Advances in Engineering Software 40 (2009) 128–140

Contents lists available at ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

Development and application of GIS-based analysis/synthesis modeling techniques for urban planning of Istanbul Metropolitan Area

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ARTICLE INFO

Article history:
Received 25 September 2006
Received in revised form 25 October 2007
Accepted 14 March 2008
Available online 20 May 2008

Keywords:
Istanbul
Geographic information systems
Modeling
Sustainability
Spatial evaluation

ABSTRACT

Istanbul is the largest city in Turkey with an area of around 5750 km^2 and population of around 10.58 M (2000). The population is increasing because of mass immigration. Planned and unplanned housing are increasing while green areas are decreasing in area. Rapid, uncontrolled and illegal urbanization accompanied by insufficient infrastructure has caused degradation of forest, water basin and barren lands in the metropolitan area, especially within the past two decades. The study includes taking administrative planning decisions about the development of urban sustainability in the metropolitan area of Istanbul, producing rationalist solutions to the problems in environmental and natural resources, and conservation of small-scale (historical, tourist, residential, industrial, etc.) specific urban areas. By the help of this study, settlement suitability analyses have been achieved according to the natural thresholds of the area. Additionally, some kinds of formations, which may limit the development of the metropolitan area of Istanbul, such as natural structures, natural structure, ecological corridors and natural hazard areas, have been defined and developed model on the ArcGIS 9.1 platform. In the light of the policies of the European Union about sustainable cities, environmental impact assessments and sustainability policies have been determined for both the existing settlements and sustainable development areas.

1. Introduction

The area of the province of Istanbul is 5750 km^2 and it covers 0.97% of Turkey. The population living in Istanbul is approximately 10 million according to the general population census of the year of 2000 [1], and this number roughly equal to 58% of the whole population of the Marmara region. Mean population density of the city is 1180 people per km^2. Istanbul has the biggest proportion (21.3%) of the Gross National Product (GNP) of Turkey [1]. Such dense proportion of the population and economic activities in such a limited area causes a rapidly increasing pressure on the natural resources, social and environmental infrastructure of the city. Therefore, our main aim is sustainable development of the city as a healthy regional center and minimization of problems caused by the pressure and complex interactions. Sustainability requires the conservation and improvement of natural resources, and leads to the enhancement in the quality of life throughout the city [2].

The principal concepts evaluated in the context of environmental sustainability are the natural resources, earth, water, air, energy and wastes produced by human activities. Earthquake risk is extremely important through 8–10 km part of the Marmara coast, and research and modeling studies on seismic conditions are going.

Humid forested areas cover approximately 2164 km^2 (approximately 40%), and the last scrubby areas of Eastern Europe exist inside the metropolitan boundaries of Istanbul. Forested areas face threats that are causing them to disappear at a rapid rate, leading to pressures on wildlife populations [8]. The Bosphorus of Istanbul is one of the main migration paths of birds traveling between the northern and southern hemispheres [3]. The most significant points, which are also critical components of biological diversity and urban life support systems, on both sides of Istanbul are the shore and forested areas between Terkos and Kasatura, the sand dunes of Gümüşdere (Kilyos), the upper parts of the Bosphorus of Istanbul, the lakes of Büyükçekmece and Küçükçekmece, the scrubby areas and grasslands between Hadimköy and Kemerburgaz, the hilly areas through the Asian side, the sand dunes and forested areas between Sahilköy and Şile, and the islands of Şile. These areas are density populated and have high demands for water supplies and new settlement areas [4].

These natural areas undertake many diverse functions such as cleaning the air, conserving the earth, providing nutrients to underground water resources, etc. Therefore, from the viewpoint of sustainability, these areas are indispensable for continuity of

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doi:10.1016/j.advengsoft.2008.03.016

urban life and for increasing the quality of life of people. Thus, it is fundamental to sustain the presence of natural resources through time as long as possible [5].

Although the first grade agricultural areas cover 14.3% of the province area, urbanization and industrialization pressures over agricultural lands has climbed to dangerous levels [17]. It is important to prevent the destructive misuse of agricultural lands, such that these lands can no longer sustainable support urban areas.

Main water basins in Istanbul are Ömerli, Elmali, Küçükçekmece, Büyükçekmece, Alibeyköy, Terkos, Sazlidere and Darlik. These basins cover approximately 60% of Istanbul. There are many riverbeds throughout the basins and some industrial organizations use them as their water resources. Previously, settled industrial areas have become attractive newer industries and the number of such industrial formations has increased in recent years [6]. Organized Industrial Zones (OIZ) settled around the basins offer great potentials for employment, and have also encouraged population increase and new settlements around their locations.

In spite of the previous plans and the present regulations, new settlement areas with poor infrastructure have been established because of rapid and uncontrolled construction. Through the transformation from rural areas to urban areas, basin municipalities have allowed new densely populated settlements to become established on the basins, which have limited construction permissions. This situation causes pressure on the limited water resources in some municipalities [8,9]. At present, there are 7000 ha of settlement areas in the basins of Istanbul. The amount of daily solid waste production in Istanbul is approximately 10000 tons [10]. Both garbage collectors and municipalities collect the wastes for recycling purposes.

2. Methodology used

The study area was encompassed the Istanbul Metropolitan Area (Fig. 1). The study includes three stages (Table 1). In the first stage, the sufficiency and reliability of the data are questioned; the layers that do not have appropriate features are eliminated and left out of the scope of the study. During this selection, SWOT test is used. As a result of the first stage 38 of the 52 data layers regarding the research area are considered sufficient in terms of employability and included in the data set. In the second stage of the model; when the targets of the study, structure of the data layers and the feature of the studied region are taken into consideration it is considered that the most suitable solutions for the required analysis can only be made with the help of decision-making mechanisms with multi-criteria and, in this stage, among the methods that are examined, it is determined that Delphi technique is the most suitable one for this study, so this method is preferred for analysing the data.

In the third stage of the model; it is determined that the results that are generated as a result of the analysis of the data layers by the selected method should be subject to a classification, in this stage, among the classification techniques that are examined, because it will provide the most suitable approach for the targets of the study, the Natural Breaks Method is endorsed.

Throughout the study process, the environmental sustainability of an area was used to determine the corresponding urban sustainability of that area. Fig. 2 summarizes the methodology of the study and the basic factors directing the study. It also defines how areas were classified into spatial and administrative groups based on environmental sustainability.

2.1. Swot analysis

SWOT analysis that is commenced to be used firstly in 1970s with the aim of business management SWOT; is held as a tool for analysis and planning for different application areas in the following years. SWOT is an abbreviation including the capital letters of the words Strengths, Weaknesses, Opportunities and Threats. With this method that, as the base, has the principle of analysing the four parameters regarding the present structures by explicating, analysis relating both quantitative and qualitative features can be done and with explicating Swot matrix that is formed as a result of the analysis a strategically view relating the present program can be established. According to this, an evaluation considering how strong or weak the data are relating the study area (reliability and sufficiency), how much they enable the contribution to the study (how employable/questionable they are in GIS

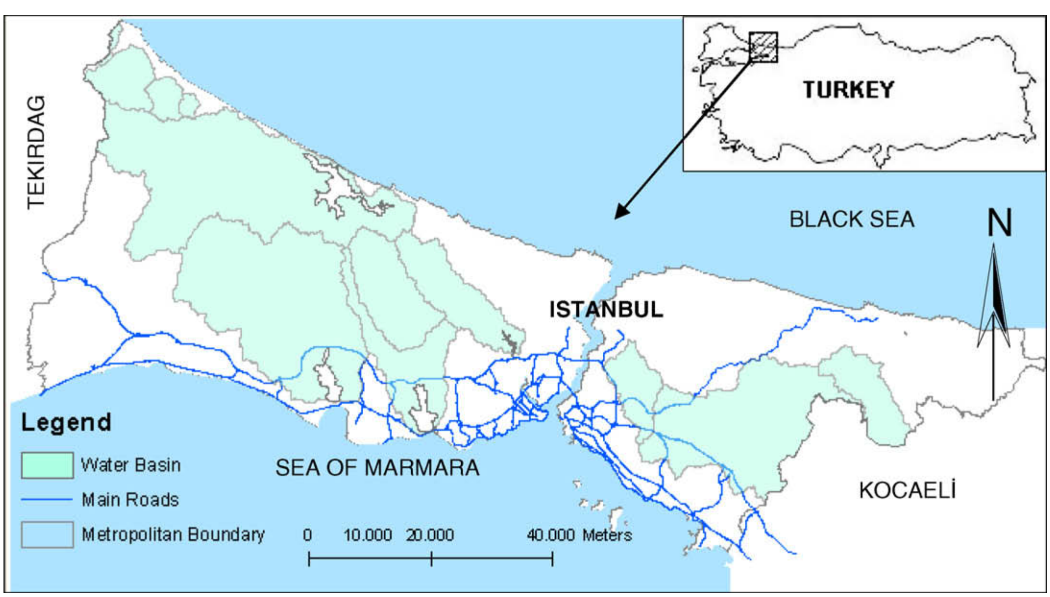
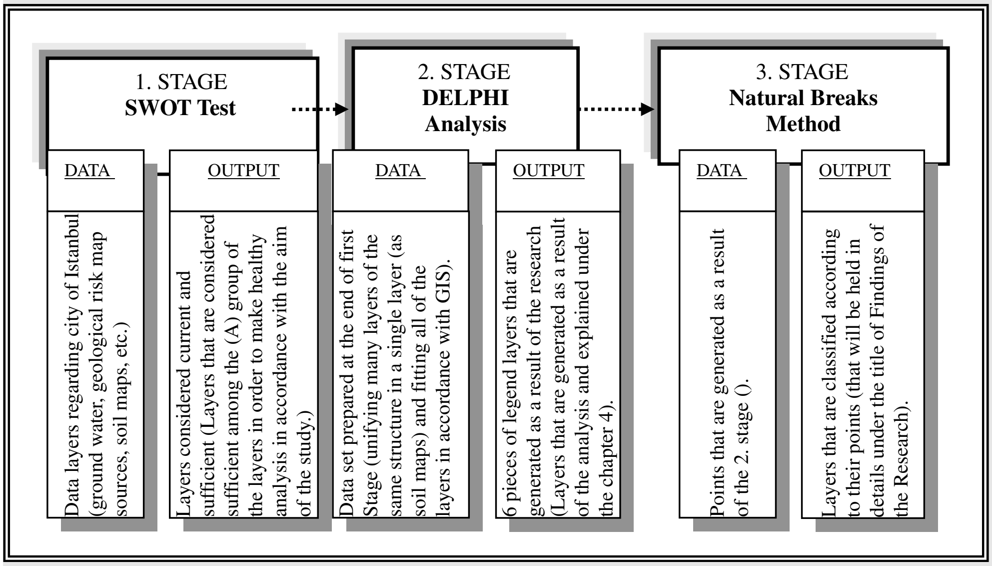


Fig. 1. Location of the study area.

Table 1
Application flow diagram



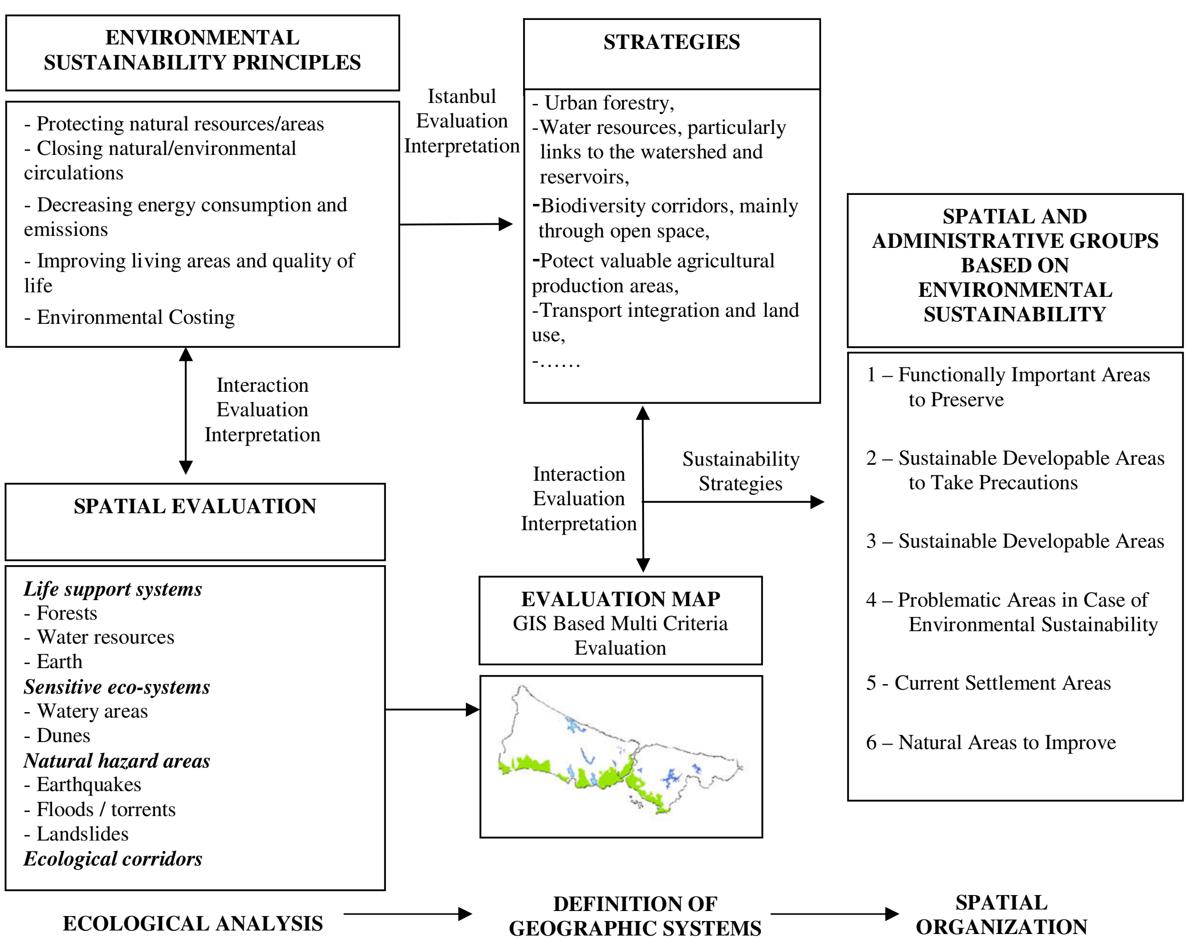


Fig. 2. Methodology.

discipline) and in the case that they have to be used in the study despite they are inefficient/limited in what direction and degree will they affect the result of the study is made, thus the first stage of the study is completed.

2.2. Delphi technique

This technique can be applied as experts of a specific subject comes together as a group, discuss and write their views and proposals about the subject on given forms or give points to the questions in the form or make multi-voting [21,22].

2.3. Natural Breaks (Jenks) Method

Natural Breaks is a classification method based on Jenks' Optimization Method (algorithm), which groups data into like categories. Historically, the Natural Breaks Method for defining classes required that the user (or cartographer) analyses the distribution of the attribute and decide where the appropriate class breaks should occur [14–16,19]. Using natural breaks, data are grouped so there is a minimum difference within each data class and a maximum difference between classes. The classification method used for each suitability surface was chosen based upon the data distribution and how well the data would be distributed amongst the 10 classes. The desired result was a range or gradient of ranked areas that represent the overall distribution of the original data [11].

The Jenks optimization is a statistical method used by ArcMap to find existing groups of values in the data and put them together, thus exploiting the natural gaps in the data. This is the default classification method of ArcMap. It is also a good choice for unevenly distributed data such as population density – where there are many low and medium density countries, but a few high densities countries [12]. Data were classified in ArcMap to the selected number of classes using the Natural Breaks Method of classification. This method uses an algorithm to find the natural breaks in a histogram of data, providing groups of like values. When data values were large and the Natural Breaks Method provided numerically detailed class breaks, these break values were rounded to a number which would be easier to read and interpret but retained the overall pattern of the original natural breaks [13]:

$$\mathrm{GVF} = 1 - \frac{\sum_{j=1}^{k}\sum_{i=1}^{N_j}(z_{ij}-\bar{z}_j)^2}{\sum_{i=1}^{N}(z_i-\bar{z})^2} \quad \text{Natural Breaks optimization formula} \qquad (1)$$

where GVF is the goodness of variance fit; z_{ij} is the sum of squared deviations from the array mean; $\bar{z}_j$ is the sum of squared deviations between classes.

Most of Jenks' NaturalBreaks.java code as follows:

```
/**
   * @return int[ ]
   * @param list com.sun.java.util.collections.ArrayList
   * @param numclass int
   */
  public int[ ] getJenksBreaks(ArrayList list, int numclass) {
    //int numclass;
    int numdata = list.size();
    double[ ][ ] mat1 = new double[numdata + 1][numclass+ 1];
    double[ ][ ] mat2 = new double[numdata + 1][numclass+ 1];
    double[ ] st = new double[numdata];
    for (int i = 1; i <= numclass; i++) {
      mat1[1][i] = 1;
      mat2[1][i] = 0;
      for (int j = 2; j <= numdata; j++)
        mat2[j][i] = Double.MAX_VALUE;
    }
    double v = 0;
    for (int l = 2; l <= numdata; l++) {
      double s1 = 0;
      double s2 = 0;
      double w = 0;
      for (int m = 1; m <= l; m++) {
        int i3 = l - m + 1;
        double val = ((Double)list.get(i3-1)).doubleValue();
        s2 += val * val;
        s1 += val;
        w++;
        v = s2 - (s1 * s1) / w;
        int i4 = i3 - 1;
        if (i4 != 0) {
          for (int j = 2; j <= numclass; j++) {
            if (mat2[l][j] >= (v + mat2[i4][j-1])) {
              mat1[l][j] = i3;
              mat2[l][j] = v + mat2[i4][j -1];
            };
          };
        };
      };
      mat1[l][1] = 1;
      mat2[l][1] = v;
    }; int k = numdata;
    int[] kclass = new int[numclass];
    kclass[numclass - 1] = list.size() - 1;
    for (int j = numclass; j >= 2; j--) {
      System.out.println("rank = " + mat1[k][j]);
      int id =  (int) (mat1[k][j]) - 2;
      System.out.println("val = " + list.get(id));
      //System.out.println(mat2[k][j]);
      kclass[j - 2] = id;
      k = (int) mat1[k][j] - 1;
    }; return kclass;
  }
  class doubleComp implements Comparator {
  public int compare(Object a, Object b) {
   if (((Double) a).doubleValue() < ((Double)
b).doubleValue())
     return -1;
   if (((Double) a).doubleValue() > ((Double)

b).doubleValue())
     return 1;
   return 0;   }  }
```

3. Environmental sustainability issues

Sustainable management of the natural resources, energy and waste needs a holistic approach. Natural resource consumption and waste production levels have been accelerating in urban areas. Therefore, in our cities, it is indispensable to make the necessary adaptations to emulate the sustainability of natural systems [7]. Cities continuously require raw materials, and the flows of those raw materials are all directed inward toward the cities. Creating more sustainable cities depends on managing the outflow of wastes in a manner in which they can be sustainable absorbed by natural ecological processes. Environmental sustainability assessment of Istanbul has been completed in the boundaries of Istanbul Greater City Municipality and it includes:

Air (air quality).
Water (water resources, water quality, waste water management).
Soil (soil quality, agricultural use, land structure).
Flora/fauna (biological diversity, sensitive eco-systems, etc.).
Energy (heating, transportation, production).
Waste (fluid and solid waste management).

4. Urban environment sustainability and spatial analyses for Istanbul

Istanbul is the greatest metropolitan city of Turkey, and is a center of economic, social and cultural activities. Thus, through the efforts to increase the quality of life, sustainability principals have become determinative for the analyses and syntheses.

Methodology through the process of analyses and syntheses has been discussed in the context of moderating the almost overwhelming pressures on the natural ecosystem and resources. Life support systems and natural hazard areas have also been evaluated in this context. In the scope of determining the life support systems, the maps generated by Istanbul Metropolitan Planning (IMP) Natural Structure Group have been used as reference, at a scale of 1:100,000 and within the boundary of Istanbul Greater City Municipality. As result:

A sensitivity analysis concerning natural and ecological structure has been realized.
Naturally/ecologically integrated areas and ecological corridors (such as mineral and stone mines) have been defined.
Geological risk factors such as earthquake, landslide, flood and filled ground have been evaluated.

The study mainly includes three layers regarding water resources (hydro-geological structure analysis, ground water and basins), soil and land resources (soil–land use classes, topography and slope analysis), biological diversity and ecology (land cover, sensitive eco-systems). Information on each layer has been transferred to the life support system matrix (Table 2) and these evaluations have been classified into five groups as:

1. Less important.
2. Moderately important.
3. Important.
4. Very important.
5. Strongly important.

A subjective grading technique has been applied on the evaluation matrix of life support systems. We developed this table as a tool to guide the professionals. Through the grading, it has strongly considered to answer basic needs of not only today but also next generations based on natural resources. In addition, long time conservation and use of natural resources have also been thought through the process. According to this classification and grading technique based on the main principles of environmental sustainability:

Water is very important for sustainable spatial planning, but the high demand for water may exceed the capacity of this resource to renew itself. It is therefore classified as a semi-renewable resource. Water has been considered as one of the most important elements in the frame of spatial analyses made for Istanbul. Map evaluations related with hydro-geological and hydrological structure have been used throughout the analyses.
Soil and topography have also been identified as highly significant data for sustainable spatial planning, and they are evaluated in the context of Land Use Ability Classes. Slope information has also been used in all of the evaluations based on the idea that defends preserving the landform in context of sustainable spatial planning. Slopes have been classified as 0–15%, 15–30% and over 30%.
Land cover, ecologically/biologically important areas and natural conservation areas have been evaluated in the scope of biological diversity and ecology evaluations.

The scores calculated using the evaluation matrix of life support systems have been evaluated using the ArcGIS Model Builder in ArcGIS 9.1. Fig. 3 shows a sample of the model used to identify protected lands. The first step converts several input layers to raster format and makes use of some Spatial Analysis tools. All input polygons have scores, and the model preserves the highest scoring areas using the Local Maximum tool. The resulting contiguous areas of protected land are given a mean score via zonal tools.

Base maps generated by the Natural Structure Group have been transferred to ArcGIS throughout the evaluation procedure and the most suitable of 52 base maps have been classified according to their ecological qualifications according to the age of the map, functionality. After classifying and assigning scores to each data layer in the matrix in Table 2, a final 'total values' layer was generated based on the quarter boundaries on the base map. The layer has been evaluated by the 'natural breaks' classification methodology, and it shows the sensitivity of natural structure of Istanbul (Fig. 4).

Using our natural structure sensitivity analysis, we defined areas of conservation class in Istanbul based on natural resource diversity and total natural productivity. In the evaluation, scores between 36 and 54 illustrate very important and strongly important areas; scores between 27 and 36 show important areas; and scores between 9 and 27 show less important and moderately important natural areas; and scores between 1 and 9 show unimportant areas. In case of a healthy threshold analysis, these analyses are unsatisfactory. Therefore, forestry areas, which are significant for the wholeness of natural structure, have been overlaid with the natural structure sensitivity analysis layer (Fig. 5).

According to sustainable spatial planning concepts, it is very important to draw the boundaries of naturally/ecologically integrated areas and then manage human activities damage on these special lands. In this aspect, Fig. 5 is significant for the determination of these areas, which have a fragile natural structure and are primarily conservation areas. Fig. 6 shows the layer of natural risk areas based on the present data classification scheme. Additionally, it is helpful to evaluate the areas to be developed or renovated, to integrate the risk assessment to planning process, to determine the geologically dangerous areas (i.e. risky in case of flood, earthquake, landslide, avalanche and seismic areas) and to define areas with active ground layers.

Natural risk factor has been considered in all of the following steps through the evaluation procedure. Fig. 7 is a result of the integration of natural structure sensitivity analysis and natural risk areas, containing basin boundaries and risky quarters. Fig. 8 combines this evaluation with life support systems and ecological corridors.

This analysis has become very helpful to identify those areas that should not change functionally, those areas that can be sustainably developed with some restrictions, and otherwise generally sustainable development areas. By this step of the study, we have seen that there is no available land/zone that is appropriate for development of dense settlement areas in the metropolitan area boundaries, and the region around Silivri is appropriate for low dense urbanization. These areas have high risk for a potential earthquake, and they also includes many productive agricultural lands.

Sustainability-based threshold analyses and land use studies about Istanbul have primarily shown two main threats to functional conservation areas. The first threat includes mineral and stone mines (Fig. 9), and the second threat is urbanization (Fig. 10).

After the assessments made on settlements over defined thresholds in Fig. 10, the threshold synthesis in Fig. 11 has been generated.

LandSat TM 2005 images for Istanbul Metropolitan Area were evaluated and classified (Fig. 12). We examined the LandSat TM

Table 2
Life support systems evaluation matrix

Criteria / Score*	1	2	3	4	5
WATER					
Hydro-geological structure analysis					
Unconsolidated formations forming vast and rich aquifers					X
Consolidated formations forming vast and rich aquifers					X
Unconsolidated formations forming local and unsolidated aquifers				X	
Consolidated formations forming local and solidated aquifers				X	
Formations including local underground water			X		
Formations not including underground water	X				
Ground – Underground water resources					
Ground water resources (lake, dam and etc.)					X
Underground water basin					X
Basin rivers				X	
Basin dry rivers			X		
Out of basin rivers				X	
SOIL AND LAND					
Soil (Land Use Ability Classes)					
1st class					X
2nd class } Absolute Agricultural					X
3rd class				X	
4th class				X	
5th class			X		
6th class Marginal Agriculture			X		
7th class		X			
8th class	X				
Slope (Degree)					
> 30					X
15-30			X		
0-15	X				
BIOLOGICAL DIVERSITY AND ECOLOGY					
LAND COVER					
Forestry Areas					X
Private Forestry Areas		X			
Ecologically/biologically Important Areas					
Ecologically/biologically important areas					X
Conservation Areas					
Nature conservation areas					X
Wildlife protection/improvement areas					X
Protecting and propagating hunt fowls					X
Grove areas					X
1st grade natural conservation area					X
2nd grade natural conservation area				X	
3rd grade natural conservation area				X	
Natural parks				X	
Forest picnic areas			X		

SCORES*
1. Less important 2. Moderately important 3. Important
4. Very important 5. Strongly important

classes from Fig. 12 that corresponded with each development class from Fig. 11. The classification study also focuses on the acquisition and analysis of LandSat TM satellite image reflecting the significant land cover changes years of 2005. The land cover categories in the LandSat TM satellite image follow closely those defined by Anderson et al. in his 1976 publication [20]. Brief descriptions of the 13 land cover categories are shown in Table 3. Ten out of these 13 categories (built-up area, barren, cloud, cropland, forest-deciduous, forest-evergreen, grassland, scrub/brush, water and wetland) which are applicable to Istanbul, and presented in the summary tables. In this research, Erdas Imagine 8.5 and ArcGIS 9.1 are the selected software. Initially,

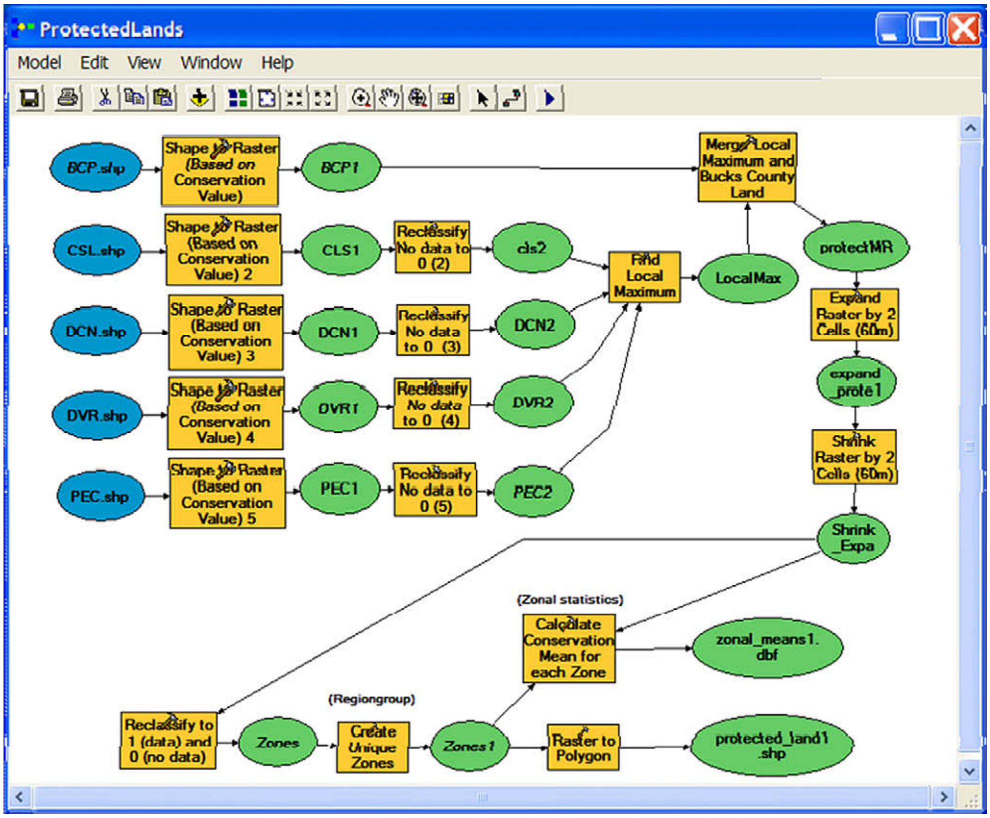


Fig. 3. Sample of the model design.

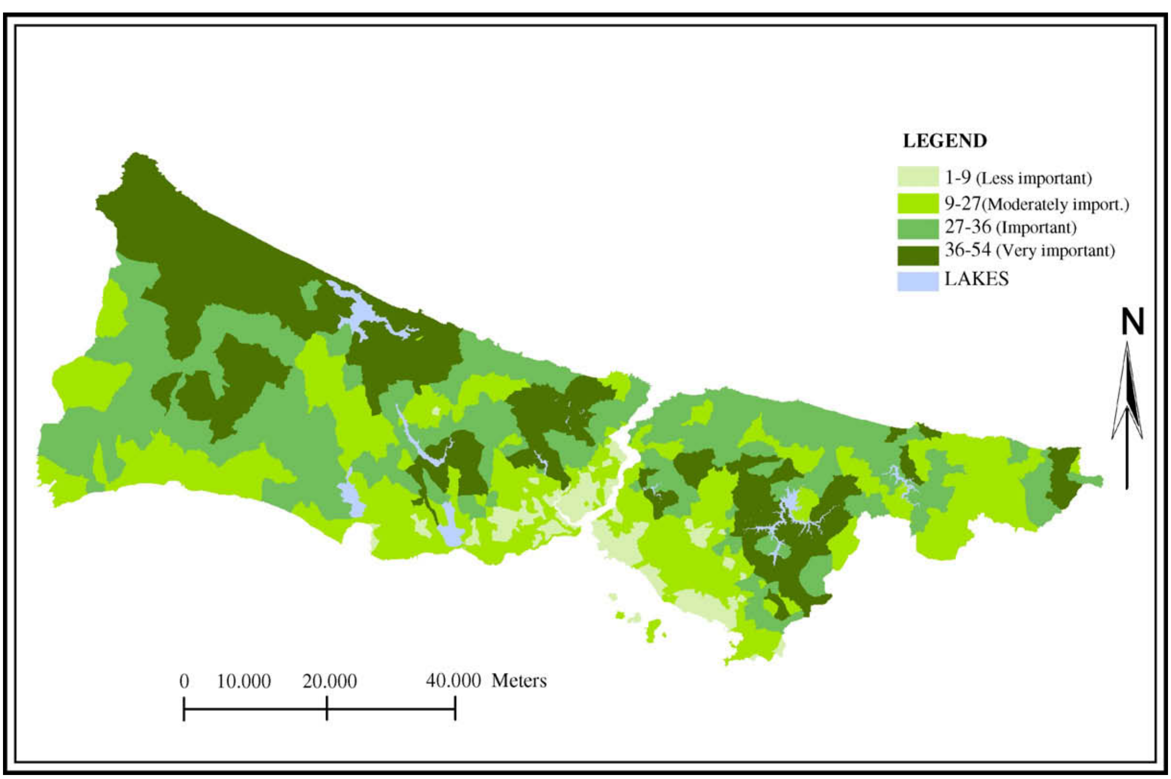


Fig. 4. Natural structure sensitivity analysis.

all images are rectified to the UTM coordinate system. Erdas Imagine is used to classify the land uses from the satellite images, after which the obtained raster images are converted to vector maps. The following steps are completed in the ArcGIS

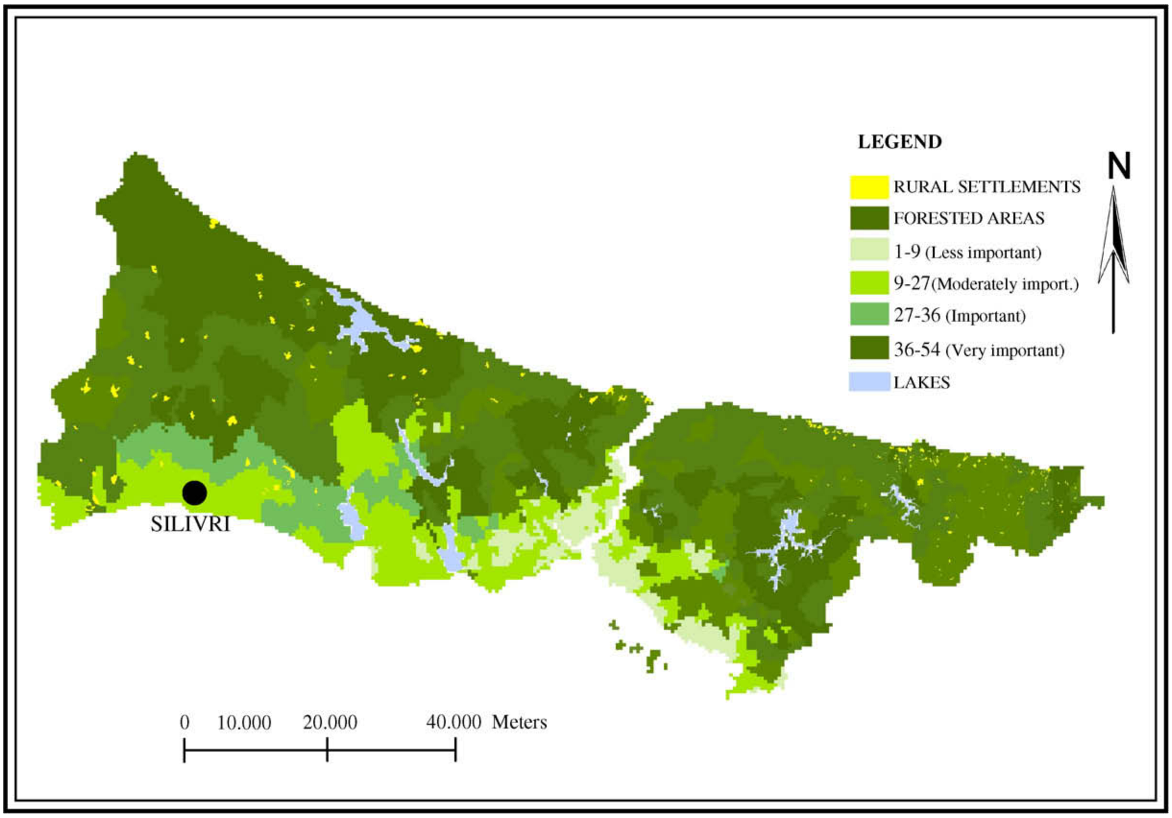


Fig. 5. Natural structure sensitivity analysis and forested areas.

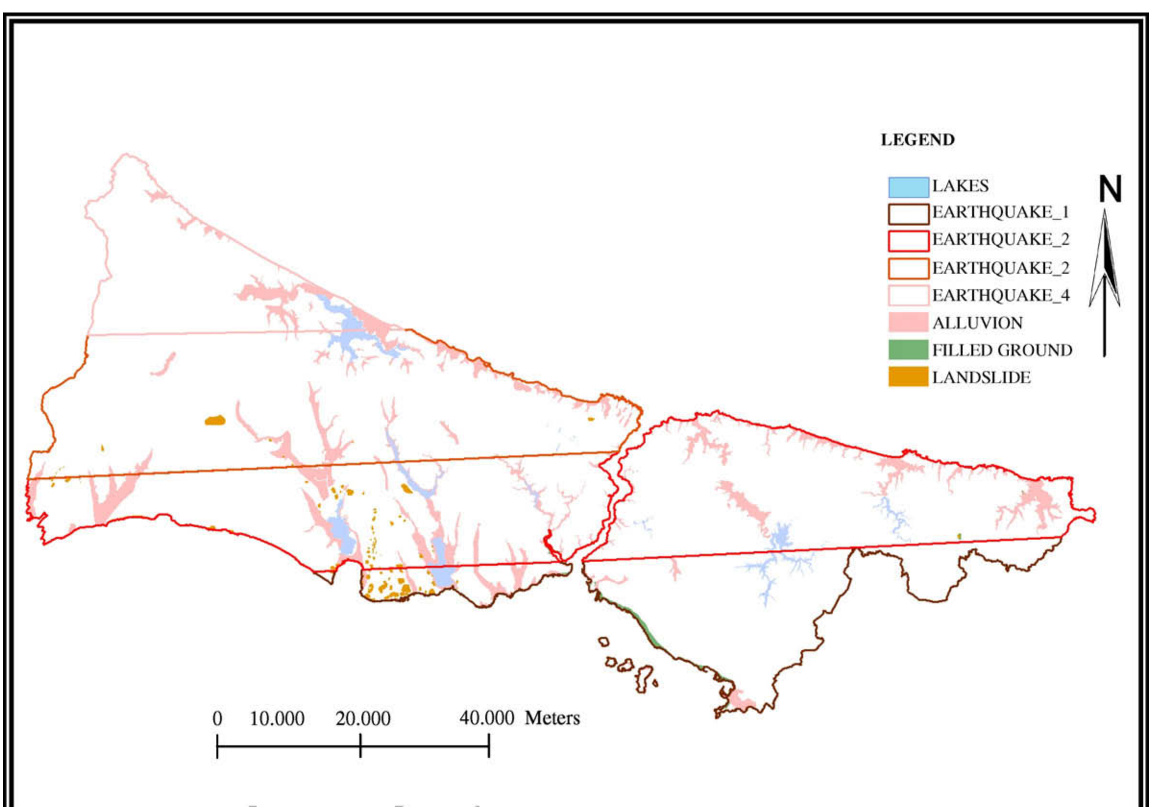


Fig. 6. Natural risk areas [18] (http://www.deprem.gov.tr/linkhart.htm).

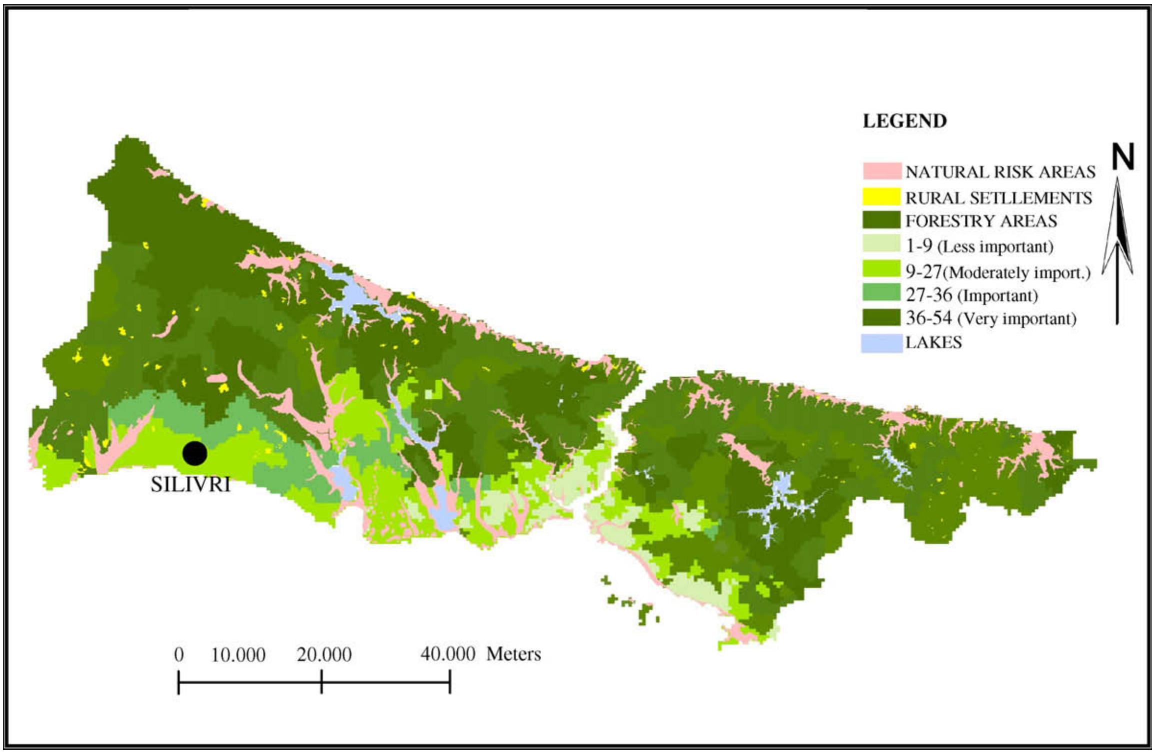


Fig. 7. Natural structure sensitivity analysis, forestry and natural risk areas.

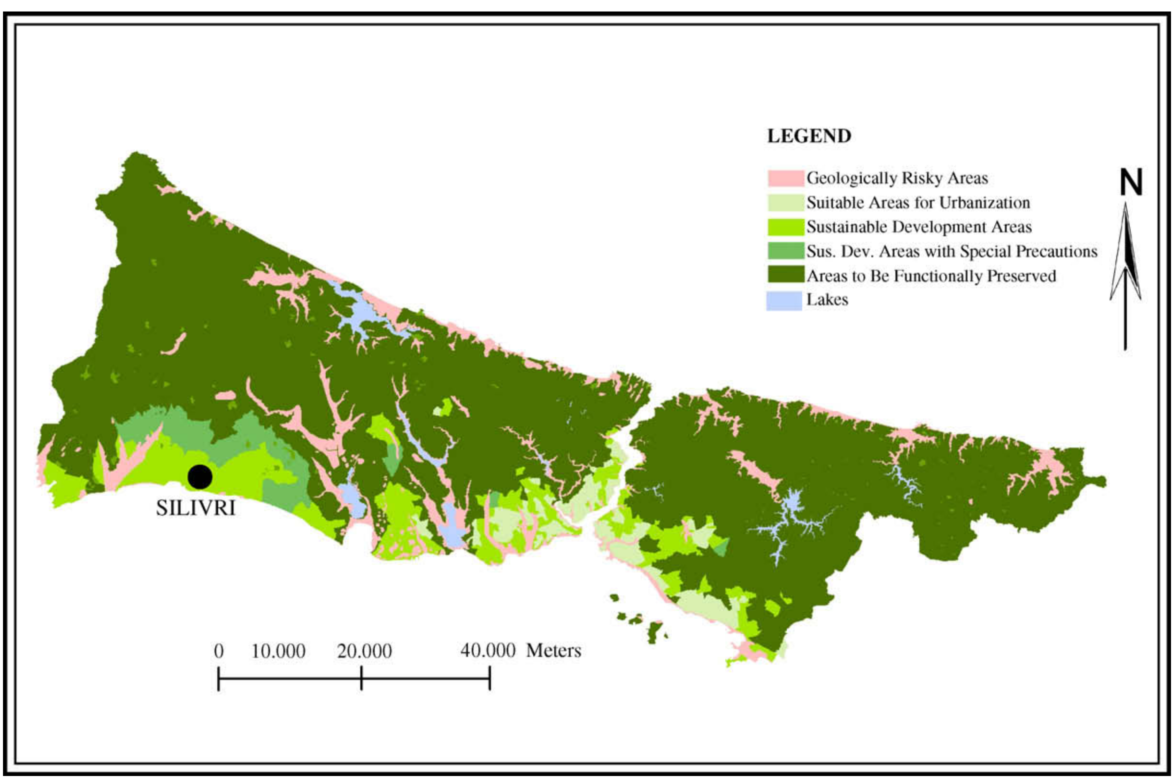


Fig. 8. Life support systems and ecological corridors.

environment. An interface has been developed in ArcGIS 9.1 environment, which provides the users an efficient and correct area calculation tool. Then the land use changes are measured and the obtained values are summarized in table forms for all land use changes in Istanbul.

5. Findings

Metropolitan area of Istanbul has been classified into six groups based on protecting the natural environment and achieving the sustainability strategies.

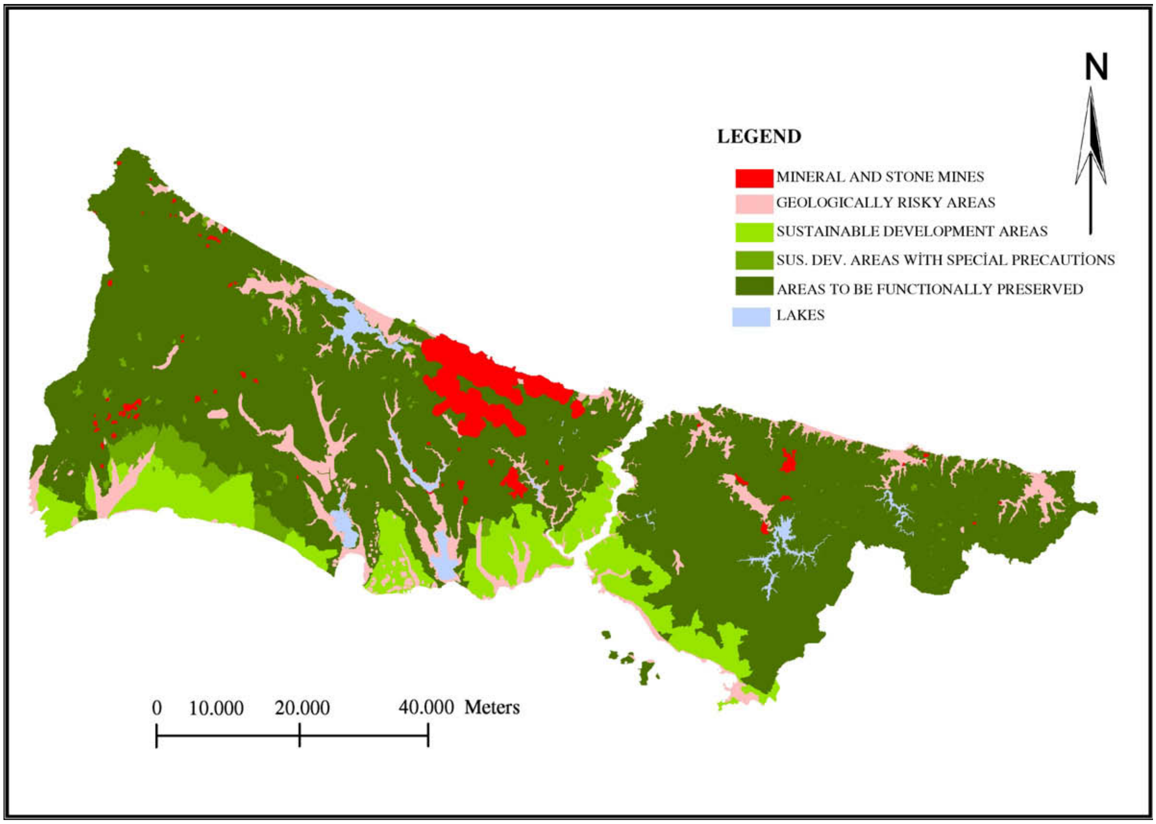


Fig. 9. Mineral and stone mines.

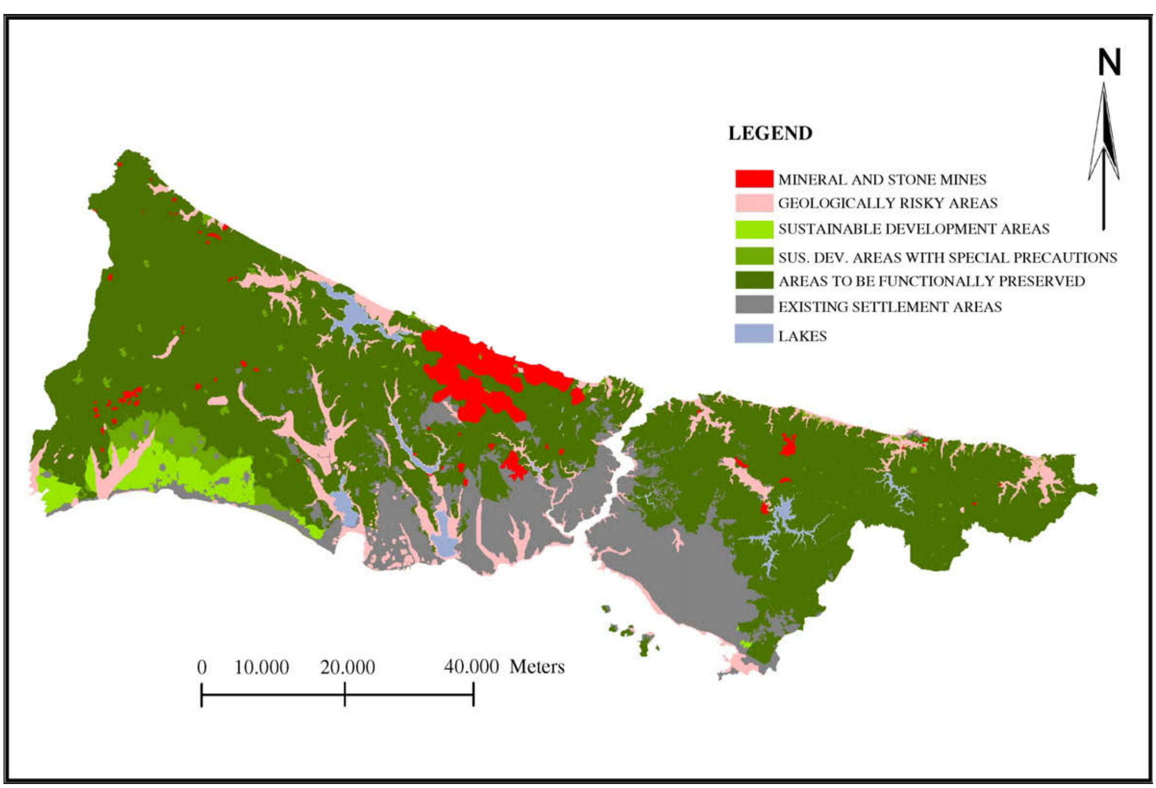


Fig. 10. Existing settlement areas.

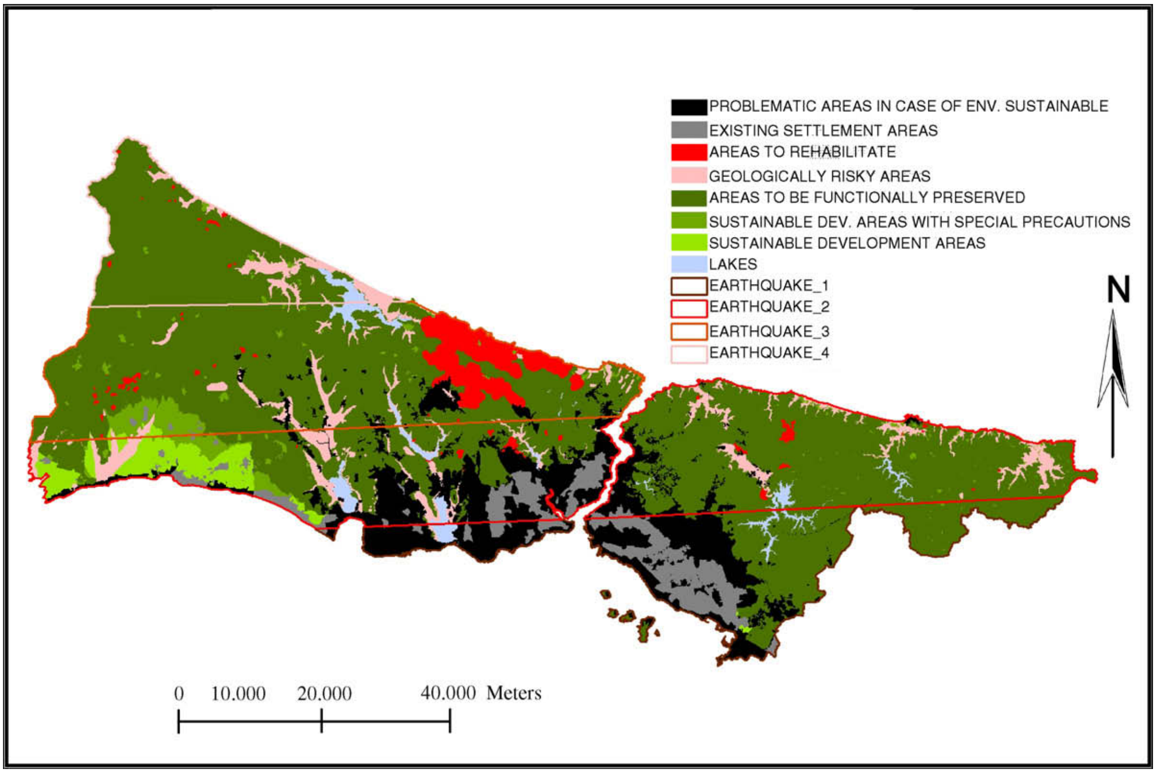


Fig. 11. Environmental and spatial sustainability threshold synthesis.

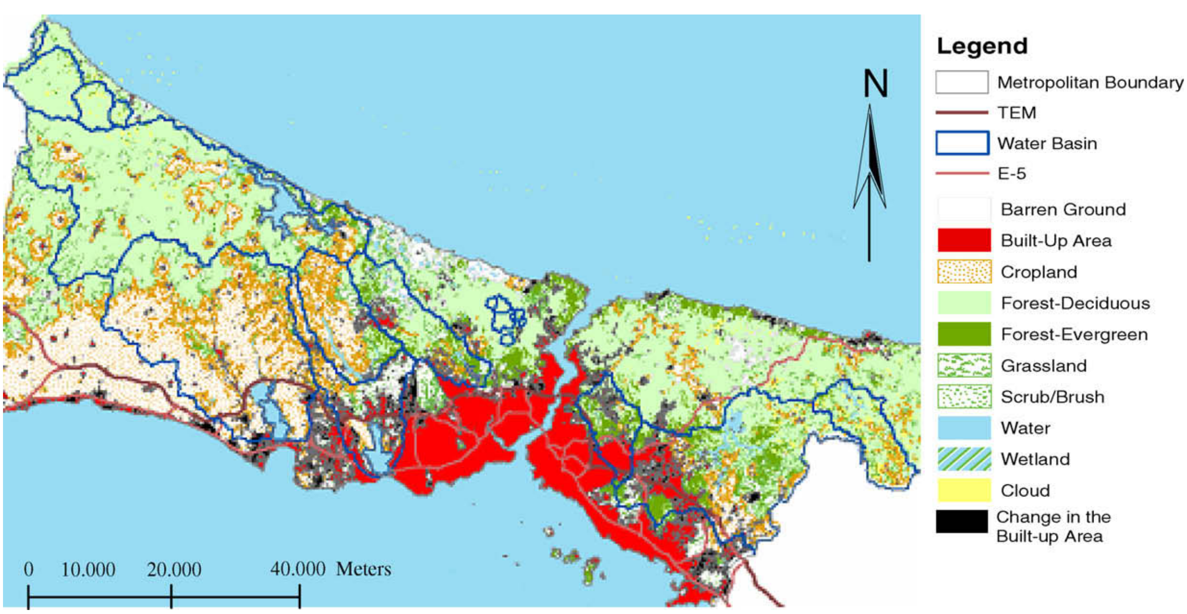


Fig. 12. Land use classification by Landsat TM 2005.

5.1. The areas to be functionally preserved

These areas lose their natural functions or become highly damaged when they are exposed to human affects, and they can never be returned to their original forms after being deteriorated. The areas to be functionally preserved are assurance of metropolitan-scale life quality, so they have an indispensable importance for the self-sufficiency of the metropolis.

5.2. Sustainably developable areas having special precautions

Sustainably developable areas having special precautions are characterized by ground and underground water resources, water basins, forested areas, high biological diversity and rich soil resources. These areas also serve to delay and to limit urban growth and they may support metropolitan-scale recreational areas, education areas, low-density public uses, low-den-

Table 3
LandSat TM land cover legend

Number	Classes	Definition
1	Forest, deciduous	Trees >3 m in height, canopy closure >35% (<25% intermixture with evergreen species), of species that seasonally lose leaves
2	Forest, evergreen	Trees >3 m in height, canopy closure >35% (25% intermixture with deciduous species), of species that do not seasonally lose leaves
3	Shrub/scrub	Woody vegetation <3 m in height, with at least 10% ground cover
4	Grassland	Upland herbaceous grasses, >10% ground cover
5	Barren/minimal vegetation	Land with minimal ability to support vegetation, including rock, sand and beaches
6	Urban/built-up	Developed areas at least 60 m wide
7	Agriculture, general	Cultivated crop and pasture lands, except paddy agriculture
8	Agriculture rice/ paddy	Paddy croplands characterized by inundation for a substantial portion of the growing season
9	Wetland, permanent/ herbaceous	Areas where the water table is at or near the surface for a substantial portion of the growing season
10	Wetland, mangrove	Sheltered coastal (i.e., estuarine tropical wetlands supporting woody species of mangrove)
11	Water	All water bodies of size greater than 0.08 ha
12	Permanent ice and snow	Land areas covered permanently or nearly permanently with ice or snow
13	Cloud/cloud shadow/no data	Areas where no land cover interpretation is possible due to obstruction caused by clouds and their shadows, smoke, haze, terrain shadow, or satellite or transmission malfunction

sity agricultural uses, ecotourism and other low-impact activities.

5.3. Sustainably developable areas

Sustainably developable areas may be suitable for urbanization if the necessary sustainable planning principles are well performed. Therefore, specific precautions must be undertaken, such as controlling the polluter factors and arrangement of infiltration processes to conserve ground and underground water resource.

Planning in sustainably developable areas should include: (1) environmental recycling, (2) decreasing energy consumption and emissions, (3) improving living conditions and quality of life and (4) conserving natural areas and resources. Development of urban areas should incorporate strategies to protect against natural and human threats such as earthquakes and floods.

5.4. Problematic areas in case of environmental sustainability

Urgent precautions have to be taken to re-establish environmental sustainability on these areas. Planning in sustainably problematic areas should include: (1) conserving the natural areas and resources, and (2) improving living places and quality of life. The affects of these settlements on the surrounding areas must be decreased, and human dispersion must be controlled by the help of buffer zones surrounding around the settlements.

5.5. Existing settlement areas

The aim of dealing with the existing settlement areas includes improving the existing settlements to an environmentally sustainable level, decreasing the risk levels of probable threats and natural hazards, and increasing the resistance of the urban technical infrastructure to these probable risks.

Planning in sustainably existing settlement areas should include: (1) closing environmental recycling, (2) decreasing energy consumptions and emissions, (3) improving living environments and quality of life, and (4) taking precautions against natural and artificial risks.

5.6. Natural areas to rehabilitate

In the context of these natural areas, open mining management areas and other activities which inflict unrecoverable damages to the natural structure have been evaluated. On the European side, primarily the northern parts, widely dispersed pits and mines lie along the shores of the Black Sea. When the spatial dimensions of the problem and the level of damage are considered, it is seen that specific and holistic solutions are indispensable. The aim of rehabilitation is to return the areas to their natural functions and to make them resilient to hazards like flood, etc.

6. Conclusion

In 1980, the population was only 4.7 M and then Istanbul has been more than doubled in only two decades. The population has been increasing as a result of mass immigration. An urbanization process continues and it causes serious increases in urban areas while decreasing the amount of green areas. This rapid, uncontrolled and illegal urbanization accompanied by insufficient infrastructure has caused degradation of forest and barren lands in the metropolitan area, especially through the last two decades. The watershed basins inside the metropolitan area and the transportation network have accelerated the land cover changes, which have negative impacts on water quality of the basins.

As a result of poorly planned site selection decisions throughout the metropolis, urban growth in the northern direction causes increasing levels of pressures and threats to conservation areas and resources, such as drinking water basins and forested areas. It is highly important to re-establish sustainability of these resources to have higher levels of quality of life. In this context, as a conclusion derived from threshold analysis and synthesis studies, a linear urban growth should be directed through the western parts of Istanbul.

Total productivity and diversity assessments have shown that Silivri and surrounding areas may be thought as the alternative focal points, because of their resilient structure compared to the northern parts of Istanbul. On the other hand, this region includes the most valuable agricultural lands and needs a detailed geological study. Development decisions regarding this region must be taken according to sustainability principles, and technical precautions must be taken with both planning and application procedures. Satisfying these conditions is important to not only protect the natural structure but also to prevent the negative consequences caused by natural risks. Thus, the necessary natural risk analyses (primarily earthquake risk) must also be considered for the questioned significant land.

If Fig. 10 is closely examined with respect to the locations natural structures and natural risks, it is seen that defining a belt suitable for new settlements is almost impossible in the present conditions. Moreover, under current conditions urbanization continues to exceed the natural thresholds and thereby harms the natural resources. Istanbul has always shown a linear development through its historical process. It first became the most important development center and then the biggest metropolitan area; and now unplanned development continues in the directions of north, east and western parts.

In conclusion, instead of trying to find new suitable settlement belts, it will be better for Istanbul to improve the existing structure, to increase the level of quality of life, to take technical precautions and to achieve environmental sustainability principles and consequently decrease the pressure on the natural resources in the next years.

Acknowledgements

This paper has been developed from the outcomes of research projects. This study was supported with financial and field support from the Istanbul Metropolitan Planning (IMP), who provided the necessary assistance at every stage of this study. The authors extend their gratitude to IMP and the project team who participated in this project.

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