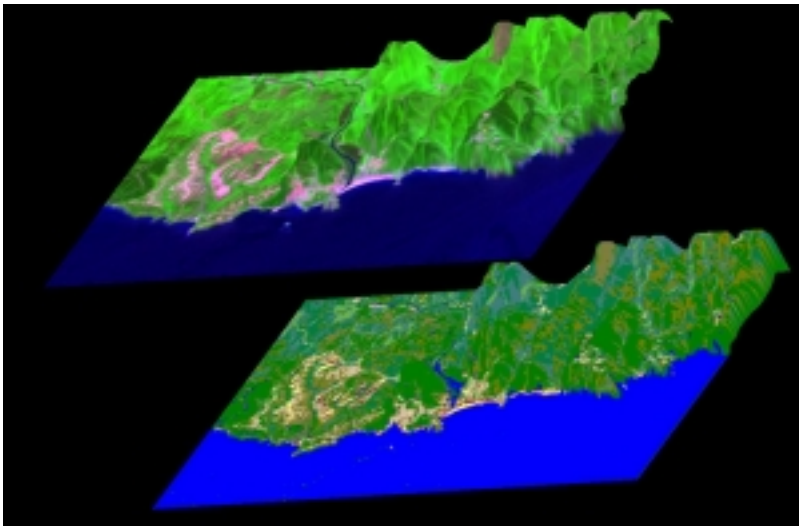


Figure 4 False Color and classified images -3D (2001)

Table 2 Classification Results

	YEAR		
Class	1984(km^2)	1992(km^2)	2001(km^2)
Water	36,0	37,1	48,4
Coast	1,5	1,7	1,5
Lake	9,3	9,7	
Forest	207,0	219,1	222,1
Agricultural Land	23,4	17,1	17,4
Sand	1,0	1,6	5,7
Urban and Destroyed area	4,1	5,1	4,4
Others	107,0	97,9	89,7
Total	389,2	389,2	389,2

Geographic Information System (GIS)

Geographic information systems provide opportunities for creating more dynamic and meaningful analysis for potential users by integrating multiple of spatial information. GIS technology with

remote sensing will provide maximum information content and analysis capabilities to the users Seker, et al. 2000). In this study different data have been integrated and analysed in the common system. Digital Terrain Model of study area has been produced by means of GIS software and image dated 2001 draped into this model for better visualisation. Obtained view is given in Figure 7.

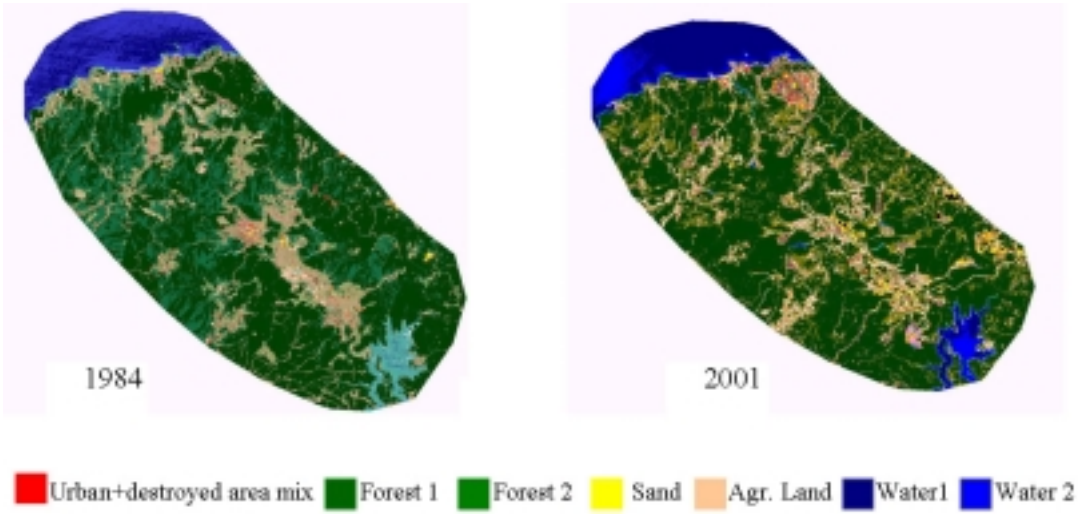


Figure 5 Classified satellite images dated 1984 and 2001

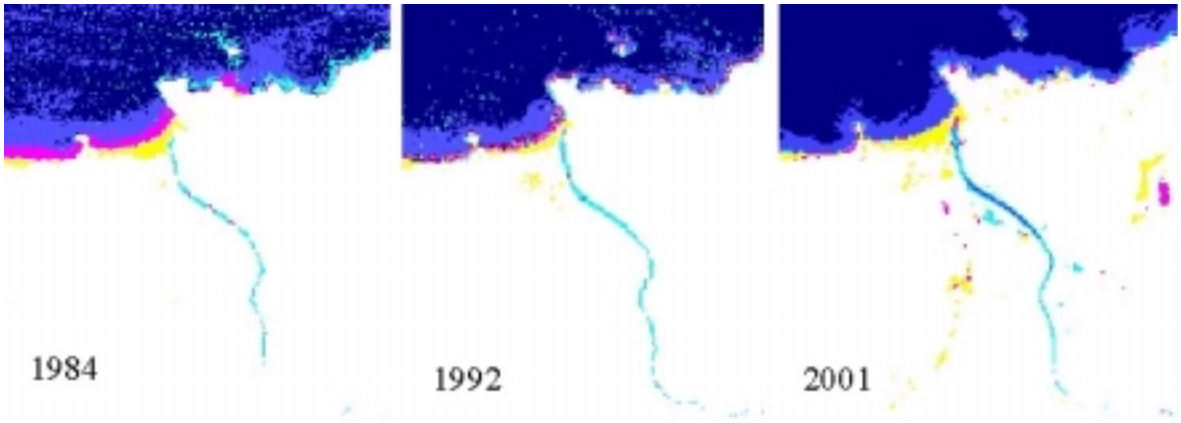


Figure 6 Images obtained by selecting only the water and sand classes and masking other classes

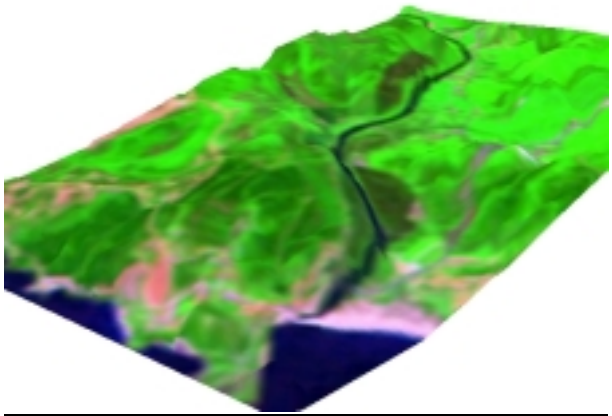


Figure 7 3D View of Study area covered with the image (produced in ArcView)

EVALUATION of DATA

Slope-aspect topographic correction methods commonly require a digital elevation model of study area. In this study, digital topographic maps in the scale of 1/5000 have been used. Contours have

been produced every 1 m. DTM of the study area has been produced by means of desktop GIS software, and covered with the satellite image dated 2001, used in this study is given in Figure 8.

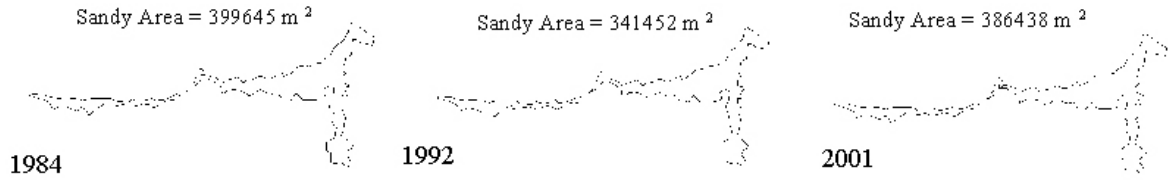


Figure 8 Calculated Sandy areas on the different dated images by the technique of on the screen digitising.

Size of the sand volume on the shore in 1974 and 1984 is significant, around 399645 m ^{2}. The striking situation here is the increase is in period until 2001. Although this situation reveals a result that appears to be in reverse in the first assessment in a way that the volume of sand increases vis-à-vis decrease in solid substances coming from the basin, it also shows that the source the sand that creates the increase in the sandy coast changed morphologically. When the bathymetry in front of the shoreline is examined, it can be seen that the shallow area at the bay narrowed within the period of time in question, its line receding as far as the centre from the outer boundary, almost eliminating the offshore bar formation. In other words, the sand reaching the shoreline comes by means of cross-score transport under normal wave circumstances.

This formation is due to closure of the bay against the dominant waves in the Black Sea by the cape in the east. But in case of an extreme NE wave, it can be expected that important erosion may occur on the shore due to elimination of the offshore bar formation. This did not happen in the periods when the satellite images were taken.

As a result of the increase in the sand and decrease in the flow speed, discharge point of the Riva River at sea can be blocked by sand accumulation where flushing capability of the river does not exist any longer. As about 6 km- long section of the Riva River from the shoreline onwards has very low slope, it is suitable for small craft navigation. Therefore, closure of the river estuary bore social reaction. Consequently, as a very wrong decision, it was decided to build a settee for the purpose of estuary arrangement. It is not difficult to guess that the coastal morphology will be totally disturbed in case structural measures are implemented. It should be said that this is the indirect impact of the dams on coastal morphology.

One other indirect impact of the dams on coastal areas is the striking changes in the point of view of the society about the rivers and the coasts. As a result of the fact that the river estuaries become less changeable compared to the past, there is growing demand in the society to use the land in the coastal areas near the shoreline and the river. Satellite images show reedy areas that start on the eastern bank of the river immediately behind the shoreline. The society started to fill these areas to reclaim them are usable land. This development can be considered as a process, which will, in the long run, make it impossible for the river to convey the 500m3/second probable flow coming out of the dam spillway. In case of such type of a flow, it is great possibility that the river would overflow in a way to destroy extremely important dunes on the left bank of the river.

CONCLUSIONS

By means of satellite images, it is possible to display in visual format and express in digital values the changes in river basins and coastal areas, starting from the past up until today. One of the most

important problems in management of the coastal areas is to define how the natural conditions have been in the past. Without giving a healthy answer to that question, it is not possible to define the sustainable development fully and precisely for the area in question. Satellite images help greatly in finding the answer to this question.

When satellite technology is used, development of the impact of the dams on coastal areas can be ascertained. For that, it has been shown that the use of remote sensing data together with classical data collection methods as well as the contemporary data evaluation systems is necessary. Significant results could thus be attained.

An ability to apply physical models to satellite data for estimating and documenting the magnitude and spatial changes of an environmental hazard is significant for resource managers. Changes in the areas, which have dynamic, structure such as study area has to be compared in the different time using different techniques. Remote sensing is the most convenient technique to collect large amount of data for large areas. Data, which can be used for solving this kind of problem, is produced from satellite data. GIS is the technique analyses and visualize data and help for decision-making process.

References

Beven, K.J.,Wood, E.F. and Sivapalan, M. (1988). On hydrological heterogeneity: catchment morphology and catchment response. *Journal of Hydrology*, 100, 353–375.

Campbell, J. B., 1996. Introduction to Remote Sensing, second edition, The Guilford Press, USA.

Curran, P. and Novo, E. (1988). The relationship between suspended sediment concentration and remotely sensed spectral radiance: a review. *Journal of Coastal Resou,* 4, 351-368.

Ehlers M., Jadkowski A.M., Howard R.R. and Brostuen D. (1990). Application of SPOT Data for Regional Growth Analysis and Local Planning. *Photogrammetric Engineering and Remote Sensing*, 56 (2), 175-180.

Forster, B. C. (1985). An Examination of some Problems and Solutions in Monitoring Urban Areas from Satellite Platforms. *International Journal of Remote Sensing,* Vol.65. No:4, pp:443-451.

Narumalani, S., Yingchun, Z. and Jeensen, J. R. (1997). Application of remote sensing and geographic information systems to the delineation and analysis of riparian buffer zones, *Aquatic Botany*, 58, 393-409.

Musaoglu, N. (1999). Possibilities of Determining the Types of Tree Stocks in The Forest Lands and the Units of Growing Sites by Means of satellite Images Obtained From The Electro Optical and Active Microwave Sensors, Ph.D. Thesis, ITU Institute of Science and Technology (in Turkish).

Nellis, D., M., Harrington J., A. Jr. and Wu, J. (1998). Remote Sensing of temporal and spatial variations in pool size, suspended sediment, turbidity, and Secchi depth in Tuttle Creek Reservoir, Kansas: 1993, *Geomorphology*, 21, 281-293.

Seker, D.Z., Musaoglu, N. and Kaya, S. (2000). Investigation of Vegetation in Turkey by Using Remote Sensing Data and GIS, XIXth Congress of ISPRS, Proceedings Part B7, 1357-1363.

Treitz P.M., Howarth P.J. and Gong P. (1992) Application of Satellite and GIS Technologies for Land-Cover and Land-Use Mapping at the Rural Urban Fringe: A Case Study. Photogrammetric Engineering and Remote Sensing, Vol.58, pp.439-448.

Zhou, X., Dandan L., Huiming Y., Honggen C., Leping S., Guojing Y., Qingbiao H., Brown L. and Malone J.B., 1998.Use of landsat TM satellite surveillance data to measure the impact of the 1998 flood on snail intermediate host dispersal in the lower Yangtze River Basin, *Geomorphology*, 21, 281-293.