MAPPING QUALITY OF LIFE IN METROPOLITAN ATHENS USING SATELLITE AND CENSUS DATA

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ABSTRACT

This study is an attempt to measure and map the quality of life in the urban area of Athens, Greece, using Landsat 7 Enhanced Thematic Mapper (ETM+) image data combined with census data in a Geographic Information System (GIS). The physical environment of the city is described by the variables of normalized difference vegetation index (NDVI), surface temperature and land cover/use; the first two are extracted from the satellite image data, whereas land cover/use information is provided by the Corine Land Cover 2000 (CLC00) database for Greece. On the other hand, the socioeconomic variables of population density, unemployment rate, education level, and median home value, all obtained from the 2001 Greek census, are used to represent the living environment of the city. Integration of the physical with the socioeconomic variables in a GIS framework using an aggregated ranking score approach is employed in order to derive the quality of life scores for the city of Athens. Results demonstrate the effectiveness of the index to evaluate and map the quality of life over the study area, as well as to highlight those variables that may be responsible for a low life quality.

INTRODUCTION

Evaluation of the life quality of the urban population on a continuing basis is important, because it may support decision-making, regarding sustainable urban management and planning. To assess quality of life, various indices are used in order to represent the most important aspects of a citizen, which include, for example, housing, education, employment and physical environment. In the past, most quality of life evaluation studies made use of only the census data to extract socioeconomic indicators (i,ii), whereas in some studies researchers have employed aerial photographs in conjunction with socioeconomic data from census to measure the quality of the urban environment (iii,iv). Most recently, Weber and Hirsch (v) used remote sensing data in conjunction with cartographical and census data in order to study the life quality of Strasbourg, France. In their work, three indices were developed from mixed data, a housing index, an attractivity index and a quality index which were then implemented for the Strasbourg urban agglomeration so as to map its landscape quality. Later, Lo (vi) used Landsat Thematic Mapper (TM) data with socioeconomic variables obtained from the U. S. census data for quality of life assessment of the Athens-Clarke Country of Georgia.

The objective of this study is to analyze the urban environment of Athens, Greece by using an aggregated quality of life index representing the combined attributes of the physical, economic and social environment of the city. The index is developed on the basis of the high-resolution Landsat ETM+ (multispectral) image data and 2001 Greek census data. Urban quality is expressed by means of a scale, which combine the socioeconomic and physical data in a GIS for a complete evaluation.

The metropolitan Athens area lies in a basin of about 500 km^2 surrounded by mountains of various altitudes in the NW, NE and SE directions. It has a total population of 2,664,776 inhabitants in 2001, which is 24.3% of the total population of Greece. Forty-eight municipalities make up the metropolitan Athens area (Figure 1). The quality of life index is computed for each municipality and the overall quality of life is evaluated.

Figure 1. The 48 municipalities of metropolitan Athens.

METHODS

A summer Landsat ETM+ image over the study area is used in the present research. The ETM+ sensor on board the Landsat 7 satellite can provide image data from the visible to thermal infrared spectral regions. Landsat 7 is chosen in this study, because it collects thermal measurements with the highest spatial resolution currently available from space. More specifically, ETM+ thermal band 6 (10.4 - 12.5 μm) has a spatial resolution of 60 m at nadir, which can be considered suitable for capturing the complex intra-urban surface temperature differences allowing thus, an effective and detailed analysis of the urban thermal environment. The Landsat ETM+ image was acquired through the US Geological Survey (USGS) Earth Resource Observation Systems Data Center in level 1G data and registered to the Universal Transverse Mercator (UTM) projection. Landsat ETM+ image processing for extracting the surface temperature and the NDVI index includes:

SURFACE TEMPERATURE

For thermal image data calibration, a two-step process as proposed by the Landsat Project Science Office (vii) is performed: a) conversion of the digital number (*DN*) values of band 6 into spectral radiance *L* (Wm^{-2}sr^{-1}μm^{-1}) using the following equation:

$$L = 0.0370588 \cdot DN + 3.2 \quad (1)$$

and then b) conversion of the spectral radiance L to at-sensor brightness temperature BT in Kelvin. The conversion formula is given by:

$$BT = \frac{K_2}{\left\{ 1n\left[\frac{K_1}{L} + 1 \right] \right\}} \tag{2}$$

where BT is the at-sensor brightness temperature in Kelvin, K_2 is a calibration constant (1282.71 K), K_1 is a calibration constant (666.09 $Wm^{-2}sr^{-1}\mu m^{-1}$), and L is the spectral radiance at-sensor ($Wm^{-2}sr^{-1}\mu m^{-1}$). Conversion to surface temperature T_s is carried out using an emissivity value of 0.92 for non-vegetated surfaces (viii). Thus, the emissivity corrected surface temperature T_s is obtained from the following equation:

$$T_s = \frac{BT}{1 + \left(\frac{\lambda \cdot BT}{\alpha} \right) \cdot 1n\varepsilon} \tag{3}$$

where λ = wavelength of emitted radiance (11.5 μm), α = hc/K (1.438×10^{-2} mK), BT = at-sensor brightness temperature (K) and ε = spectral surface emissivity. Surface temperature is regarded as a negative indicator of the physical environment, since high surface temperatures are related to urban heat islands (ix, x), human thermal discomfort (xi) and energy demand (xii, xiii).

NDVI INDEX

From the Landsat ETM+ image data, the Normalized Difference Vegetation Index (NDVI) is calculated so as to measure the degree of greenness present within the urban environment of Athens. The equation used is given as:

$$NDVI = \frac{ETM4 - ETM3}{ETM4 + ETM3} \tag{4}$$

where ETM3 and ETM4 are the red band (0.63-0.69 μm) and the near infrared band (0.76-0.90 μm) of ETM+ sensor, respectively. Prior to the NDVI calculation, the Landsat ETM+ image is atmospherically corrected using the COST method developed by Chavez (xiv). This method is applied to the raw digital number (*DN*) values of the Landsat image from which atmospherically and radiometrically corrected surface reflectances of the ETM3 and ETM4 bands are derived and used thereafter for the calculation of the NDVI from equation (4). NDVI is regarded as a positive indicator of the physical environment.

LAND COVER/LAND USE

In order to understand the urban surface characteristics of the study area, the CORINE land cover 2000 (abbreviated as CLC00) database for Greece is used (*source: Corine land cover, Greece, Hellenic Ministry for the Environment, Physical Planning & Public Works, 2004*). CLC00 is a geographic land cover/land use database produced by the European Environment Agency, encompassing many countries that define a pan-European region. Its development aimed at the establishment of a comprehensive quantitative land cover database, providing consistent information on land cover across Europe. CLC00 describes land cover (and partly land use) according to a nomenclature of 44 classes organized hierarchically in 3 levels of detail at a scale of 1:100 000 (xv). The database was made available in a vector based format projected into the Transverse Mercator projection. The geographical extent of this database corresponding to the metropolitan city of Athens is used in this research. For the study area, the following eight land cover/use classes are identified: (a) continuous urban fabric (b) discontinuous urban fabric (c) industrial/commercial and transport units (d) mineral extraction, dump and construction sites (e) green urban/leisure areas (f) agricultural areas (g) forests and semi-natural areas and (h) water bodies. Because industrial/commercial and transport units as well as mineral extraction, dump and construction sites are generally considered to be negative aspects of the physical environment, classes (c) and (d) are grouped into one class named as "urban use", which is regarded as a negative indicator of the physical environment and is then used in the measurement of the Athens quality of life index.

SOCIOECONOMIC VARIABLES

Socioeconomic variables such as population density (# inhabitants/km^2), unemployment rate (%), education level (expressed as the percentage of university and higher technical graduates) and median home value for the reference year 2006 (€/m^2) are used in this study in order to describe the living environment of Athens. All variables were obtained from the Greek census data (*source*: *General Secretariat of National Statistical Service of Greece, Hellenic Republic Ministry of Economy and Finance*) and were available at the municipality level, which was the best spatial resolution available. Socioeconomic data are incorporated into a GIS polygon layer depicting of the administrative boundaries of each municipality for the Athens prefecture and then, each variable is valued as either positive or negative. In this way, education level and median home value are regarded as positive indicators of the living environment, whereas population density and unemployment rate are regarded as negative ones.

QUALITY OF LIFE INDEX

Since quality of life is a measure of how well people feel about their environment, the values of each physical and socioeconomic variable are ranked by using a scale of 1 to 10 according to the degree of influence they have on quality of life. More specifically, the maximum and minimum value of each variable is defined and then each variable is classified into 10 levels applying an equal interval method. In the following, a rank score is assigned to each level depending on whether the variable is regarded as a positive or negative indicator of the environment. For example, in the case of unemployment rate which is a negative indicator, high values are given low scores (< 5), whereas low values are given high scores (> 5). Then, all ranked variables are overlaid in a GIS and quality of life scores for each municipality consisting the metropolitan Athens are obtained by employing an aggregating score approach. Finally, classification of the quality of life index is performed using five classes to describe the quality of life: low, fair, moderate, good and high.

RESULTS AND CONCLUSIONS

Figure 2 shows the quality of life map derived for the 48 municipalities of metropolitan Athens. It is found that good and high levels of life quality are associated with municipalities that extend to the eastward and north-eastward directions from the central municipality of Athens, whereas fair and low levels of life quality are observed at the central and western municipalities of the metropolitan Athens area. The municipalities of Psichiko, Filothei, Kifissia and Ekali exhibit a high quality of life, with Ekali reporting the highest life quality score. Their high life quality can be attributed to all variables, since all have a high contribution to the final score. On the other hand, the following six municipalities are characterized by a low quality of life: Peristeri, Aigaleo, Agia Varvara, Tauros, Kallithea and Moschato. Among them, Tauros has the lowest life quality score. The poor physical environment along with the low education level can be held responsible for the low quality of life of these municipalities.

It must be mentioned that this study is a first diagnostic study performed by using selected socioeconomic and physical variables. Although the results of the study are satisfactory, in the sense that the aggregated index applied can effectively provide an evaluation measurement and mapping of the urban life quality, the use of more data such as household finances, acceptability to services, personal security, environmental quality, etc. would favour the more accurate determination of the quality of life level for a study area and contribute to the overall life quality assessment. Considering this, a future study using more input variables and an extended series of satellite images is planned.

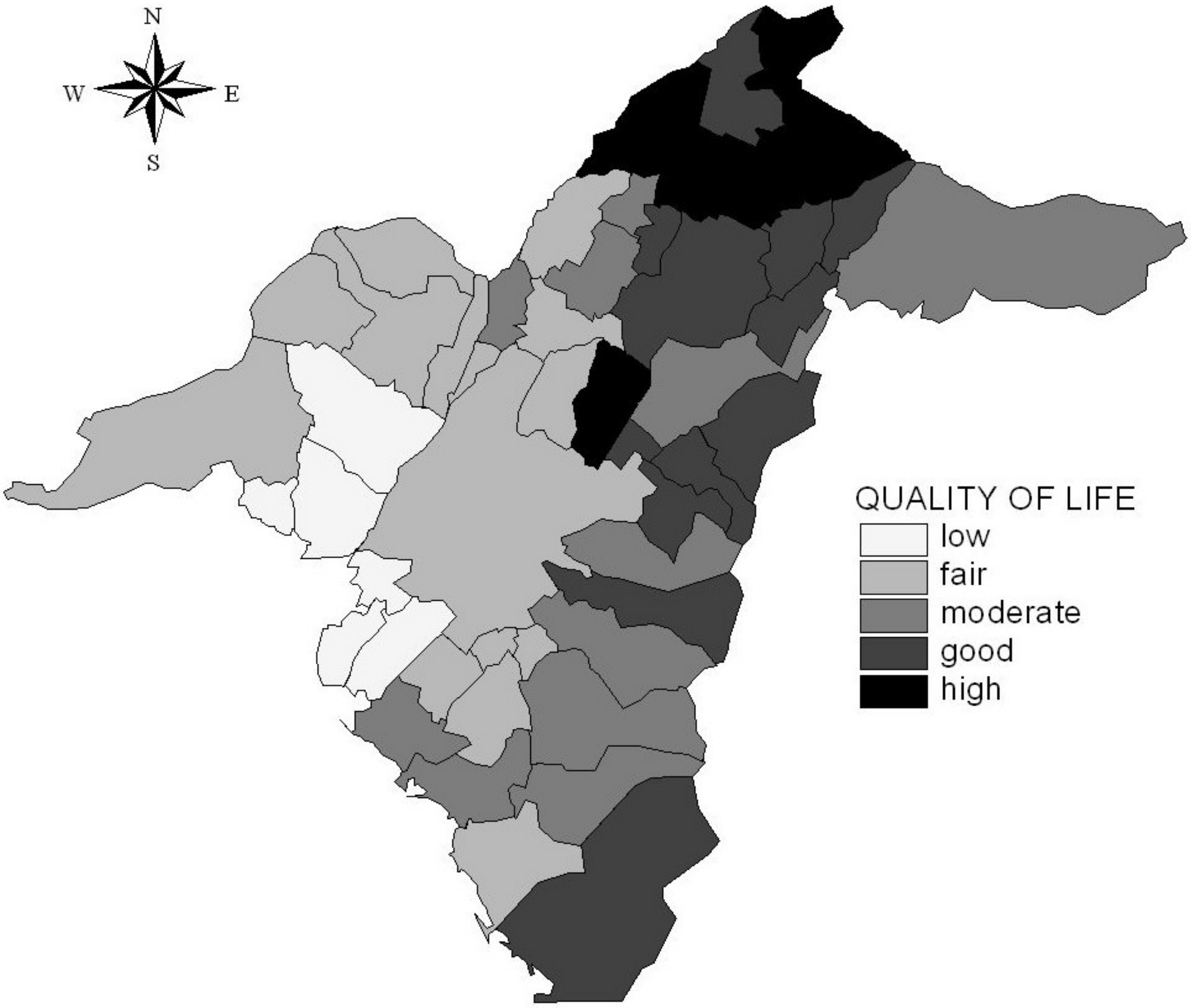

Figure 2. Quality of life map for the metropolitan Athens area.

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