

Land Use Land Cover Changes in Response to Urban Sprawl within North-West Anatolia, Turkey

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Abstract—In the present study, an attempt was made to state the Land Use Land Cover (LULC) transformation over three decades around the urban regions of Balıkesir, Bursa, and Çanakkale provincial centers (PCs) in Turkey. Landsat imageries acquired in 1984, 1999 and 2014 were used to determine the LULC change. Images were classified using the supervised classification technique and five main LULC classes were considered including forest (F), agricultural land (A), residential area (urban) - bare soil (R-B), water surface (W), and other (O). Change detection analyses were conducted for 1984-1999 and 1999-2014, and the results were evaluated. Conversions of LULC types to R-B class were investigated. In addition, population changes (1985-2014) were assessed depending on census data, the relations between population and the urban areas were stated, and future populations and urban area needs were forecasted for 2030. The results of LULC analysis indicated that urban areas, which are covered under R-B class, were expanded in all PCs. During 1984-1999 R-B class within Balıkesir, Bursa and Çanakkale PCs were found to have increased by 7.1%, 8.4%, and 2.9%, respectively. The trend continued in the 1999-2014 term and the increment percentages reached to 15.7%, 15.5%, and 10.2% at the end of 30-year period (1984-2014). Furthermore, since A class in all provinces was found to be the principal contributor for the R-B class, urban sprawl lead to the loss of agricultural lands. Moreover, the areas of R-B classes were highly correlated with population within all PCs ($R^2 > 0.992$). Depending on this situation, both future populations and R-B class areas were forecasted. The estimated values of increase in the R-B class areas for Balıkesir, Bursa, and Çanakkale PCs were 1,586 ha, 7,999 ha and 854 ha, respectively. Due to this fact, the forecasted values for 2,030 are 7,838 ha, 27,866, and 2,486 ha for Balıkesir, Bursa, and Çanakkale, and thus, 7.7%, 8.2%, and 9.7% more R-B class areas are expected to locate in PCs in respect to the same order.

Keywords—Landsat, LULC change, population, urban sprawl.

I. INTRODUCTION

HUMANS have considerable effects on earth surface by changing it depending on their needs. One of the most observable changes is known to be urbanization process. This process is mostly driven by population growth and economic development, and reported to have many impacts on the environment [1]. Moreover, latest reports designate that in the

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This study was based on preliminary results of Melis Inalpulat's PhD. Thesis.

near future, the world is going to be faced with the widest urban expansion wave in history [2], [3]. Due to these facts, the influences of urban expansion on ecosystems have been a major concern among researchers and planners working in various disciplines, including both natural and social sciences.

Since LULC changes are mostly driven by the preferences of mankind rather than by natural events within the area, changes in the LULC dynamic are considered to be a good indicator to assess the influences of urban expansion. On the other hand, since the land patterns affected by socio-economic factors [1], understanding the interactions is an insufficient effort and it should be supported by predictions of future land status, which are required for planning and management strategies. However, in many developing countries, as well as Turkey, researchers maybe confronted by challenges including the lack of historical LULC inventories. In this context, remote sensing technology provides rapid, reliable and relatively economic tools for these issues at local, regional and even global scales.

The present study aimed to quantify the LULC changes and amounts of agricultural lands which were converted to R-B classes between the 1984-1999 and 1999-2014 periods, and to forecast future status based on the population in three main settlements (Balıkesir, Bursa, and Çanakkale PCs) of North-West Anatolia (NWA), Turkey. To achieve these aims, multi-temporal Landsat images and census data were employed in the study.

II. MATERIALS AND METHODS

A. Study Sites

The study was conducted in urban areas in main provincial centers (PCs) (Balıkesir, Bursa and Çanakkale PCs) located in North-West Anatolia, Turkey (Figs. 1 (a) and (b)). In the present study, the North-West Anatolia (NWA) term is restricted by the watershed boundaries of the South-Marmara, North-Aegean, and the Susurluk watersheds (Fig. 1 (b)). The extent of each study site is identified depending on the urban area regions (hereafter Urban Growth Boundary; UGB), and the LULC changes around the UGBs were investigated. The UGBs were determined via visual image interpretation. The considered area of Balıkesir PC was 20,560 ha (Fig. 2), Bursa PC was 95,288 ha (Fig. 3), and Çanakkale was 9,325 ha (Fig. 4).

B. LULC Status and Change

The LULC changes were assessed using Landsat imageries acquired for the summer seasons of 1984 (TM), 1999 (ETM), and 2014 (OLI). The images were downloaded from the

USGS website [4]. The Landsat scene path/row numbers of the images were 180/32, 181/32 according to the World Reference System (WRS). Visible, NIR, and SWIR bands (6-

band) of each of the images were stacked, and isolated depending on the present UGBs (Figs. 2-4).

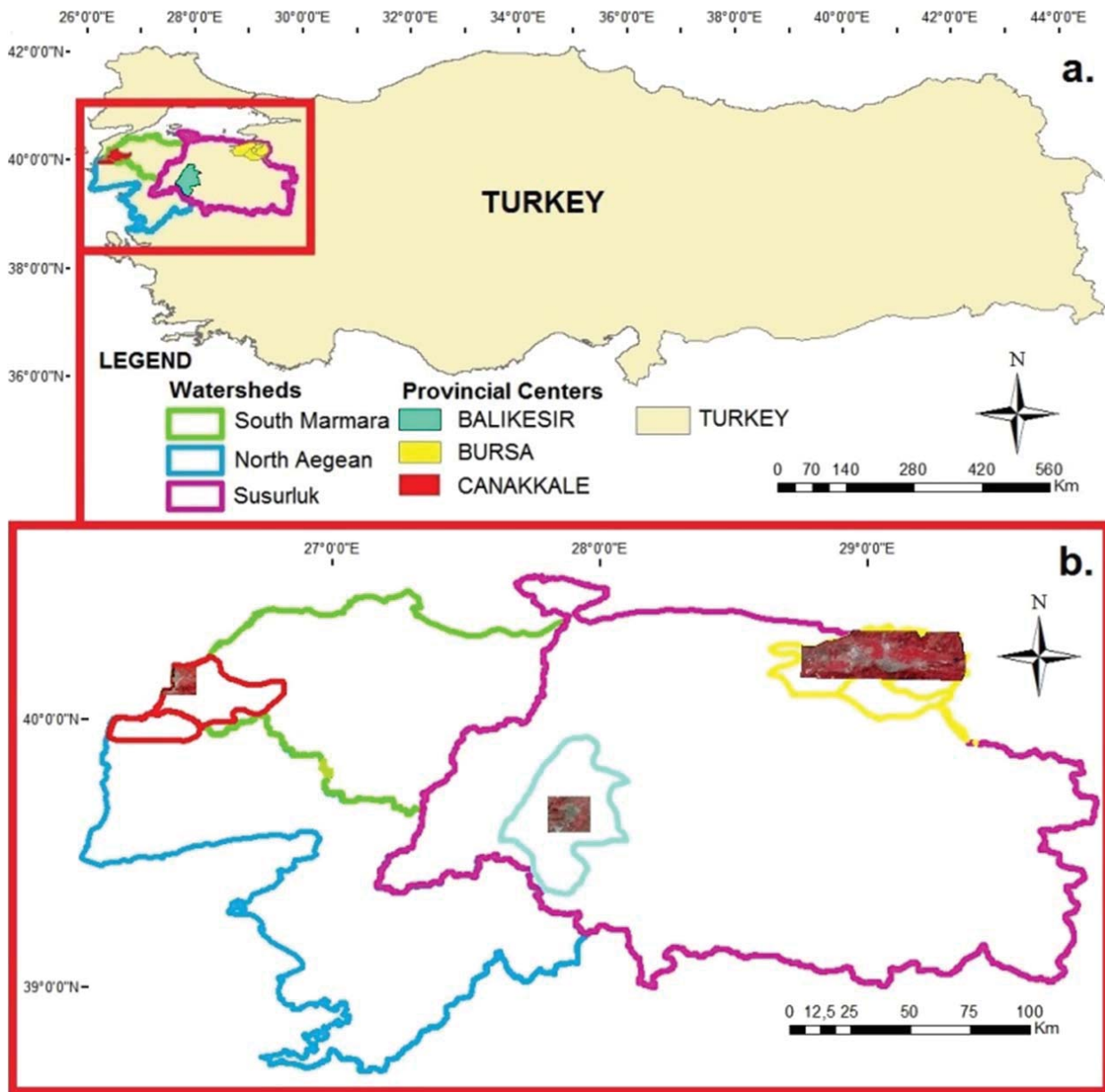


Fig. 1 Locations of study sites within Turkey (a), NWA (b)

The supervised classification maximum likelihood algorithm was adopted to develop the LULC maps. Five main LULC classes were considered; forest (F), agricultural land (A), residential area (urban) - bare soil (R-B), water surface (W), and other (O). However, there were no water collection units within the Balıkesir PC site in the present study. Due to this fact, the water surface (W) class was disregarded for this

PC.

Subsequent to the image classification, neighborhood analyses (3×3) were applied. General changes and the conversion from all LULC types to urban (R-B class) were evaluated in terms of 1984-1999, and 1999-2014. All image analysis was conducted in Erdas Imagine (2011) software.

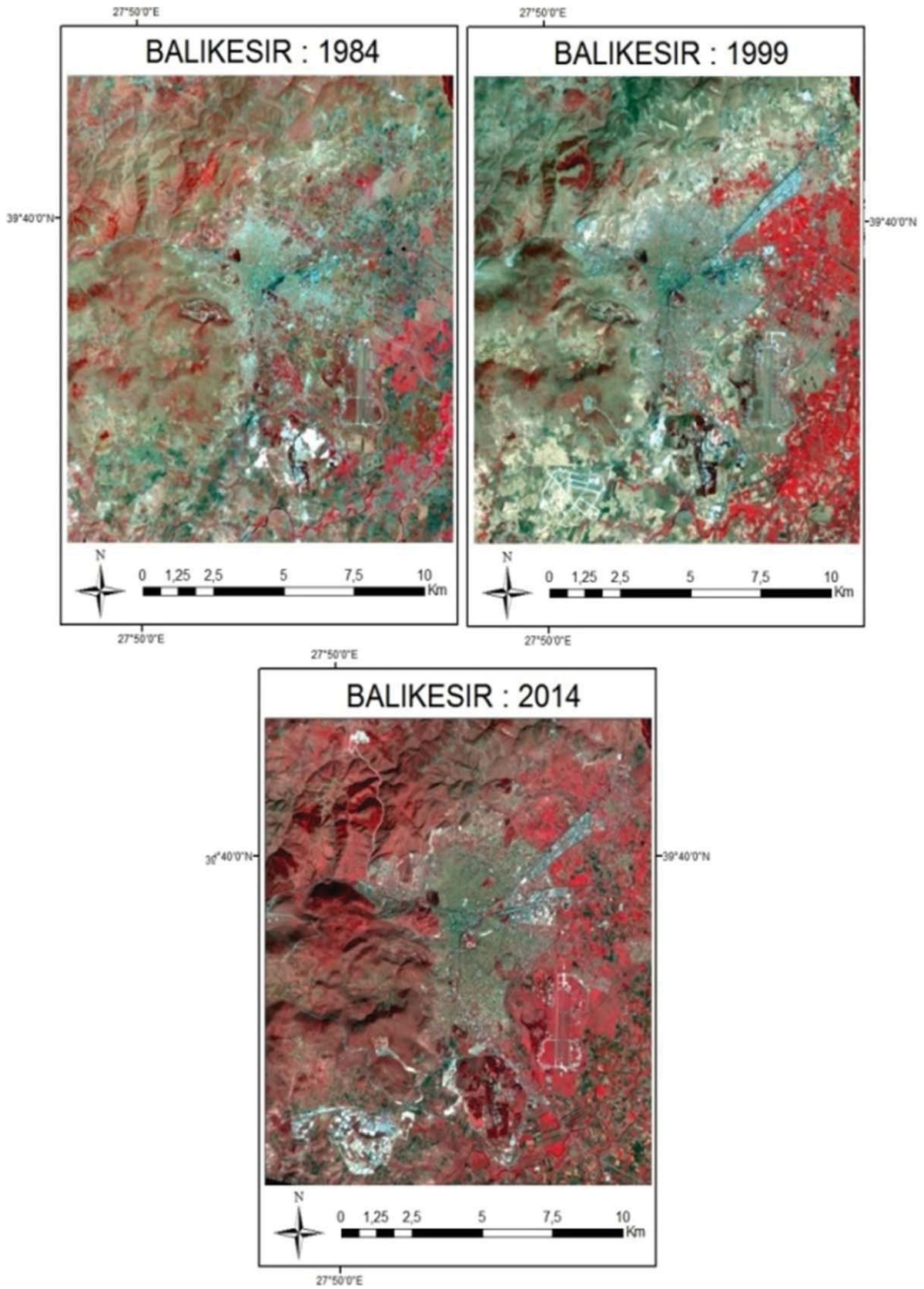


Fig. 2 Landsat images covering study site of Balıkesir PC

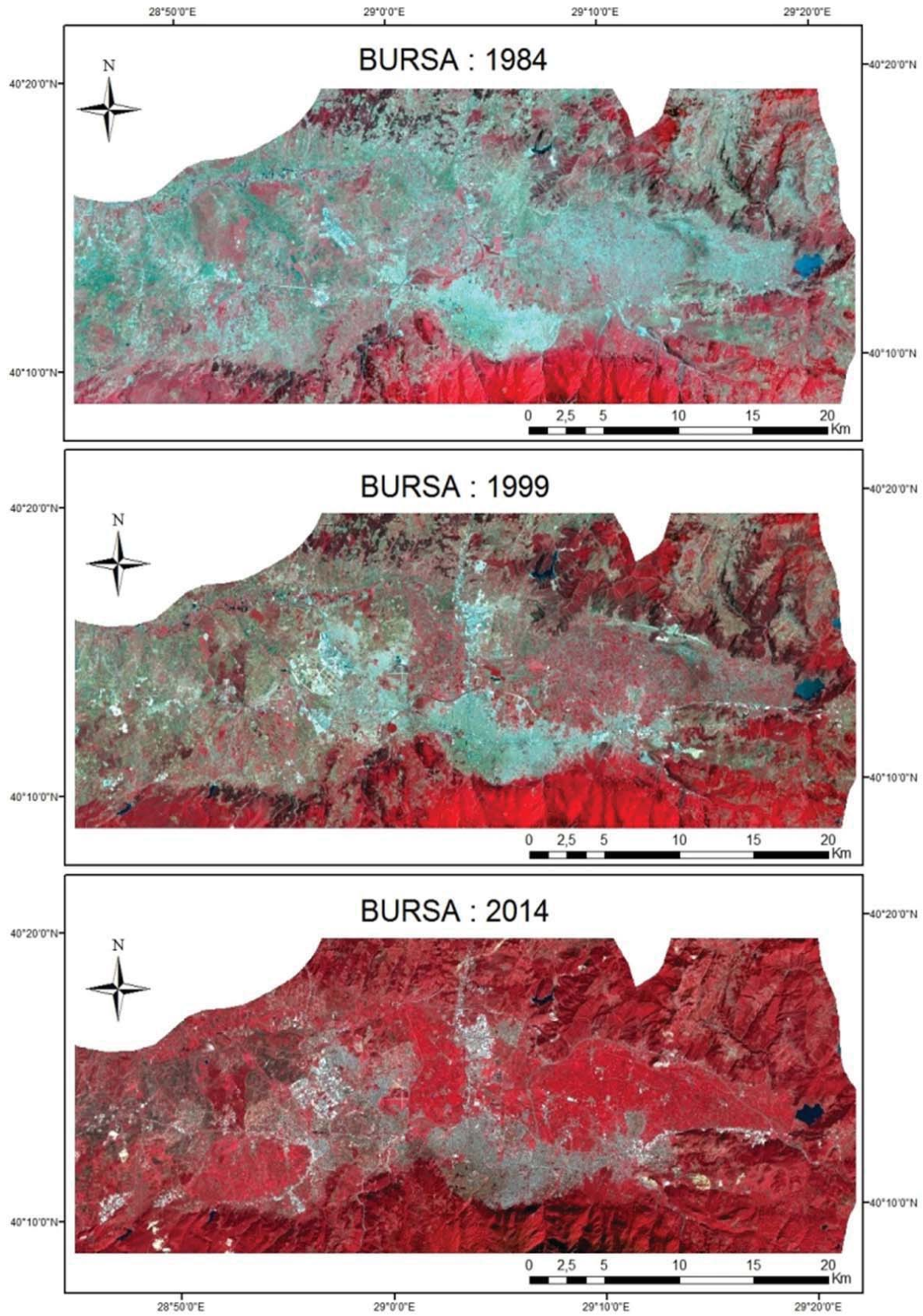


Fig. 3 Landsat images covering study site of Bursa PC

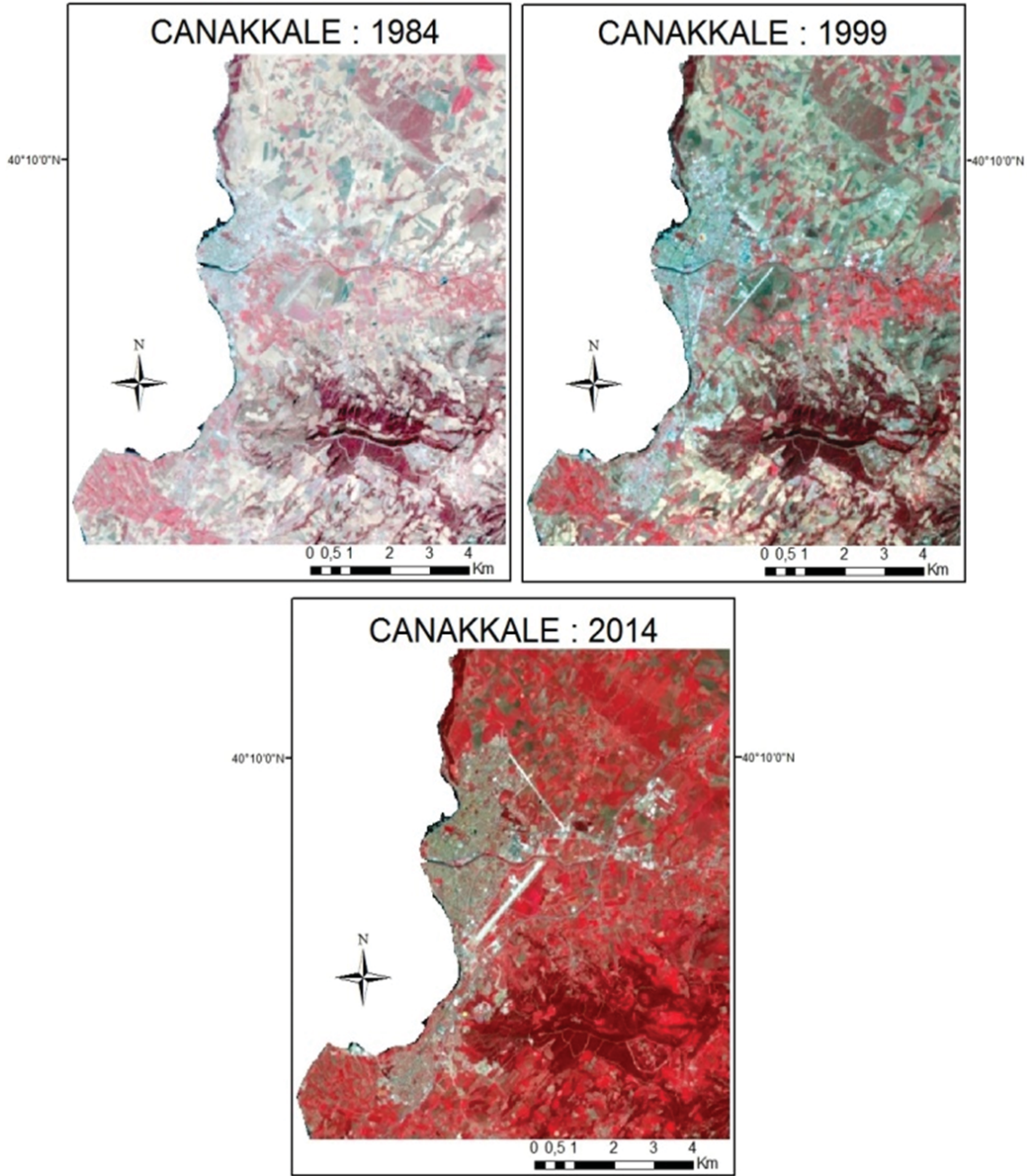


Fig. 4 Landsat images covering study site of Çanakkale PC

C. Population Trends, LULC Relations and 2030 Forecasts

Census data of PCs were downloaded from the TurkStat (Turkish Statistical Institute) website [5].

Census data were collected every five years until 1990. As a result of political decisions, the followed census was recorded in 2000. Thus, 1985 and 2000 census data were used instead, due to the lack of data available for 1984 and 1999. However, adoption of the Address Based Population Registration System (ABPRS) provided annual population records after 2007. Therefore 2007-2015 population records are available for each

year.

Trends in population were investigated, and 2030 populations for the province centers were forecast depending on the trends of the past decade. Future (2030) land demands for urban areas were predicted depending on the relations between LULC and population for each 15-year period (MS Excel). The formulas for the forecasts are given (1)-(3):

$$ax + b \tag{1}$$

$$a = \bar{y} - b\bar{x} \tag{2}$$

$$b = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2} \quad (3)$$

where, x and y are the sample means of known x,y.

III. RESULTS AND DISCUSSIONS

A. LULC Changes and Impacts of Urban Sprawl

The LULC maps of Balikesir, Bursa and Çanakkale are given in Figs. 5, 8, and 11, respectively. The areas of the LULC classes were given in Figs. 6, 9 and 10. As it can be seen, the most remarkable changes are the great deal of increases in the R-B classes. Thus, contributions of from all LULC classes to R-B class were examined to determine the urbanization effect on LULC (Figs. 7, 10 and 12). The conversion rates of each LULC type to the R-B class was investigated and summarized in Tables I-III.

B. Balikesir Provincial Center

The LULC maps for 1984, 1999, and 2014 Balikesir PC are given in Fig. 5. The areas of the LULC classes in percentages (%) were calculated from related the LULC maps and the results are plotted in Fig. 6, depending on temporal changes. Fig. 7 represents; a. the 1984 LULC status of the 2014 R-B areas, b. The 1999 LULC statuses of the 2014 R-B areas, and, c. the 2014 R-B areas. As mentioned before, the urban areas are covered under the R-B class. The conversion rates (%), which were calculated from Figs. 7 (a)-(c) in Erdas Imagine (2011) software, are given in Table I.

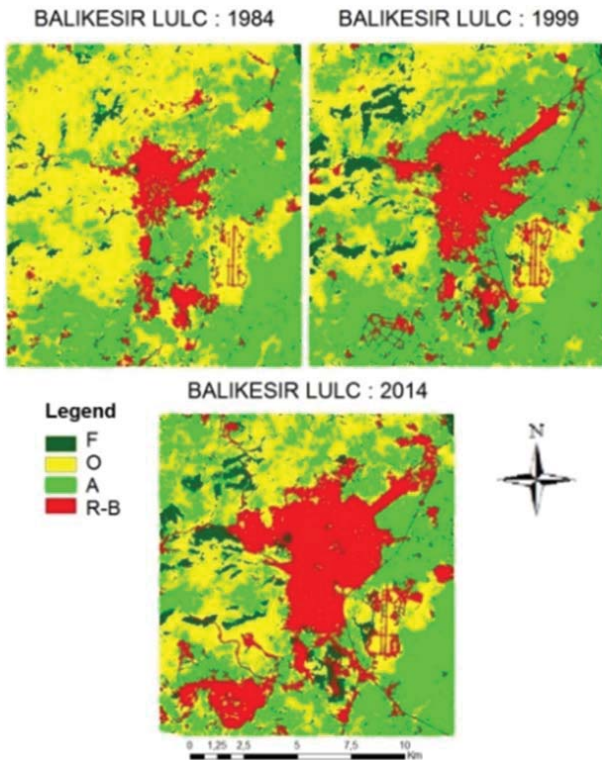


Fig. 5 LULC maps of Balikesir provincial center UGB

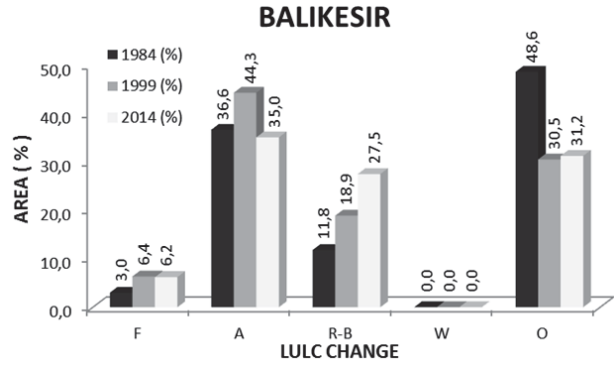


Fig. 6 Temporal changes in LULC types within Balikesir PC site

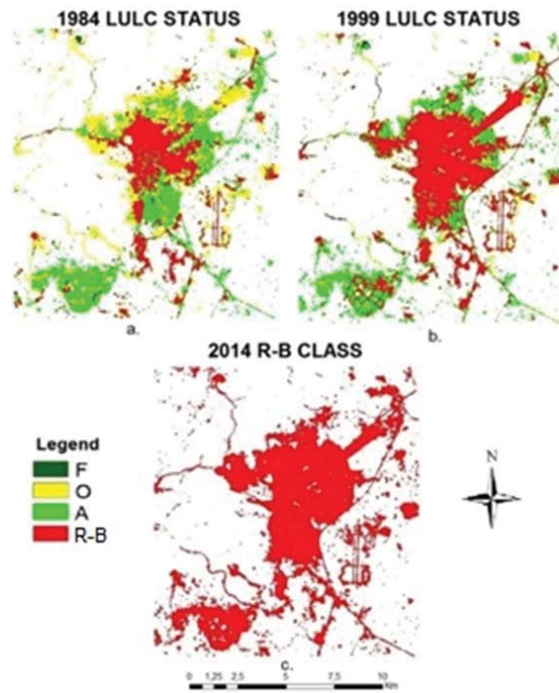


Fig. 7 LULC conversions to 2014 R-B class

TABLE I
TRANSFORM AMOUNTS (%) INTO R-B CLASS: BALIKESIR

1984 LULC Class	1999 R-B Class	1999 LULC Class	2014 R-B Class
F	0.36	F	1.27
A	29.46	A	32.85
R-B	43.51	R-B	57.81
O	26.67	O	8.07
Total	100	Total	100

According to Table I, 43.51% of the 1999 R-B areas belonged to the same class (R-B) in 1984. On the other hand, a comparable amount of 1999 R-B areas was converted from agricultural lands (29.46%), and other LULC types (26.67%). Although 57.81% of the 2014 R-B class was also R-B in 1999, a considerable part was transformed from agricultural lands to R-B areas (32.85%) over 15 years. Moreover, 8.07% of 2014 R-B areas transformed to the other class.

C. Bursa Provincial Center

The Bursa provincial center LULC maps are given in Fig. 8. The areas of the LULC classes in percentages (%) were calculated and given in Fig. 9. Fig. 10 represents; a. The 1984 LULC status of 2014 R-B areas, b. The 1999 LULC statuses of 2014 R-B areas, and c. The 2014 R-B areas. The conversions (%) are given in Table II.

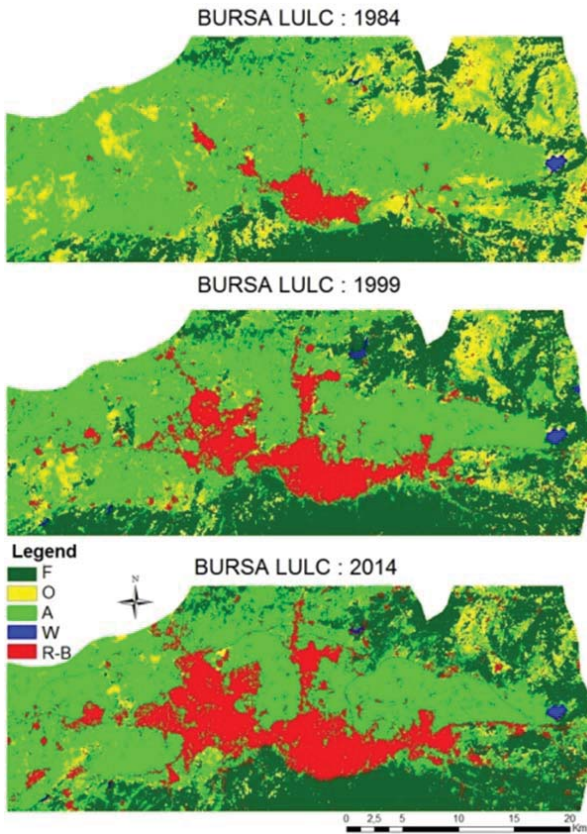


Fig. 8 LULC maps of Bursa PC site

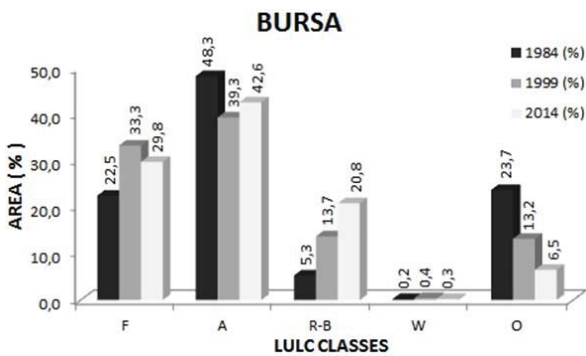


Fig. 9 Temporal changes in LULC types within Bursa PC

Table II indicated that 31.14% of the 1999 R-B areas were classified as also R-B in 1984. But 55.12% of the 1999 R-B class was found to be converted from agricultural lands, and 13.01% of the R-B areas were converted from other LULC types. The conversions of the water surfaces may be explained

by the transforming of rice paddies into the R-B class. When the 1999-2014 changes are considered, it was seen that 30.87% of R-B areas were converted from the A class, and 8.26% from the O class.

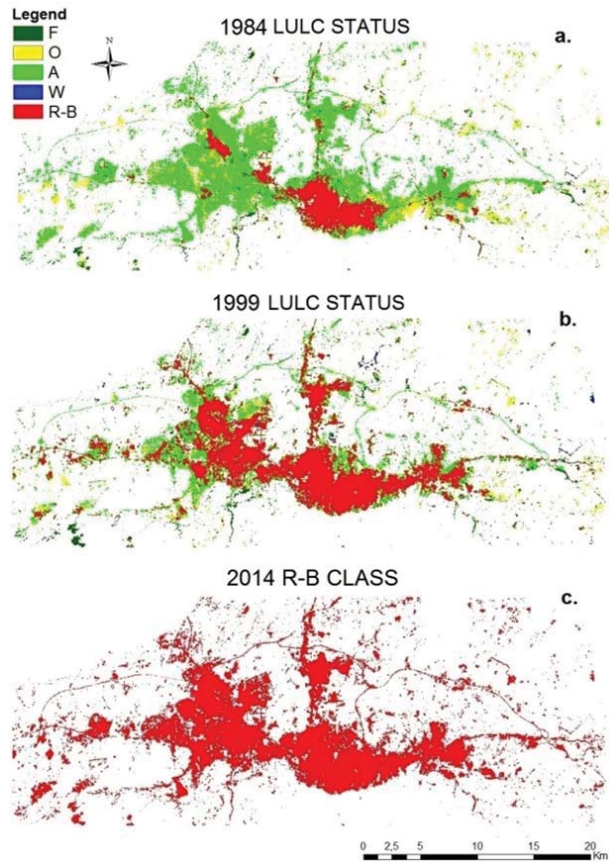


Fig. 10 LULC conversion to 2014 R-B class: Bursa

TABLE II
TRANSFORM AMOUNTS (%) INTO R-B CLASS: BURSA

1984 LULC Class	1999 R-B Class	1999 LULC Class	2014 R-B Class
F	0.72	F	5.36
A	55.12	A	30.87
R-B	31.14	R-B	54.97
W	0.01	W	0.54
O	13.01	O	8.26
Total	100	Total	100

D. Çanakkale Provincial Center

LULC maps of 1984, 1999, and 2014 Canakkale provincial center are given in Fig. 11, and Fig. 12 represents the areas (%) of LULC during the time period. Fig. 13 shows; a. The 1984 LULC status of 2014 R-B areas, b. The 1999 LULC statuses of 2014 R-B areas, and, c. The 2014 R-B areas. The conversions (%) are given in Table III.

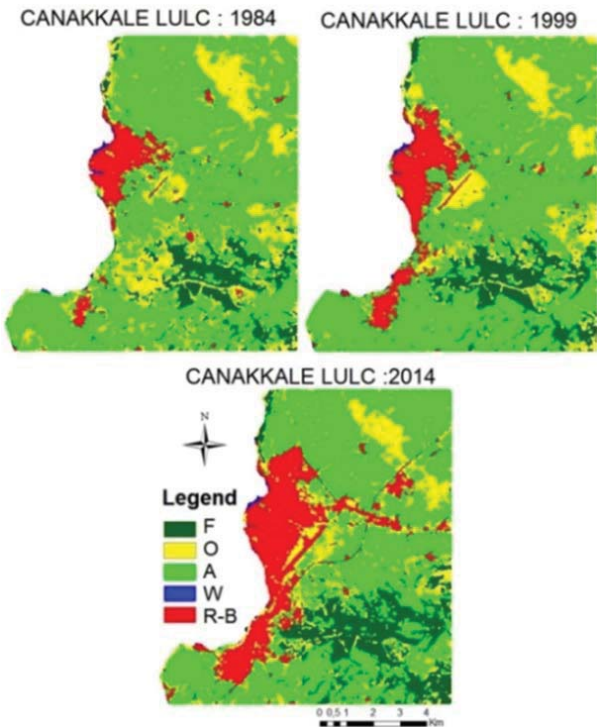


Fig. 11 LULC map of Çanakkale PC site

changes between 1999-2014 indicated that 37.50% of R-B areas were converted from A class, and 8.13% from O class.

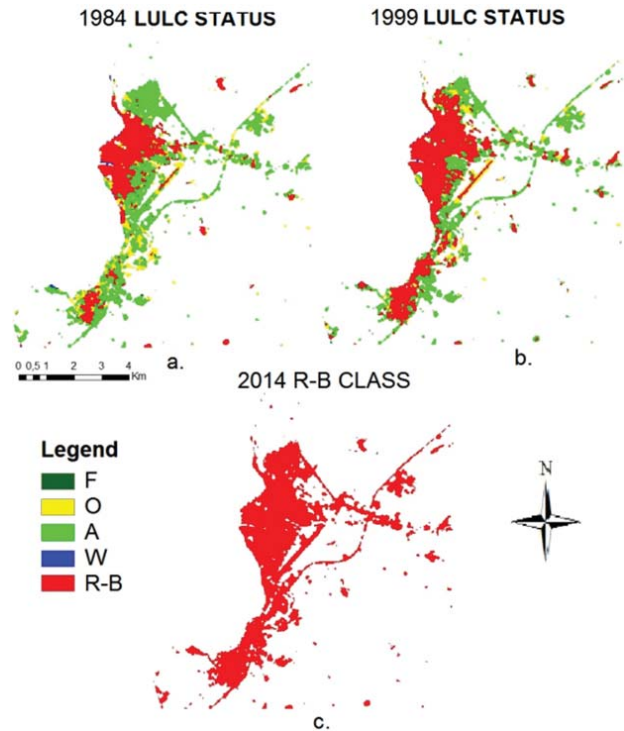


Fig. 13 LULC conversions to 2014 R-B class: Çanakkale

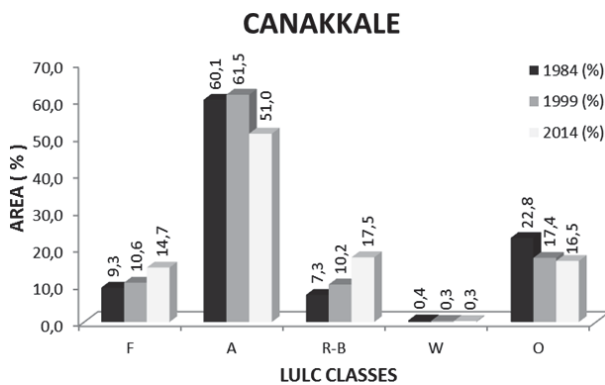


Fig. 12 Temporal changes in LULC types in Çanakkale PC

TABLE III
TRANSFORM AMOUNTS (%) INTO R-B CLASS: BURSA

1984 LULC Class	1999 R-B Class	1999 LULC Class	2014 R-B Class
F	0.18	F	0.05
A	31.15	A	37.50
R-B	56.03	R-B	53.57
W	0.50	W	0.35
O	12.15	O	8.13
Total	100	Total	100

Table III indicated that 56.03% of the 1999 R-B areas were classified as R-B in 1984. But the most significant contributor of the 1999 R-B class was found to be agricultural lands (31.15%). Moreover, 12.15% of R-B areas were converted from other LULC types. Consequently, assessment of the

E. Population Change and Forecasts

The population changes between 1985 and 2015, and forecasts for the year 2030 can be seen on Figs. 14, 15 and 16 for Balıkesir, Bursa, and Çanakkale provincial centers, respectively.

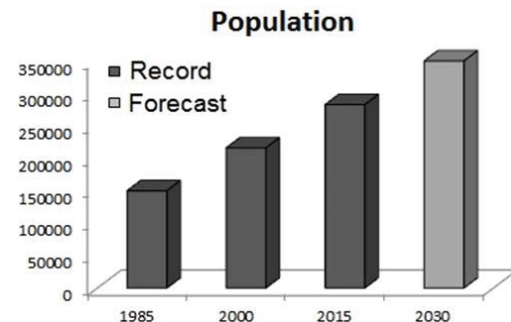


Fig. 14 Recorded and forecasted populations of Balıkesir PC

The populations of Balıkesir PC were recorded as 149,989, 215,936, and 282,657, respectively in 1985, 2000, and 2015. According to the forecast results, the population is estimated to reach almost 350,000 (Fig. 14).

The population data of Bursa PC recorded at 70,151 in 1985. It reached to 664,574 in 2000. The population growth trend continued, and over 1,190,000 people were recorded in the 2015 ABPRS. The forecast for 2030 suggests that the number of recorded people would reach nearly 1,800,000 in

Bursa PC (Fig. 15).

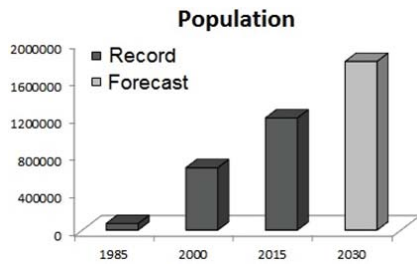


Fig. 15 Recorded and forecasted populations of Bursa PC

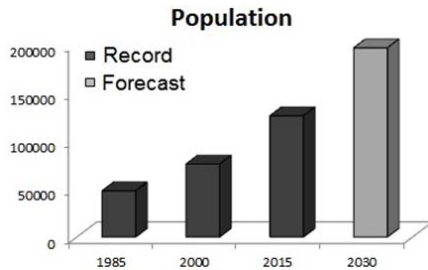


Fig. 16 Recorded and forecasted populations of Çanakkale PC

Çanakkale PC populations for 1985, 2000 and 2015 were respectively, 48,059, 75,810, and 122,613. If the tendency continues, the population is estimated to reach up to 200,000 people in 2030 (Fig. 16).

F. Forecasts of Future Urban Area Demands

The investigation of the relations between urban area (R-B class) and population showed high correlation for each province with R^2 s of over 0.99. Moreover, the total populations and urban areas showed also good correlations ($R^2 = 0.95$) (Fig. 17). Depending on this situation, future demands for urban areas in all provinces were forecasted. Estimations resulted in an increase of 7.7% in Balıkesir, 8.2% in Bursa, and 9.7% in Çanakkale PCs. This results designates that in 2030, 1,586 ha, 7,999 ha, and 854 ha of new lands for urban areas would be demanded by the growing population of Balıkesir, Bursa and Çanakkale, respectively. Therefore, by 2030, the urban areas in Balıkesir, Bursa, and Çanakkale PCs are expected to reach to 7,838 ha, 27,866 ha, and 2,486 ha, respectively. Fig. 18 represents the past trends of urban areas of each PC and the overall of study area, and the forecasted values.

IV. CONCLUSION

In present study, the LULC changes over three decades around the urban areas of Balıkesir, Bursa and Çanakkale PCs were determined. The results indicated that, A and O class areas are decreased in all PCs, while significant increments are observed in areas of the R-B classes. In addition, 1984 and 1999 LULC statuses of the 2014 R-B areas were evaluated to state the impacts of urban sprawl on LULC changes. It was seen that A and O class areas decreased against increasing urban areas.

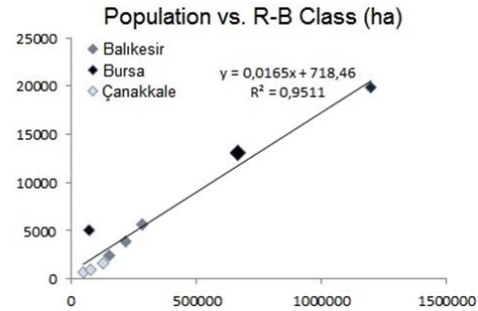


Fig. 17 Relations between population and urban areas in whole study area

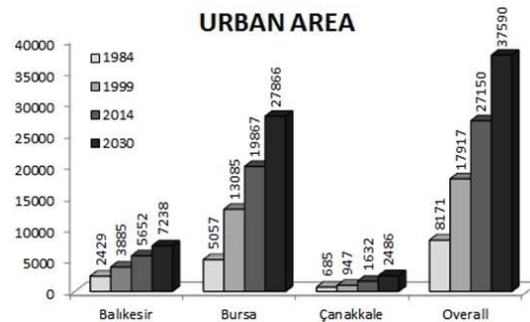


Fig. 18 Urban areas in hectares in 1984, 1999, 2014 LULC maps, and forecasts for 2030

Moreover, relations of the PCs populations and urban areas are assessed, future populations, and future land demands for urban expansions are forecasted for 2030. According to results, 1,586 ha, 7,999 ha, and 854 ha of new lands are expected to be required for urban sprawl in Balıkesir, Bursa, and Çanakkale PCs. This situation will lead to 7.7%, 8.2%, and 9.7% more urban areas within the current study sites. In consequence, agricultural lands are progressively decreased due to urban sprawl in each study site. The urban sprawl trend may cause continuous loss of agricultural lands in the future. To prevent the loss of fertile lands against ongoing expansion of urban areas, land suitability analyses are strongly advocated for the determination of urban-proper lands without causing agricultural land abandonment. A current effort is continuing to simulate a future LULC map of study sites to overcome problems relating to inappropriate use of lands within the selected area.

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