Modeling Spatial Changes in Suburban Areas of Istanbul Using Landsat 5 TM Data

Sinasi KAYA, Elif SERTEL and Dursun Zafer SEKER,
Turkey

Key words: Istanbul, District, Landsat 5 TM, Suburban, Spatial Change

SUMMARY

Population of Turkey has been steadily increasing with a yearly average rate of 2.2 %. Urban population in different cities of Turkey is comparatively higher than suburban population like several other countries in the world. While the population in the urbanized areas was %24 in 1945, it increased to %58 in 1985 and reached to % 77 in 2012. According to the statistical studies realized between 1990 and 2010 the population increase was 2.9 % in urban areas whereas a decrease of 0.75 % in rural areas. These population changes could not be described by only using birth and death rates since there is an important issue of rural exodus to larger metropolitans in Turkey. This migration has been causing abrupt land use/cover changes in the surroundings of metropolitans. It is not easy to solve this rapid urban spatial growth problem because of socio economic reasons.

In this study, district based suburban land cover changes in Istanbul were determined and analyzed using Landsat 5 TM data obtained in 1987 and 2011. After conducting geometric correction, Landsat 5 TM images were classified into four major classes namely water, vegetation, urban and soil using supervised classification technique. The results of the study pointed out the land cover changes within 24 year period. Beside the highly urbanized areas, especially changes in the suburban areas have led to the establishment of new suburban areas. Impervious areas for each district were analyzed and distributions were calculated using spatial weight rate for Istanbul metropolitan.

Modeling Spatial Changes in Suburban Areas of Istanbul Using Landsat 5 TM Data

Sinasi KAYA, Elif SERTEL and Dursun Zafer SEKER,
Turkey

1. INTRODUCTION

As a result of population migration to metropolitan areas, spatial growth of several land cover/use areas have been changing and this is among the significant environmental problems in the world. From urbanization perspective, large cities are the main focus since the population of each large city is more than several countries. In 2011, 23 urban agglomerations having at least 10 million inhabitants were qualified as megacities (UN World Urbanization Prospects, 2012). It is estimated that there will be new megacities in the future considering the population increase.

Since Landsat TM satellite sensors have been providing an extensive archive image data from 1984 to date, several scientists have been used these data set for multi-temporal monitoring of urban expansion within the cities (Jensen and Cowen, 1999, Small, 2001, Hung, 2002, Lee et al., 2005, Lu and Weng, 2006, Kaya and Curran, 2006, Kaya, 2007). Spatial, spectral and temporal characteristics of remotely sensed data used for urban monitoring studies should be carefully selected for accurate mapping of urban areas. These characteristics could provide important information for the determination of urban areas and their spatial growth. Remote sensing experts interpret and process multi-date satellite images to provide quantitative measures for land use/cover classes of the study area which significantly improves the monitoring and understanding of land use/cover changes and their trends. Among different methods for quantitative information extraction from satellite imagery, Vegetation-Impervious-Soil (V-I-S) model is one of the well-known approaches (Ridd, 1995). Ridd (1995) showed that V-I-S model could be used for the analysis of urban morphology, biophysical and human systems. Remotely sensed data could be used to form V-I-S model and the results obtained from satellite image based V-I-S model could be used to analyze land use/cover changes in different time periods.

This paper aims to determine land use/cover changes in 34 different districts of Istanbul city using V-I-S model and Landsat 5 TM imageries obtained in 1987 and 2011. Istanbul is one of the significant metropolitans of the world and the biggest of Turkey considering its population, socio-economic patterns and industrial infrastructure. 1987 and 2011 dated satellite sensor images were classified into three main land cover categories namely Vegetation, Impervious Land and Soil. These categories were located on the appropriate positions on the V-I-S diagram based on their % distributions. A specific attention was given to the impervious class and its change considering the urbanized lands fall in this category. The results of this study illustrated that only 3 out of 34 districts had 70% or more impervious surfaces in 1987 whereas the number of districts having significant impervious areas increased to 11 in 2011.

2. METHODOLOGY

2.1 Study Area

Istanbul, selected as the study area, is the biggest metropolitan city of Turkey covering a total area of ~ 57 500 km^2 and having a population of about 14.2 million according to the population census of 2013. It is among the most populated metropolitan cities of the world as well. Population of Istanbul was only 4.7 Million in the year of 1980. As a result of the rapid population growth and urbanization, the urbanized area has extremely expanded causing significant changes in land use/cover. City planners and policy maker's have been working on to evolve better strategic plans related to protection environment, infrastructure development and maintenance, and land development. Thus, they need to access to up-to-date base maps and systematic information on the land use patterns, environmental problems and infrastructure facilities. Multi-temporal remotely sensed data has been commonly used to determine land use/cover changes and their impact to environment.

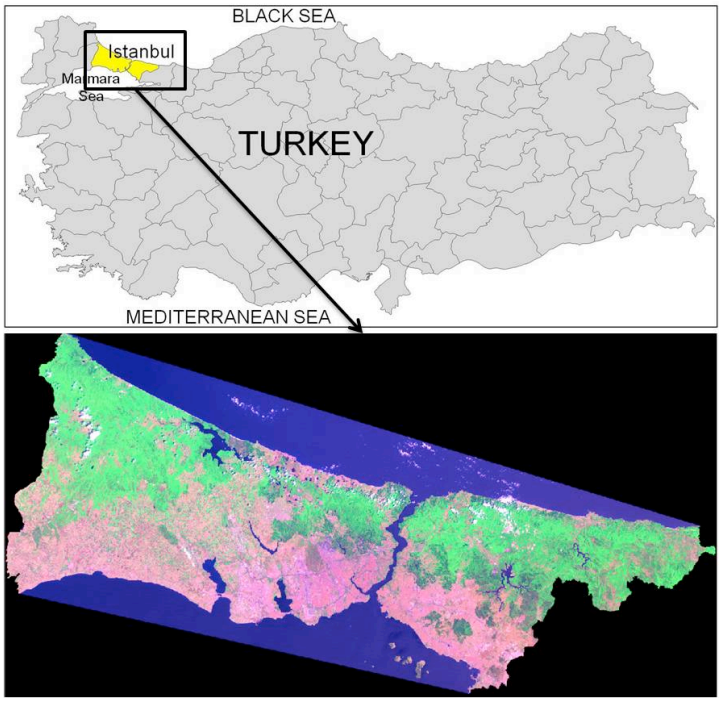


Figure 1. Study Area

2.2 V-I-S Model

V-I-S model includes three main components which are vegetation, impervious and soil to represent different land cover/use density of the related region. This model was applied to satellite images to represent the urban morphology by using three main components instead of several land cover/use classes (Ridd, 1995). Each component is shown over one axis as can be seen in Figure 2. Different values over each axis show the % value of each component for the related region. The spatial unit for this study is district and 34 different V-I-S values were created for 34 different districts for each year. According to V-I-S diagram shown in Figure 2,

the following statements could be made:

- ✓ if vegetation value is 100 % then impervious value will be 0 %,
- ✓ if impervous value is 100 % then soil value will be 0 %,
- ✓ if soil value is 100 % then vegetation value will be 0 %

All other combinations will fall among the above stated values. V-I-S model could provide valuable information for the detection of natural and environmental changes with respect to time. This model could be used to analyze expansion of urbanized areas and changes and trends of these expansions by time (Mathavan, et al., 2001, Phinn et al., 2002, Pekin ve Kaya, 2010, Kaya et al., 2012).

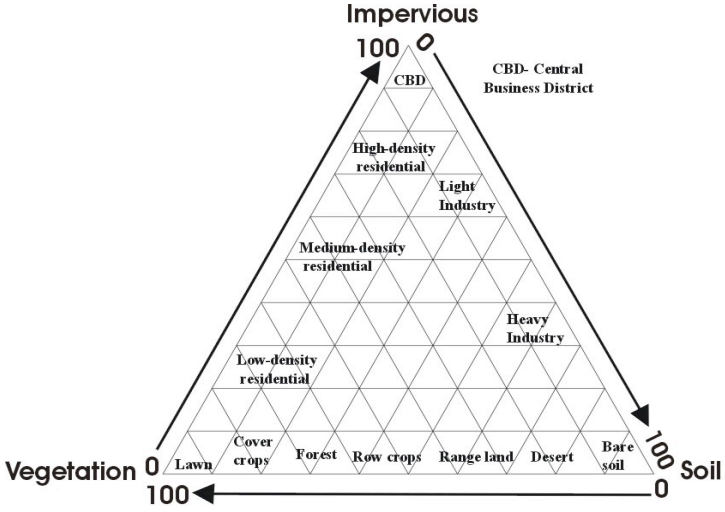
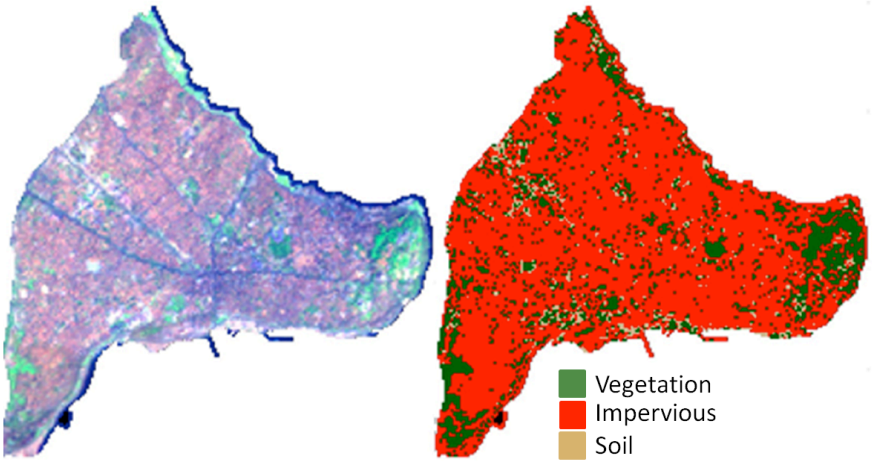


Figure 2. The V-I-S model (Ridd, 1995)

3. RESULTS

Landsat 5 TM satellite imageries obtained in 1987 and 2011 the years were classified into 25 clusters using ISODATA (The Iterative Self-Organizing Data Analysis Technique) clustering algorithm. These clusters were then merged into four main classes which are; Vegetation, Impervious Surface, Soil and Water. In this study Water class is not considered to be used in V-I-S model. Istanbul metropolitan area was divided into 34 districts before 2010. Subsets of the Landsat 5 TM satellite imageries of each separate district were obtained using administrative boundaries. Then these obtained subset images classified separately. False color and classified images of Fatih District for the 1987 are displayed in Figure 3 as an example of the realized process. Distribution of Vegetation, Impervious Surface and Soil components in all districts were calculated as percentage. Calculated distributions for the year of 1987 and 2011 are displayed in V-I-S diagram as given in Figure 4. In this figure, changes and codes of each district were displayed. According to this diagram, the districts having impervious surface over 70% in 1987 are Kadikoy, Fatih and Zeytinburnu. In 2011, Kadikoy, Fatih, Zeytinburnu, Bakirkoy, Bahcelievler, Bagcilar, Gungoren, Besiktas, Uskudar, Sisli and Beyoglu as presented in Figure 5. These results indicate that the metropolitan area of Istanbul is under the highly occupied with the impervious surface.



a **b**

Figure 3. a) Landsat 5 TM (1987) of Fatih District b) Classified Landsat 5 TM image

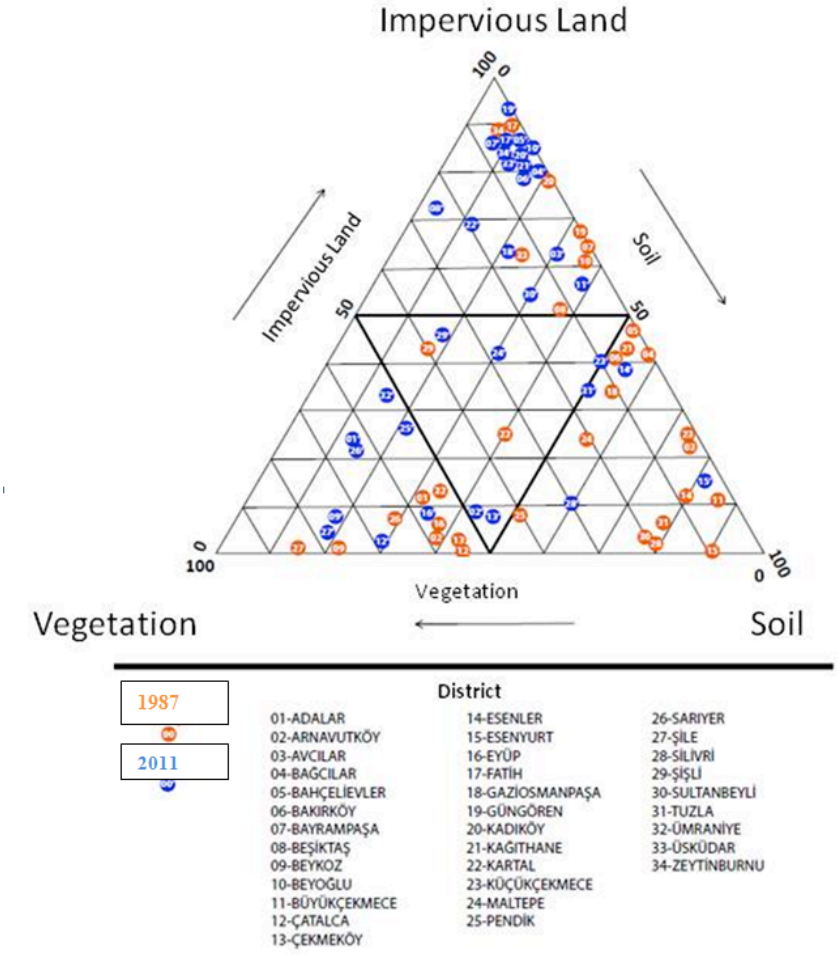


Figure 4. Vegetation, Impervious and Soil components of all districts on V-I-S diagram

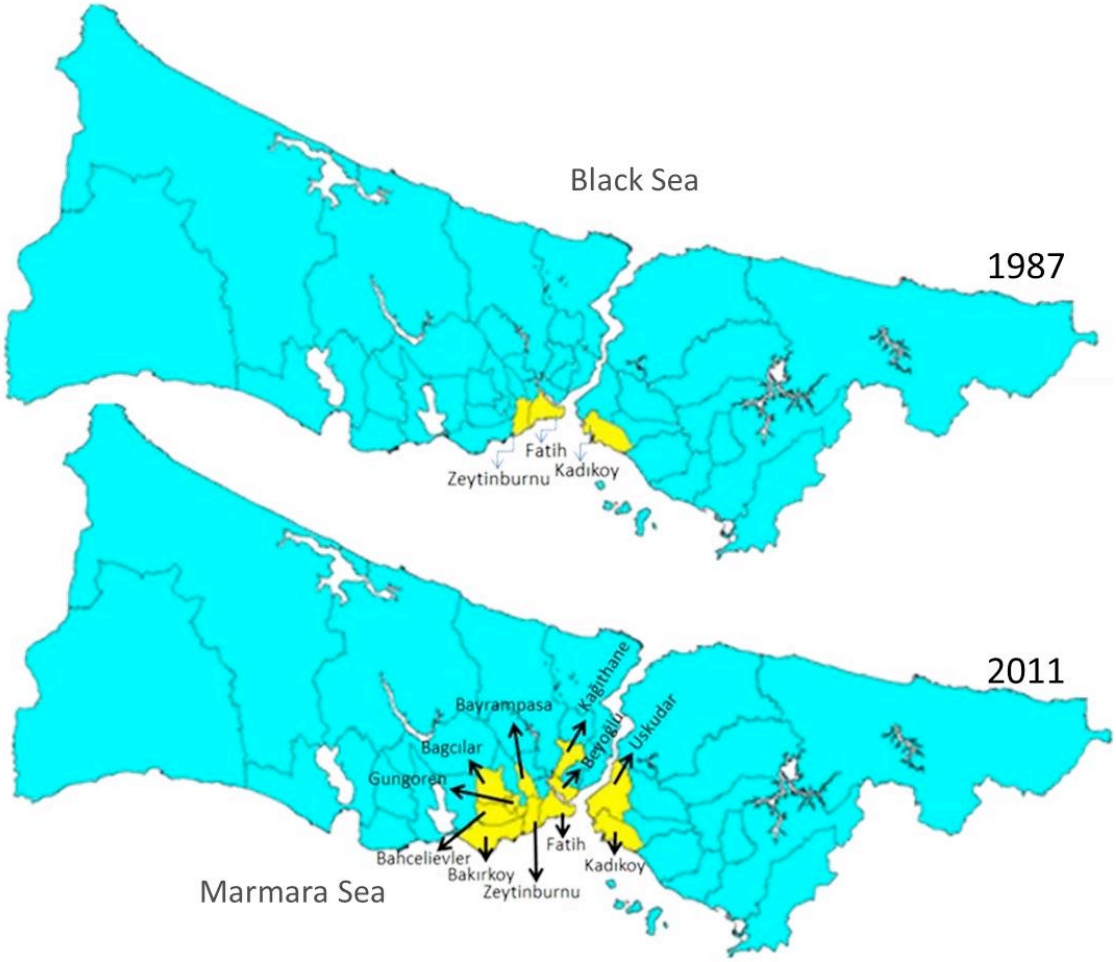


Figure 5. Districts having more than 70% impervious surface for the year of 1987 and 2011

4. CONCLUSION

Spatial distribution of land use/cover of a city could be determined quickly and economically using multispectral satellite imageries. In this study Landsat 5 TM satellite imageries were used to determine land cover changes in Istanbul based on V-I-S model. This study demonstrated that remotely sensed data could be successfully used to determine urbanization induced environmental changes. Vegetation, Impervious Surface and Soil components were determined for Istanbul using Landsat 5 TM satellite imageries dated 1987 ad 2011. Percentage distributions of these three components were displayed on V-I-S diagram. In this study only impervious surface areas were evaluated. Results show that, there was only three district which have more then %70 of impervious surface in 1987, number of districts reached to 11 which has the same level of impervious surface in the year of 2011. This study also indicated that the V-I-S model can be applied to satellite images for the analysis of spatial changes and their trends.

REFERENCES

http://esa.un.org/unup/pdf/WUP2011_Highlights.pdf, World Urbanization Prospects, The 2011 Revision, United Nations, New York, 2012.

Hung, MC. 2002. Urban land cover analysis from satellite images, Pecora 15/Land Satellite Information IV/ISPRS Commission I/FIEOS 2002, Conference Proceedings, p 1.

Jensen, J.R. and Cowen, D.C. 1999.Remote Sensing of urban suburban infrastructure and socio-econemic attributes, Photogrammetric Engineering and Remote Sensing, 65, 611-622.

Kaya, S. 2007. Multitemporal Analysis of Rapid Urban Growth in Istanbul Using Remotely Sensing Data, *Environmental Engineering Science*, 24(2): 228-233.

Kaya, S., Curran, PJ. 2006. Monitoring urban growth on the European side of the Istanbul metropolitan area: a case study, *International Journal of Applied Earth Observation and Geoinformation*, 8(1): 18-25.

Kaya, S., Seker, DZ., Tanik, A. 2012. Analysis of urbanized areas using V-I-S components model, *Fresenius Environmental Bulletin,* 21(11): 3243-3248.

Lee, S.; Lathrop, RG. Jr. 2005. Sub-pixel estimation of urban land cover components with linear mixture model analysis and Landsat Thematic Mapper imagery, *International Journal of Remote Sensing*, 26(22): 4885-4905.

Lu, D., Weng, Q. 2006. Use of impervious surface in urban land use classification, *Remote Sensing of Environment*, 102(1-2):146-160.

Madhavan, B.B., Kubo, S., Kurisaki, NT., Sivakumar, VLN. 2001. Appraising the anatomy and spatial growth of the Bangkok Metropolitan area using a vegetation-impervious-soil model through remote sensing, *International Journal of Remote Sensing*, 22: 789-806.

Pekin, F., Kaya, S. 2010. Automation of V-I-S model using Matlab & Simulink, Third Remote Sensing and Geographical Information Systems Symposium, UZALCBS, Proceedings in CD, 11-13 October, Gebze-Kocaeli, pp. 428-435. (in Turkish).

Phinn, S., Stanford, M., Scarth, P., Murray, AT., Shyy, PT. 2002. Monitoring the composition of urban environments based on the vegetation-impervious surface-soil (VIS) model by sub pixel analysis techniques, *International Journal of Remote Sensing*, 20: 4131-4153.

Ridd, MK. 1995. Exploring a V-I-S model for urban ecosystem analysis through remote sensing: comparative anatomy for cities, *International Journal of Remote Sensing*, 16: 2165-2185.

Small, C. 2001: Estimation of urban vegetation abundance by spectral mixture analysis, *International Journalof Remote Sensing* 2001, *22*: 1305-1334.

BIOGRAPHICAL NOTES

Associate Prof. Dr. Sinasi Kaya is currently working at ITU, Istanbul Technical University, Civil Engineering Faculty Department of Geomatics. His current research areas are Remote Sensing, GIS and Photogrammetry.

CONTACTS

Assoc. Prof. Dr. Sinasi KAYA
ITU, Istanbul Technical University
Civil Engineering Faculty, Department of Geomatics, 34469, Maslak
Istanbul
TURKEY
Tel. +90 212 2856100
Fax + 90 212 2856587
Email:kayasina@itu.edu.tr
Web site: http://akademi.itu.edu.tr/kayasina/

Assoc. Prof. Dr. Elif SERTEL
ITU, Istanbul Technical University
Civil Engineering Faculty, Department of Geomatics
34469 Maslak-Istanbul TURKEY
Tel. +902122853803
Fax + 902122856587
Email: sertele@itu.edu.tr
Web site: http://akademi.itu.edu.tr/sertele/

Prof. Dr. Dursun Zafer SEKER
ITU, Istanbul Technical University
Civil Engineering Faculty, Department of Geomatics
34469 Maslak-Istanbul TURKEY
Tel. +902122853755
Fax + 902122856587
Email: seker@itu.edu.tr
Web site: http://web.itu.edu.tr/~seker/