GAZİOSMANPAŞA BİLİMSEL ARAŞTIRMA DERGİSİ (GBAD)
Gaziosmanpasa Journal of Scientific Research
ISSN: 2146-8168
http://dergipark.gov.tr/gbad
*Araştırma Makalesi (Research Article)*

Cilt/Volume : 6
Sayı/Number: Özel (ISMSIT2017)
Yıl/Year: 2017
Sayı/Pages: 81-93

*Alınış tarihi (Received)*: 16.10.2017
*Kabul tarihi (Accepted)*: 26.12.2017

*Baş editor/Editors-in-Chief*: *Ebubekir ALTUNTAŞ*
*Alan editörü/Area Editor*: *Turgut ÖZSEVEN / Bülent TURAN*

# Analysis of the Relationship Between Urban Area and Development by Using Nighttime Images and Socio-Economic Indicators

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**ABSTRACT:** The purpose of the present study was to reveal the urban areas in cities in Turkey in 2010 and to investigate the relationship of these urban areas with the socio-economic indicators of the urban areas using GIS technologies. In the study, the nighttime images belonging to the year of 2010 were used to determine the urban areas. The study included three parts. In the first part, the nighttime images of 2010 were classified with the cell-based classification method to reveal the urban areas. In the second part, based on the Principle Components Analysis, the development order of the cities was obtained using the socio-economic indicators of the cities. In the last part, the relationship between the urban areas and the socio-economic development was examined and explained using correlation and multi-linear regression analysis. Besides these analyses, Moran I analysis was conducted to determine the spatial distribution and auto-correlation of the variables.
According to the urban area results, the cities with the largest urban area were located in the western and middle parts of the country. Similarly, the cities with higher development levels were more in the western part, while the underdeveloped cities were mostly located in the eastern and southeastern parts of the country. In addition, the results of the multi-linear regression analysis regarding the relationship between the socio-economic indicators and urban areas revealed that the indicator group with the highest rate of explaining the urban area included the demographic and economic indicators. The results of Moran I demonstrated that both socio-economic development and urban area had spatial auto-correlation.

***Keywords –*** *Moran I, Multiple Linear Regression, Night Time Images, Socio-Economic Development, Urban Areas*

**ÖZET:** Çalışmamızda Türkiye'deki illerin 2010 yılına kentsel alanlarının ortaya çıkarılması ve bu kentsel alanların kentin Sosyo-ekonomik göstergelerle ilişkinin CBS teknolojileri kullanılarak irdelenmesi amaçlanmıştır. Çalışmamızda kentsel alanların tespit edilmesinde 2010 yılına ait gece görüntüleri kullanılmıştır. Çalışmamız üç kısımdan oluşmaktadır. İlk kısımda 2010 yılına ait gece görüntüleri hücre tabanlı sınıflandırma yöntemine göre sınıflandırılarak kentsel alanlar ortaya çıkarılmıştır. İkinci kısımda Temel Bileşenler Analizine göre illere ait Sosyo-ekonomik göstergeler kullanılarak illerin gelişmişlik sıralaması elde edilmiştir. Son kısımda ise kentsel alanlar ile Sosyo-ekonomik gelişmişlik arasındaki ilişki korelasyon ve çoklu doğrusal regresyon analizi yapılarak açıklanmaya çalışılmıştır. Bu analizlerin yanı sıra değişkenlerin mekânsal dağılımını ve otokorelasyonunun tespiti için Moran I analizi yapılmıştır. Kentsel alan sonuçlarına göre en büyük kentsel alana sahip illerin ülkenin batı ve orta kısmında yer aldıkları görülmüştür. Benzer şekilde gelişmişlik sıralaması üst sıradaki iller ülkenin batı kesimine doğru yoğunlaşırken, az gelişmiş illerin doğu ve güneydoğu bölgelerinde olduğu sonucu ortaya çıkmıştır. Sosyo-ekonomik göstergeler ve kentsel alan arasındaki çoklu doğrusal regresyon analizi sonuçlarına göre kentsel alanı en yüksek açıklama oranına sahip gösterge grubunun demografik ve mali göstergeler olduğu ortaya çıkmıştır. Moran I sonuçlarında hem Sosyo-ekonomik gelişmişliğin hem de kentsel alanın mekânsal otokorelasyon içinde olduğu ortaya çıkmıştır.

***Anahtar Kelimeler:*** *Moran I, Çoklu Doğrusal Regresyon, ,Gece Görüntüleri, Kentsel Alan*

## 1. Introduction

In our country, where there is intense migration from villages to cities, there has been an observable increase in urban areas. This increase in urban areas inevitably has effects on social, cultural and economic characteristics of a city. Therefore, the present study will not only try to reveal urban areas and to determine the related socio-economic development but also explain how these two factors influence one another.

Urban growth is a concept influenced by several different variables. Though there are various definitions made by a number of researchers, urban development can be defined in general as the expansion of a city to outer its areas. (Bruegmann, 2005; Yue and et al., 2016). While a city expands to its outer parts, several problems such as destruction of agricultural lands and lack of a sufficient transportation network are encountered especially in cases of lack of coordinated growth. The primary data source to be used to suggest solutions to these problems that occur due to uncontrolled growth is the one providing remote sensing data (Chen and et al., 2016; Wu and et al., 2015; You, 2016)

Another phenomenon that occurs with urban development is socio-economic development, which is shaped with the influence of social, economic and political variables (Dinçer and et al. 2003). Such factors influential on socio-economic development as population density, energy consumption and socio-economic activities play an important role in the change in cities. Therefore, socio-economic development and urban development are two concepts which occur simultaneously and influence one another (Johnson, 2001; Montgomery, 2008; Shukla and Parikh, 1992).

Use of the intensity of light in the DMSP-OLS nighttime images helped obtain information about urbanization activities on local and global basis. In related studies, the enlightenment value was associated with a number of variables. While Sutton and et al., (2001) examined the relationship between the brightness value and population, Doll and et al., (2006) ve Ghosh and et al., (2010) examined the relationship between the brightness value and Gross Domestic Product. In addition, Zhang and Seto (2011) predicted future development based on the relationship between the brightness value and population.

## 2. Material and Method

The study included three phases. In the first phase, the urban areas in city centers were revealed using the nighttime images belonging to the year of 2010. In the second phase, the socio-economic development order was determined for the cities. In the last phase, the relationship between the urban areas and the socio-economic development using statistical methods (Figure 1).

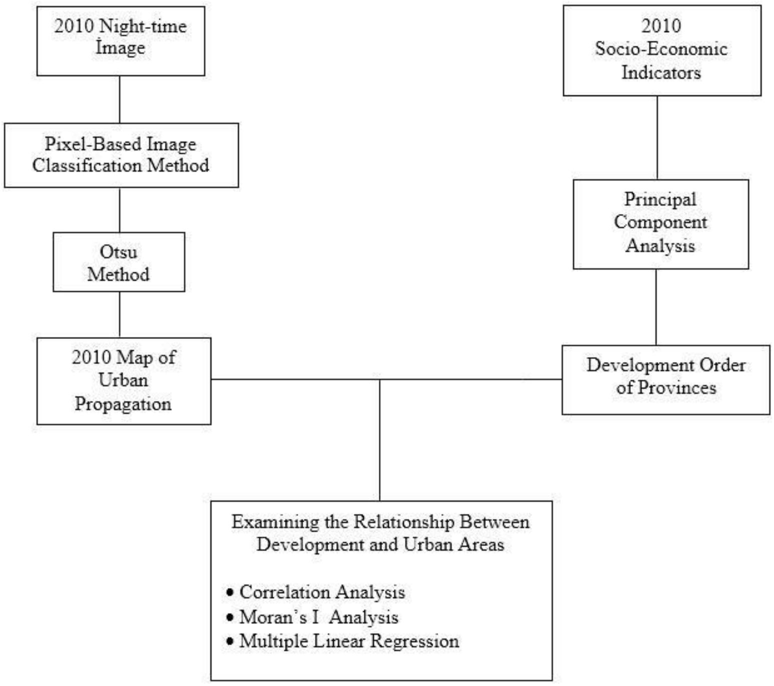


***Figure 1.*** Study flow chart

## 2.1 Determining the Urban Areas via the Nighttime Images

While determining the urban areas, the nighttime images of the year 2010 were used. The DMSP-OLS (Defense Meteorological Satellite Program- Operational Linescan System) nighttime image is a recently common data set formed by the US Air Forces Meteorological Satellite Program. The temporal series of the products is available on the website of http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html, and the nighttime images for the study area were obtained free of charge via this website.

Each cell in the nighttime images has a resolution of 30x30 arcsecond (or 0.86 $km^2$ on the Equator), and the images cover the area on Earth between the longitudes of +180 and -180 and between the latitudes of -65 and +75. The nighttime images were formed as a composite presentation of two satellite images taken at cloudless nights. Each composite set was labeled by satellite name and year.

In the study, while determining the urban areas, the Otsu method, a method of cell-based image analysis, was used. The Otsu method is a method of determining threshold which allows determining the most appropriate threshold value to be used while degrading a grey-level image to two groups. The name of the Otsu method originates from Nobuyuki Otsu, who developed this method. While using this method, the image is assumed to include two color classes: background and foreground. Following this, for all the threshold values, the in-class variance value for these two color classes is calculated. The threshold value which causes this value to be lowest is the optimum threshold value. When the in-class variance value is minimum, the variance value between classes is maximum. Since calculation of the between-classes variance value requires a less procedure, calculation of between-classes variance for the background and foreground pixel classes allows obtaining results faster while transforming the method into codes. The method runs on grey-level images, and it only considers the frequency of the colors in the images. For this reason, first, the color histogram of the image is calculated, and all the procedures are carried out on the histogram sequence (Atasoy, 2017).

## 2.2 The Development Order Based on Socio-Economic Indicators

Socio-economic development refers to development in social and economic aspects. Therefore, besides quantitative development in economy, the qualitative development is taken into account as well. This concept covers not only the changes in the socio-cultural structure but also such changes and developments in the economic structure as per capita income, increase in production or income and productivity in economy. In other words, socio-economic development includes numerical and structural changes together (Özdemir and Altıparmak 2005; Sakarya and İbişoğlu 2015).

In order to reflect the socio-economic development correctly, the variables related to the cities were kept consistent and comprehensive within the framework of reliability. For the purpose of determining the socio-economic development of the cities, the indicators belonging to the 81 cities were obtained via the database of Turkish Statistical Institute (Table 1). While determining and grouping the indicators, the indicators in the studies of SEGE 2003 and 2011 carried out by the Ministry of Development.

***Table 1.*** Indicator Groups Used for the Developments of the Cities

| | |
|---|---|
| Demographic Indicators | 6 indicators |
| Employment Indicators | 3 indicators |
| Educational Indicators | 4 indicators |
| Health Indicators | 4 indicators |
| Agricultural Indicators | 3 indicators |
| Financial Indicators | 8 indicators |
| Life Quality Indicators | 9 indicators |
| **Total** | **37 indicators** |

In several studies, for the socio-economic development order, use of the Principle Components analysis, which produces correct results and which allows conducting significance tests on results, is quite widespread among researchers (Dinçer and et al., 1996; Das, 1999; Cahil and Nicolas, 2001; Dinçer and et al., 2003; Wang, 2007; Yıldız and et al., 2010; Tuncer, 2013).

In general, Principle Component Analysis (PCA) used to remove the dependence between variables or to reduce the dimensions is an analysis itself, and it is also used as a data preparation technique for other analyses. In multi-variate statistical analysis, a certain number of variables (features) (p) for a certain number of individuals (n) are examined. The fact that most of these variables are related to each other and that the number of variables (p) is quite high makes it difficult to do various evaluations. In such cases, PCA is the most important technique applied (Tatlıdil, 1992).

## 2.3 Relationship between Urban Area and Socio-Economic Development Order

In this part of the study, related statistical analyses were conducted to reveal the relationship between urban areas and socio-economic development.

Besides these analyses, Moran I analysis was applied to determine the spatial distribution and autocorrelation for the variables in the area.

In order to reveal whether there was a relationship between development and urban areas and to examine the degree and direction of the relationship if any, correlation analysis was used. Pearson correlation coefficient obtained via correlation analysis is the coefficient determining the size and direction of the relationship between independent variables. This coefficient takes a value between (-1) and (+1). Positive values refer to a direct linear relationship, while negative values refer to an inverse linear relationship (Şıklar , 2000).

For the purpose of determining the influence of socio-economic indicators and the ratio of their explaining the urban areas, multi-linear regression analysis was conducted. In this analysis, urban area was taken as the independent variable, and socio-economic indicators were taken as the dependent variable. The purpose of applying the multi-linear regression analysis was to reveal the size and direction of the influence of the socio-economic indicators on urban area and to determine the related ratio of explaining the urban area. Regression analysis is generally defined as "finding connections to explain the relationship between the dependent variable and the independent variables with the help of mathematical models." These connections are referred to as regression equations. In multi-linear regression analysis, the researcher has certain goals as follows:
* Calculating the multi-explanatory coefficient ($R^2$) and the multi-correlation coefficient (r) between the dependent variable and the independent variable,
* Predicting the dependent variable values with the help of easily-accessible independent variables,
* Determining which of the independent variables have more influence and which of them have less influence on the dependent variable,
* Making prediction of coefficient in relation to the other variables,
The prediction equation for multi-regression to achieve these purposes is,

$$y=a + b_1 x_2 + b_2 x_2 + b_3 x_3 + \dots\dots + b_p x_p$$

where y refers to dependent variable; x refers to independent variable; b refers to the regression coefficients for the independent variables; and a refers to the constant or the prediction point showing the point where the regression line cuts y axis (Alpar, 2014).

Using the method of Moran I, the relationship of the development coefficients of the cities and the sizes of the urban areas with the spatial auto-correlation was examined. Moran I analysis is a common method used to reveal whether the feature examined has a spatial correlation or not. The relationship between the concept of spatial auto-correlation and geography was first mentioned by Tobler (1970) as follows: "All things have a relationship with one another, but objects close to each other have closer relationships when compared to distant objects." It is also regarded as the process of positive or negative evaluation of the features of spatial objects based on distance. Spatial auto-correlation is referred to in three different ways; Positive correlation demonstrates that objects with similar features are grouped together; negative correlation shows that objects without any similar features are grouped together; and according to zero correlation, objects are grouped together based on spatial effects (O'Sullivan and Unwin 2002).

## 3. Results and Discussion

In the study, using the Otsu method, a cell-based classification method, the nighttime images were classified. In the application carried out with Matlab, the grey-level image was divided into two groups. The consequent image was processed using ArcGIS, and the urban area map was obtained (Figure 2). Table 2 presents both the hectare and percentage of the total urban area in Turkey.

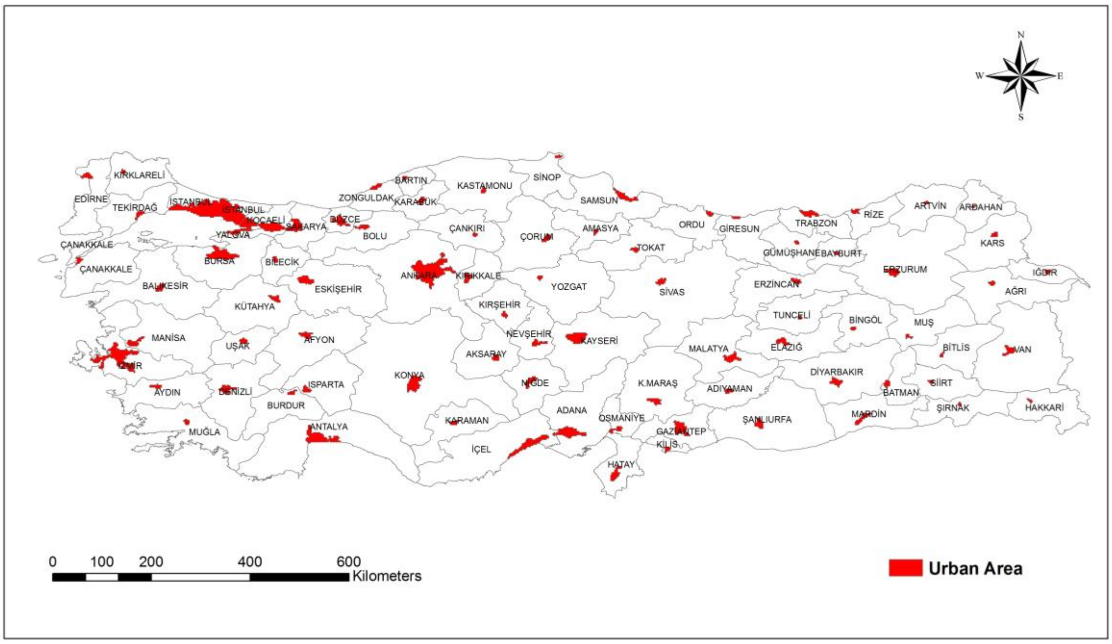


***Figure 2.*** Urban area map of the cities for the year 2010

***Table 2.*** Urban areas in Turkey for the nighttime images of the year 2010 according to Otsu method (Hectare and percentage of total urban area in Turkey)

| Order | Province | % | Hectare |
|---|---|---|---|
| **1** | İSTANBUL | 13.48 | 288306.41 |
| **2** | ANKARA | 8.78 | 187753.48 |
| **3** | İZMİR | 7.14 | 152750.24 |
| **4** | KOCAELİ | 4.55 | 97364.90 |
| **5** | ANTALYA | 4.02 | 86023.31 |
| | | | |
| **77** | HAKKARİ | 0.20 | 4299.27 |
| **78** | TUNCELİ | 0.20 | 4194.40 |
| **79** | ARTVİN | 0.19 | 4074.62 |
| **80** | ŞIRNAK | 0.16 | 3339.80 |
| **81** | ARDAHAN | 0.13 | 2722.18 |

In order to determine the development levels of the cities, 37 socio-economic indicators were used. The package software of SPSS was used to conduct Principle Components Analysis for the socio-economic indicators, and the development order of the cities was obtained (Table 3). Also, the spatial development map was formed to better analyze the development order for the whole country of Turkey (Figure 3).

***Table 3.*** Socio-economic development order of the cities in Turkey for the year 2010

| **Order** | **City** | **Index Value** |
|---|---|---|
| **1** | İSTANBUL | 3.20 |
| **2** | ANKARA | 2.46 |
| **3** | İZMİR | 1.76 |
| **4** | ANTALYA | 1.50 |
| **5** | KOCAELİ | 1.47 |
| | | |
| **77** | SİİRT | -1.79 |
| **78** | BİTLİS | -1.81 |
| **79** | MUŞ | -2.03 |
| **80** | ŞIRNAK | -2.05 |
| **81** | HAKKARİ | -2.14 |

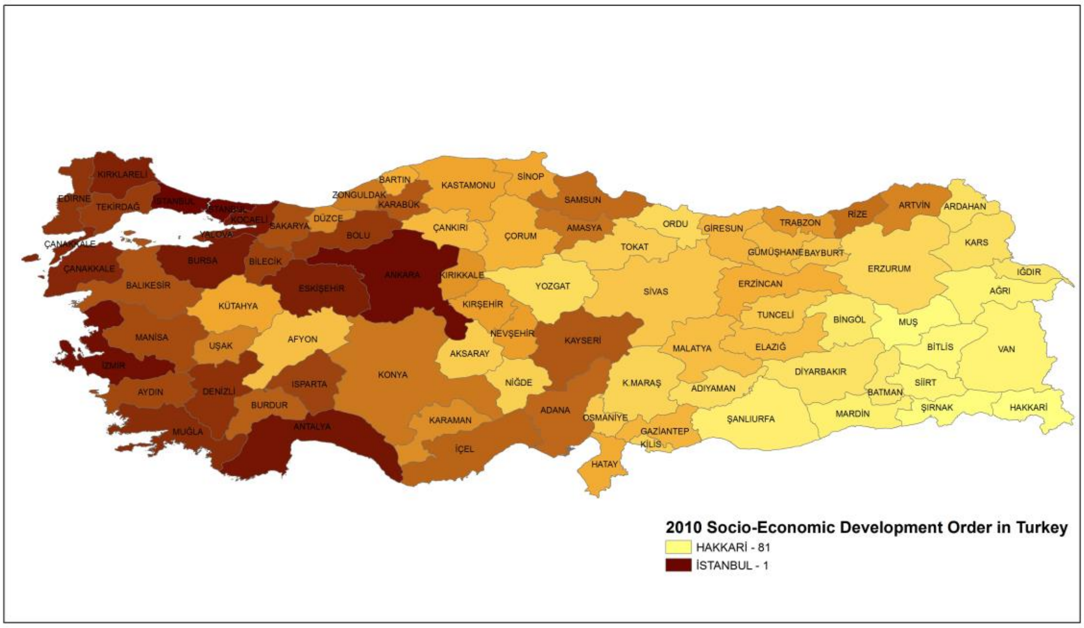


***Figure 3.*** Development map for the year 2010

When the socio-economic development order and the urban area results are examined, it is seen that the cities located in the western part of the country were in upper positions in terms of both urban are and development level. For this reason, in order to determine the relationship between these two results, correlation analysis was conducted. According to the correlation analysis, Pearson correlation coefficient was found to be 0.629 in relation to the urban are and development.

In order to determine whether the results regarding the socio-economic development and urban area had spatial auto-correlation or not, Moran I analysis was conducted. The results revealed whether the feature examined in Moran I analysis demonstrated a change based on the place (Table 4).

***Table 4.*** Moran I results regarding development and urban area

| | Development Coefficients | Urban Areas |
|---|---|---|
| Moran's Index | 0.729 | 0.332 |
| Z-score | 8.882 | 4.128 |
| P-value | 0.000 | 0.000 |

For the purpose of explaining the relationship between urban area and socio-economic development in a different way, multi-linear regression analysis was applied. In this analysis, urban areas represent the dependent variable, while the socio-economic indicators represented the independent variable. The socio-economic indicators were taken in groups in the multi-linear regression analysis (demographic, employment, education, health, agriculture, finance, quality of life). The indicator groups were subjected to regression analysis, and the indicators demonstrating 50% resemblance to one another were not included in multi-linear regression analysis. All the results of the multi-linear regression analysis conducted for a total of seven indicators were not included here due to the restricted total page number for the manuscript. Therefore, the values regarding the indicators of demographic, finance and quality of life, which all demonstrated significant results in the regression analysis on urban area are presented in Table 5, 6 and 7.

***Table 5.*** Multi-linear regression results for the urban and demographic indicators

| | **Multi-Linear Regression** | | | |
|---|---|---|---|---|
| **Indicator Number** | **B** | **Beta** | **Sig.** | **Indicators** |
| **1** | 0.155 | 0.374 | 0.000 | Total population |
| **2** | 0.166 | 0.400 | 0.000 | Ratio of urbanization |
| **3** | 0.084 | 0.201 | 0.016 | Yearly average population growth rate (per thousand) |
| **6** | -0.046 | -0.111 | 0.131 | Average household size |
| **Resquare** | 0.663 | | | |

***Table 6.*** Multi-linear regression results for the urban area and financial indicators

| | **Multi-Linear Regression** | | | |
|---|---|---|---|---|
| **Indicator Number** | **B** | **Beta** | **Sig.** | **Indicators** |
| **22** | 0.120 | 0.289 | 0.000 | Per capita export (dollar) |
| **23** | -0.028 | -0.068 | 0.531 | Gross Domestic Product per capita (TL) |
| **24** | 0.180 | 0.432 | 0.000 | Gross Domestic Product for current prices according to the economic territories: Agriculture |
| **27** | 0.188 | 0.453 | 0.000 | Total house sales |
| **28** | 0.059 | 0.142 | 0.116 | Industrial electric consumption per capita (KWh) |
| **R square** | 0.694 | | | |

***Table 7.*** Multi-linear regression results regarding the urban area and quality of life

| | Multi-Linear Regression | | | |
|---|---|---|---|---|
| **Indicator Number** | **B** | **Beta** | **Sig.** | **Indicators** |
| **30** | 0.233 | 0.561 | 0.000 | Household electric consumption per capita |
| **31** | -0.081 | -0.194 | 0.107 | Number of deaths in traffic accidents in a one-million population |
| **32** | -0.072 | -0.172 | 0.162 | Number of the wounded in traffic accidents in a one-million population |
| **33** | -0.081 | -0.194 | 0.031 | Frequency of suicide (per thousand) |
| **34** | -0.021 | -0.051 | 0.621 | Ratio of the municipality population receiving sewage system services to the total municipality population (%) |
| **35** | 0.118 | 0.285 | 0.008 | Ratio of the population receiving water supply network services to the total municipality population (%) |
| **36** | -0.054 | -0.131 | 0.179 | Yearly average sulfur dioxide (SO2) (µg/m3) |
| **37** | 0.072 | 0.172 | 0.084 | Yearly average particulate matter (PM10) (µg/m3) |
| **R square** | 0.488 | | | |

It is seen the first three cities in terms of the urban area results are Istanbul, Ankara and Izmir. These three cities are the biggest ones with respect to the population sizes of the cities in Turkey. When the spatial distribution map for the urban area values (Fig.4) is examined, it is seen that the cities located in the middle and western parts of the country had higher urban area values and that those in the eastern part had lower urban area values. Therefore, it would be better to evaluate the urban area results in accordance with the development level rather than considering the urban areas alone. In the development order results, which were similar to the urban area results, the biggest cities in the country ranked the top in the development order list. The cities with the lowest development level were found to be located in the eastern and southeastern parts of the country. Based on the fact that the urban area values and the development order values revealed similar results, it could be stated that there is a relationship between these two concepts. For this reason, Pearson correlation coefficient of 0.629 obtained via the correlation analysis statistically proves that urban area and development demonstrates 50% resemblance to each other.

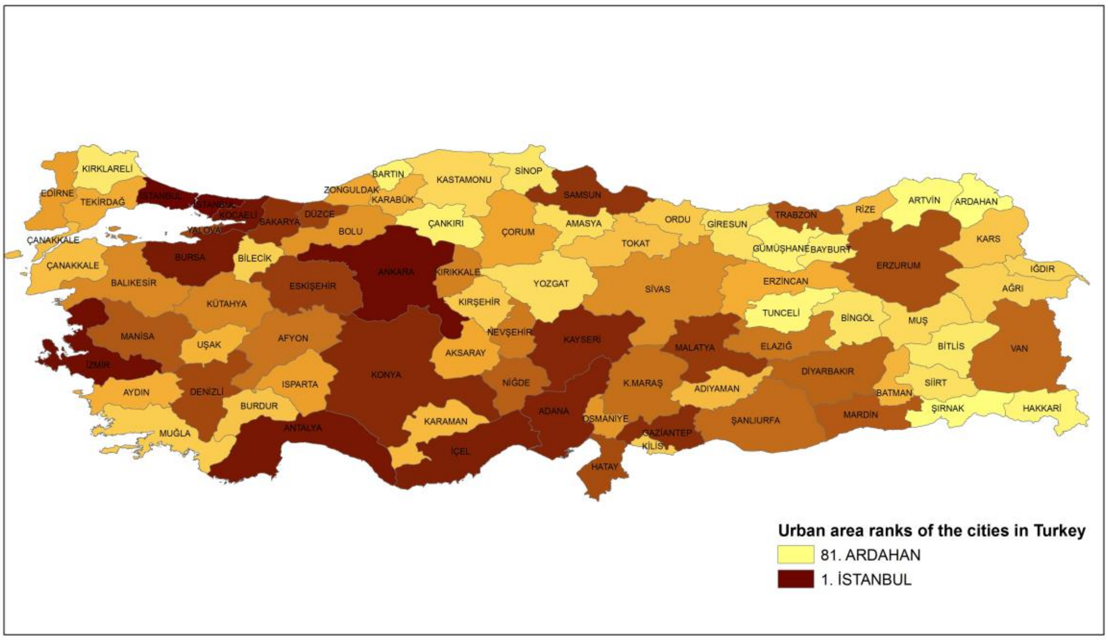


***Figure 4.*** Spatial urban area map for the year 2010

The fact that urban area and development have similar distributions with respect to the regions in the country reminds the question of whether these two results have spatial correlation or not. Therefore, Moran I spatial correlation analysis was conducted, and the results demonstrated that development z-score was 8.882 and that the urban are z-score was 4.128. When the z-scores were examined according to the range values in Figure 5 to see whether there was clustering or not, it was seen that the two results had spatial correlation. This shows that values with similar features were together; in other words, it could be stated that the cities with higher development levels are close to each other and that the cities with lower development levels are close to each other. The same is also true for the urban area. Cities with larger urban areas are close to each other, and cities with smaller urban area are close to one another.

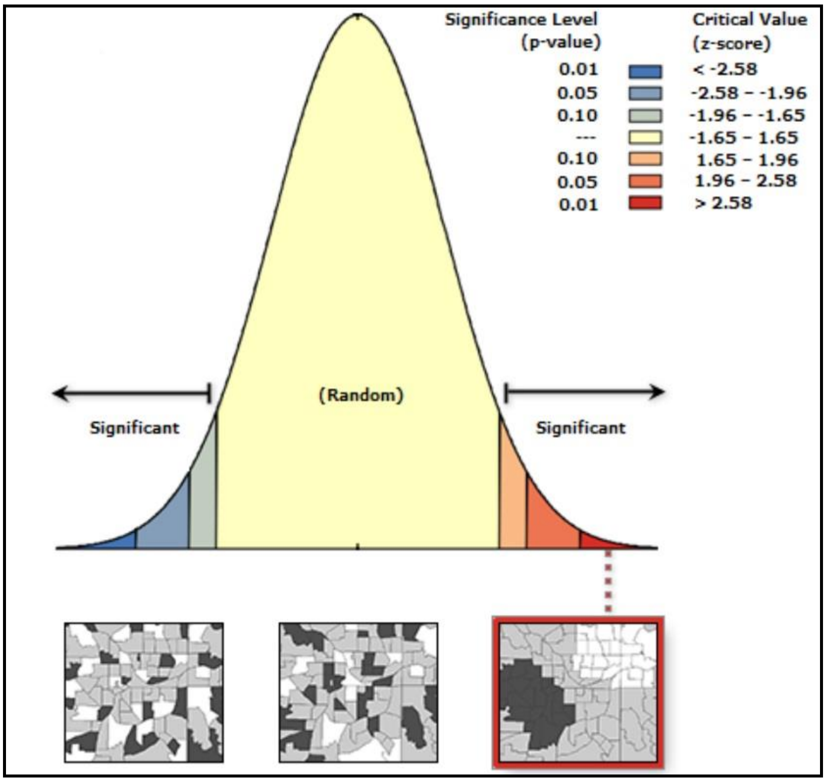


***Figure 5.*** Moran I analysis report

In the study, multi-linear regression analysis was conducted. In this analysis, urban area was taken as the dependent variable, and the indicator groups were taken as the independent variable. When the results of the multi-linear regression analysis conducted with the demographic indicators and urban area are examined, it is seen that there are indicators with positive and negative relationships with urban area. While "total population", "ratio of urbanization" and "yearly average population growth" demonstrate a positive relationship with urban area, "average household size" has a negative relationship with urban area. It is seen that urban area increases in line with the growth of population and with the accompanying urbanization. According to another value, the R square, the socio-economic indicators explained urban area with an approximate ratio of 66%.

The most striking multi-linear regression result regarding the financial indicators the influence of the agricultural gross national product on urban area. According to this result, there was a positive relationship between the influence of agricultural production on gross national product and urban area. A similar positive relationship was also seen for the indicators of "total house sale" and "per capita export". In addition, though the total electric consumption and per capita gross national product demonstrated a negative relationship, it was not significant considering the related significance value. According to the R square value, the financial indicators explained urban area with a ratio of about 70%.

The indicators of quality of life constitute a new indicator group used for the measurement of socio-economic development. The results of the multi-linear regression analysis revealed that the indicators demonstrating a positive relationship with urban area were "household electric consumption per capita" and "Ratio of the population receiving water supply network services to the total municipality population". In addition, urban area had a positive relationship with the indicator of "frequency of suicide (per thousand)". The other indicator results were not found significant with respect to the significance value.

## 4. Conclusion

In the present study, the purpose was to reveal the urban areas in Turkey for the year of 2010 and to examine the relationships between urban areas and socio-economic development. According to the Otsu Method, a cell-based image classification method, the urban areas were revealed. Socio-economic development was determined with the Principle Components Analysis using the indicators in seven different indicator groups. Both urban area and socio-economic development results revealed that the middle and western parts of the country were in higher positions in the rank list in terms of both development and urban area size when compared to the eastern and southeastern parts of the country. According to the correlation analysis conducted to examine the relationship between urban area and socio-economic development, two results were similar to each other with a ratio of 50%. Besides this analysis, the results of Moran I analysis revealed that both urban area and socio-economic development had spatial auto-correlation. As for the multi-linear regression analysis applied to the urban area and indicators, it was found that urban area was explained by the demographic indicators with a ratio of 66, by the financial indicators with a ratio of 69% and by the indicators of quality of life with a ratio of 49%.

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