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Article

Assessing the Correlation between Land Cover Conversion and Temporal Climate Change—A Pilot Study in Coastal Mediterranean City, Fethiye, Turkey

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Abstract: The rapid growth and expansion of urbanized landscapes in cities has resulted in an increase in air temperature and has lowered the bioclimatic comfort levels in urban landscapes. Recent studies to estimate the climatic response of urban landscape conversion have mostly examined the relationship between land use/land cover (LULC) change and land surface temperature (LST) data collected using advanced remote sensing (RS) techniques instead of atmospheric temperature. In this respect, four decadal Landsat images from the 1980s were used to investigate the impact of landscape transformation on atmospheric temperature. The mean and average minimum and maximum monthly air temperature datasets were used in the analysis. The CORINE (Coordination of Information on Environment) index was used to determine LULC diversity in an urban development boundary and urban periphery. Consequently, clustered LULC change values for the last three decades were integrated with decadal air temperature anomalies. The findings revealed an important relationship between monthly mean air temperature and land changes over recent decades, which resulted in an increase in urban fabric land use, deforestation land cover changes and conversion of permanent crop fields to artificial green houses for earlier vegetable production; the R-sqr values for these regressions were 97.7%, 88.5% and 90.6% respectively. On the other hand, the most important increasing temperature trends were obtained for the average monthly minimum air temperature, which supports the global warming concerns of the IPCC (Intergovernmental Panel on Climate Change) and related studies, which have concluded that an increased nighttime temperature results in urban heat islands (UHIs). The results should be used to support better urban landscape plans and architectural designs to improve human thermal comfort for sustainable urban life in Mediterranean cities. Street geometry and orientation to wind breeze, the Height/Width H/W ratio of buildings, and sizes of open and green spaces should be examined carefully in urban planning and design for climate adaptation.

Keywords: air temperature; LULC change; CORINE index; RS; sustainable urbanization; climate change

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1. Introduction

Land use refers to the human activities of developing and decreasing natural landscape resources. Agricultural, forestry, residential and industrial lands represent different land use types. Human activities, such as deforestation, expansion of artificial use of non-agricultural vegetated areas and croplands, grassland degradation, urbanization and other large-scale land uses change the natural quality of land cover. According to the Intergovernmental Panel on Climate Change (IPCC) [1], these activities may eventually result in an average air temperature increase of 4 °C by the year 2100. This will change the physical characteristics of the land surface and will affect the land-atmosphere energy interaction [2,3]. Urbanization and deforestation cause an increase in albedo, with a consequent increase in atmospheric temperatures, which will affect the thermal comfort of buildings and city life [4,5].

Urbanization transforms the natural landscape to constructional land cover such as buildings, roads and other artificial surfaces, which affects the quality of urban ecosystems [6]. The considerable changes associated with land use and land cover (LULC) lead to urban heat islands (UHIs). Urban temperatures are 2–5 °C higher than those in rural ecosystems [7]. The center of the city becomes warmer than its periphery, which produces a heat island over the city [8]. Urban development may change the urban landscape structures and urban thermal environment. Temporal changes in urban ecosystems force city planning and building design decision makers to design comfortable and sustainable urban environments [9–12].

The most commonly used index in landscape diversity, *i.e.*, the CORINE (Coordination of Information on Environment) index, is a spatial data base that allows landscape diversity indicators to be computed and comparisons among European regions to be established [13–15].

The latest studies that examined the effect of LULC changes on land surface temperature (LST) using remote sensing (RS) [16–19] indicate positive correlations with impervious surfaces. Some studies have estimated the relationship between the surface temperature and vegetation abundance of the urban ecosystem [20,21]. The results revealed a negative correlation between land surface temperature and vegetation index (NDVI) and the cooling effect of green areas. Studies on statistical relationships between measured atmospheric temperature and LULC using RS are limited (e.g., [22–26]). The most obvious and latest results that were obtained in [27,28] indicated the relationship between air temperature and LULC detection.

In this study, commonly used climatic parameters such as air temperature, relative humidity, precipitation and wind direction indicated positive and negative trends during the period of observation for Fethiye city in the Mediterranean basin. The most important increasing trend was obtained for the air temperature dataset as an important indicator of climate change for the study area. The mean and average maximum and minimum monthly air temperature datasets were evaluated decadaly, and the mean annual anomalies of each decade with monthly anomalies were integrated with decadal LULC change values. Four decadal Landsat TM/ETM+ images from the 1980s were used to investigate the impact of LULC change on air temperature, according to the CORINE index. The findings indicate an important correlation between the increasing temperature trend and the urban landscape development in built-up areas of residential and touristic buildings, deforestation, and conversion of permanent crop lands to artificial surfaces.

2. Study Area and Methodology

2.1. Study Area

Fethiye city, which is located in the south-west coastal part of Turkey (36°3′N and 29°7′E), has a worldwide reputation for improving tourism welfare. Modern Fethiye is located on the site of the ancient city of Telmessos, which was the most important city of Lycia, with a recorded history starting in the 5th century BC. The Babadag and Mendos mountains (approximately 2000 m) cover the city in the south while small mountains (600 m) cover the residential location in the north. The Mediterranean Sea is to the West and there is a narrowing large plain to the East. The observation site was in an open plain until the 1980s, which was then covered by buildings for residence and asphalt roads (Figure 1).

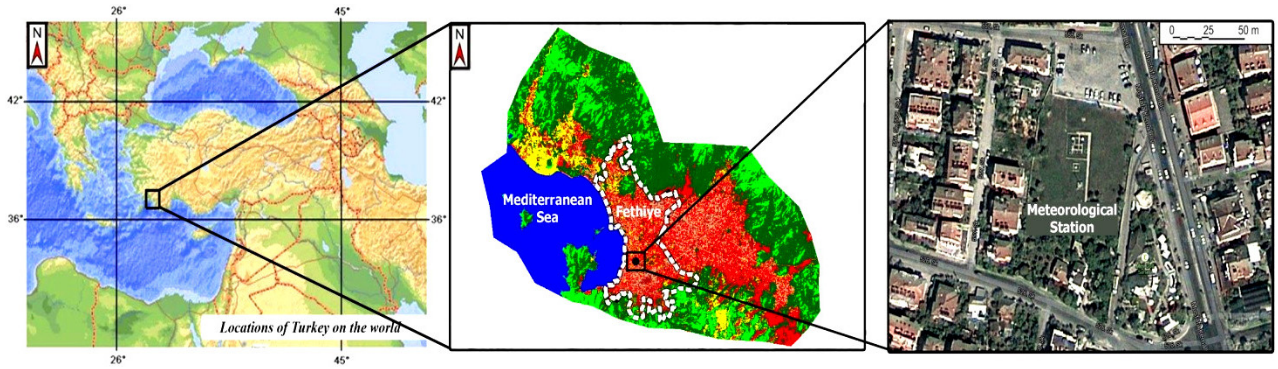

Figure 1. Location map of Fethiye in the Mediterranean region; urban development boundary and preferred urban periphery of the city for LULC change; and latest aerial view of the meteorological station.

Fethiye has a Mediterranean climate consisting of very hot, long and dry summers with an average of 34 °C; winters are cool and rainy with an average of 18.5 °C. The mean annual total precipitation is 840 mm with an average relative humidity of 76% and the sunshine duration is approximately 145 h in January and 360 h in July. The average low temperature is 10.5 °C in January and the average maximum temperature is 27.7 °C in July. During the observation period from 1940–2013, the maximum temperature was 44.3 °C in June and the minimum temperature was −6.6 °C in January. The prevailing wind direction is WSW (from the sea surface during the day) and NNE (from Mendos and Babadag Mountain to the base of Fethiye plain), with a maximum average of 11.8 km/h in February and a minimum average of 6.4 km/h in July. The Thornthwaite climatic model is B2, B’3, s2, b’3, indicating a humid, mezothermal climate; water deficiency is the highest in summer and is under a coastal effect. The DeMartonne model indicates a semi-humid climate represented by a desertification index of 22.50. The vegetation is phytogeographic Mediterranean consisting of mainly pines, mixed broad-leaf groves and Mediterranean bush (maquis).

The city population was 36,000 in the 1980s, 54,000 in 1995, 65,000 in the 2000s and 80,000 in the 2010s. The population in 2014 was 84,000 [29]. However, as a result of rapid urbanization, the city has extended out of the urban development boundary (indicated by the dashed lines in Figure 1, which is under the administration of the municipality. The enlarged area is composed of different land uses. Urbanization has spread rapidly around the city boundary. In addition, forestry, water and agricultural land covers developed over a large scale as a result of tourism and the increasing population, especially since the 1980s. Therefore, I established a study area (36°36′–36°46′N and 29°00′–29°14′E) to investigate the effect of LULC change on microclimatic changes. The study area covers an area of 25,063 ha, whereas the urban development boundary is 2571 ha. The city is considered as an important touristic and agricultural area of the country.

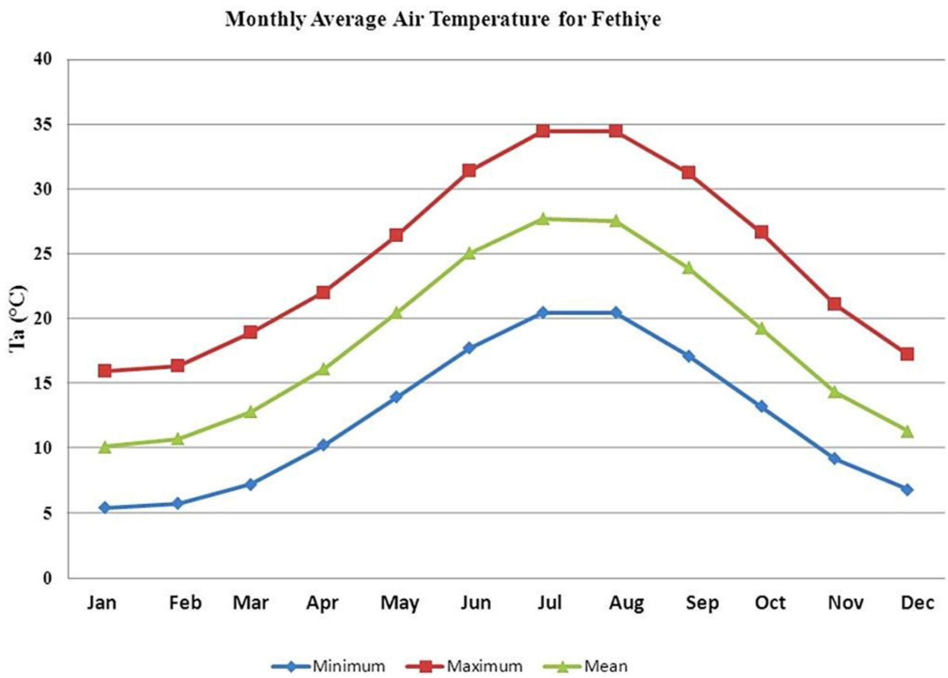

Figure 2. Average monthly air temperature of Fethiye (1940–2013).

2.2. Data and Methodology

In the study for the LULC classification, two Landsat 5 Thematic Mapper (TM) and two Landsat 7 Enhanced Thematic Mapper plus (ETM+) images covering the study area, acquired on 8 August 1984, 6 July 1995, 28 July 2003 and 18 July 2011, were used for spatial analysis. The Landsat images from the USGS website were geometrically corrected by using a 1:25,000 national topographical map and ground control points collected by GPS and then georeferenced to the WGS-84 Datum and Universal Transverse Mercator Zone 35N coordinate system (USGS download site http://landsat.usgs.gov/index.php).

The images were corrected to remove atmospheric effects and were then re-sampled to a 30-m pixel size for all bands using the nearest neighbor method. The resultant root mean squared error (RMSE) was 0.54 pixel (16.2 m on the ground) for the 1984 and 1995 images. The RMSE was 0.50 pixel (15.0 m on the ground) for the 2003 and 0.61 pixel (18.3 m on the ground) for the 2011 images.

The unsupervised classification was carried out using the Iterative Self-Organising Data Analysis (ISODATA) algorithm to determine the spectral clusters in the images. A maximum likelihood classifier was then employed for the image classification. I conducted a preliminary study to indicate the misclassification errors, including boundary and spectral confusion. For example, water was confused with shadows in the urban development boundary, and the urban/built-up areas were too difficult to separate from dry agricultural lands because they had similar spectral features. To minimize such errors, image stratification was used by dividing each image into four smaller images based on county boundaries.

Accuracy assessment was performed using a random sampling scheme. Various maps, field data, photos, interviews with local people and also my knowledge about the study area were used to reference the data. Confusion matrices were constructed to control the accuracy of the LULC maps. The overall accuracy determined for the 1984, 1995, 2003 and 2011 images was 83.5%, 79.6%, 79.6%, and 83.5%, respectively.

The climatic data for the study period of 1983–2013, in accordance with the decadal LULC data obtained using selected images, were supplied by the State Meteorological Office of Fethiye province. I evaluated all climatic parameters for the study and decided to use the mean and average maximum and minimum monthly air temperature datasets, which indicated a clear increasing trend.

The CORINE index was used to determine landscape diversity. The legend of the CORINE contains 44 classes and 3 level LULC data. The first level (five classes) corresponds to the main categories, including artificial areas, agricultural land, forests and semi-natural areas, wetlands and water surfaces.

Normality testing was conducted on observed air temperature data according to Anderson-darling using Minitab-17 statistical software. The Mann-Kendall test, which is a frequently used test, was used in World Meteorological Organization WMO applications for detecting trends in air temperature. An adjustment was made for tied observations in this test. The Kruskal-wallis test [30], using a significance level of $p < 0.05$, was applied to air temperature data to evaluate the differences during the selected latest 30 years. Consequently, the simple linear regression model in Minitab-17 software was used to determine the correlation between decadal air temperature anomalies based on annual climatic mean data (1940–2013) and LULC change.

3. Results and Discussion

3.1. LULC Changes

Four clustered maps were obtained for LULC classification by using two TM and two ETM+ images of Fethiye basin. Supervised maximum likelihood classification of images revealed LULC types. In this study, according to the CORINE legend, I determined seven LULC classes; water bodies, urban fabric, forest, shrubs, permanent crops, arable lands and others (open spaces with little or no vegetation including beaches and bare rocks) by means of selected Landsat Images and field workings (Figure 3).

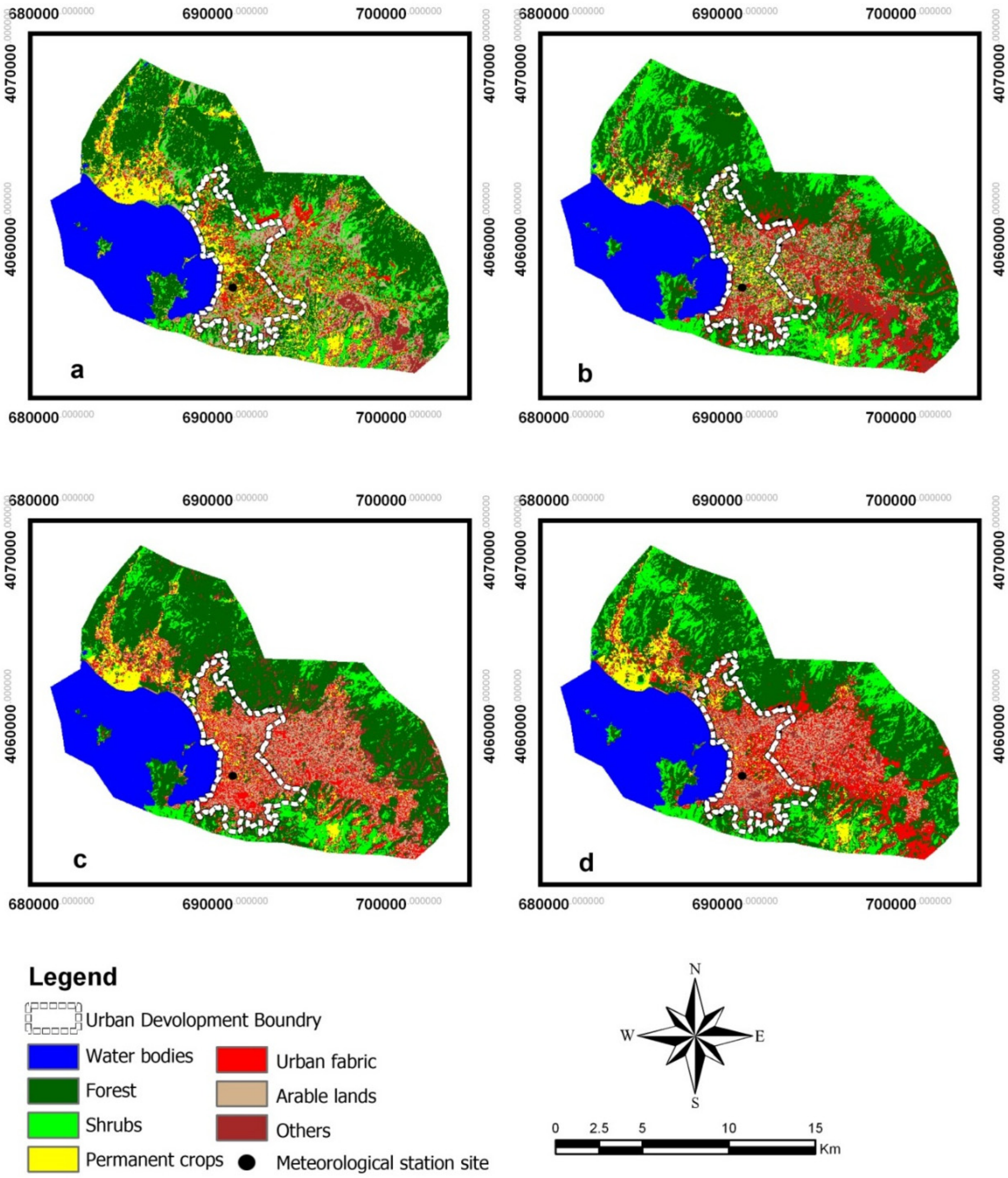

Figure 3. Obtained land cover map of the study area according to the CORINE index where (**a**) is for image of 1984; (**b**) is for image of 1995; (**c**) is for image of 2003 and (**d**) is for image of 2011 (Dashed lines indicate the governmental urban development boundary in the urban master plan).

According to Figure 3, the central location of the city extended out of the urban development boundary during the time. Rapid urbanization in the 1980s covered the site with low buildings in all directions except East. An asphalt road was constructed along the eastern side of the site during the rapid urbanization. Urbanization has extended out of the urban development boundary in an easterly and northerly direction, as small towns and villages. I decided to evaluate the natural and artificial land cover changes in the urban development boundary and the periphery, which might be effective in climatic responses. Observation site were covered by mountains, sea and urbanized large plain. Sea-land areas were also examined as a result of filling constructional applications in coastal bands. Deforestation and planting were observed during the time when agricultural activities changed from fruit production to vegetable production in greenhouses, especially in the eastern part of the plain. After all considerations, the examined area was determined as 25,063 ha, while the governmental urban development boundary was 2571 ha. The area situated between 36°36′–36°46′ N and 29°0′–29°14′ E, which is probably affected by climatic parameters, was evaluated in the study for LULC change.

Water bodies were examined using the sea water surface in the study, and in the first decade, it was lowered by about 83 ha. The cause of this decreased amount was coastal constructional activities of the municipality, especially for recreational land acquisition. A significant change in the sea water surface was not observed in 1995 and 2011. The total change was achieved in the first decade, with increasing tourism income for Fethiye (Table 1).

Table 1. Resultant land use/land cover (LULC) values and the temporal change values (ha).

CORINE Land Cover Index	LULC (ha)							
	1984	1984–1995 Change	1995	1995–2003 Change	2003	2003–2011 Change	2011	1984–2011 Total Change
Water bodies	**4718**	−83	**4635**	+16	**4651**	−17	**4634**	−84
Forest	**9543**	+838	**10381**	−468	**9913**	−373	**9540**	−3
Shrubs	**3113**	+604	**3717**	−1799	**1918**	+1093	**3011**	−102
Permanent crop	**2638**	−1456	**1182**	+73	**1255**	+22	**1277**	−1361
Urban fabric	**2018**	+112	**2130**	+806	**2936**	+918	**3854**	+1836
Arable lands	**2120**	−265	**1855**	+821	**2676**	−820	**1856**	−264
Others	**913**	+250	**1163**	+551	**1714**	−823	**891**	−90

Forest land cover was represented by coniferous forest (*Pinus brutia*) that widely covered the study area. A small mixed forest land cover represented by *Pinus brutia, Arbutus unedo, Arbutus andrachne and Ceratonia silique* was determined in the northern mountains. The Turkish Ministry of Forestry implemented reforestation policies in coastal cities in the 1980s depending on the increasing tourism activities. Therefore, forest land cover increased by 838 ha in the first decade. However, the forestation efforts could not continue after the 1990s, and therefore deforestation occurred in the related area.

Shrub land cover included maquis (e.g., *Quercus ilex, Quercus coccifera, Myrtus communis, Juniperus oxycedrus, Laurus nobilis, Nerium oleander*) and artificially constructed green urban surfaces in the study. As a result of the forestation policies of the government, the shrub area increased in the first decade of the study period. However, increasing agricultural activities depend on increasing the economic income of vegetable production in greenhouses during out of season, which increased the population, and residential built-up land cover conversion decreased the shrub land cover by about 1800 ha during the second time period. Shrub land cover increased again in the 2000s as a result of a decrease in arable land use. Agricultural activities, which slowly decreased in the 2000s, decreased the income from vegetable and fruit production (Figure 4).

Permanent crop land cover type in the study area was represented by continuous olive and orange fruit trees. In the first decade of the study, this land cover decreased strongly by about 60%, depending on the lower income of fruit production and rapid urbanization. Significant change values were not observed in the other two time periods for the permanent crop land cover class. Another agricultural land use class that was examined based on the visual interpretation of selected Landsat images was arable lands, which were represented by permanently irrigated lands. Arable lands decreased during the examined time period with increasing urban development except for the 1995–2003 period. In this unusual period, an increase in the economic income of vegetable production in greenhouses during out of season caused an approximate 22% increase in arable lands while shrub land cover decreased by 50% and artificial land use of urban development increased by almost 40%. Agricultural activities began to decrease in the middle of the 2000s; these were caused by decreasing income from vegetable and fruit production and thus the arable land use class continued to decrease.

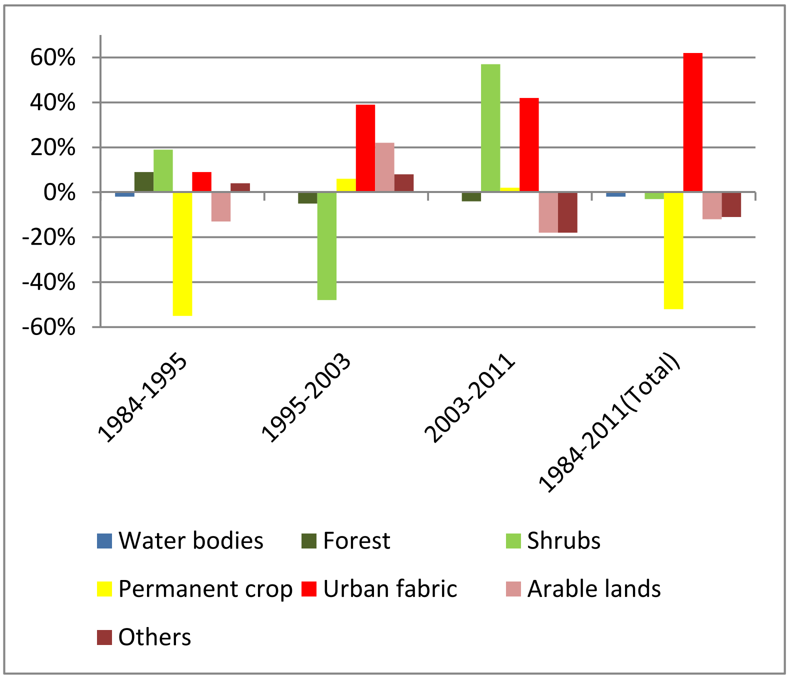

Figure 4. Temporal percentage change of LULC according to the CORINE land cover index.

As an expected impact of urban development, buildings (residential, commercial, governmental), roads and artificially surfaced lands increased during the examined period; this is clearly indicated in Figure 4. Urban land use was about 2000 ha in 1984 and 1995, and reached 3000 ha by 2003. The urban fabric land use class in the beginning of the 2000s increased by 40%. The main reason was the increase in the number of residential buildings resulting from the increasing population, which was especially related to the touristic attraction of Fethiye. However, urban fabric development was restricted since 2004 as a result of the municipality's governmental law for touristic cities, based on natural protection. In particular, the residential use of urban development decreased slowly during this period. The population increase combined with the need for residential land uses resulted in an increase in urban land use of approximately 60% during the last three decades. Permanent crops (including olive and orange trees) and arable land uses (including generally irrigated agricultural lands and vegetable production, mostly in greenhouses) exhibited a decreasing trend in the examined time period. The reason for these decreases is the land use conversion from farming lands to residential buildings and artificially surfaced areas. Forest land cover did not experience a significant change during the research period as a result of the reforestation policies of the government. Shrub land cover exhibited a slow increase in first decadal period. The reason is the decrease in agricultural activities. Some agricultural areas were naturally covered by shrubs during this period. In the second decadal period, shrub land cover decreased rapidly as a result of residential land use transformation. Shrub land cover showed an important increase in the last decadal period. The cause of this increase was the use of open green spaces by the municipality as urban parks. During this period, urban green spaces increased by about 60%, and the responsible working area of the municipality enlarged. A small decrease was observed in the use of arable lands during the study period, but this was not significant. The last land cover class, referred to as others, contained generally open spaces with little or no vegetation and beach, identified as a narrow line at the northern part of the study area along the Çalış and Yanıklar coasts.

3.2. Trend Analysis of Decadal Air Temperature

Turkey has a Mediterranean-type macro-climate and is classified as at risk in terms of the potential effects of climate change and global warming [31–35]. According to the latest and more realistic research of [36], the climate of Turkey was represented in 14 classes and Fethiye was clustered in the dry summer subtropical humid coastal Mediterranean climate.

The mean temperatures of the study area indicated a significant warming trend. The significant warming trend rates, calculated from a least-squares linear regression, is 0.34 °C per decade. Maximum temperatures were associated with a weak increasing trend. Minimum temperatures experienced a night-time warming [35,36].

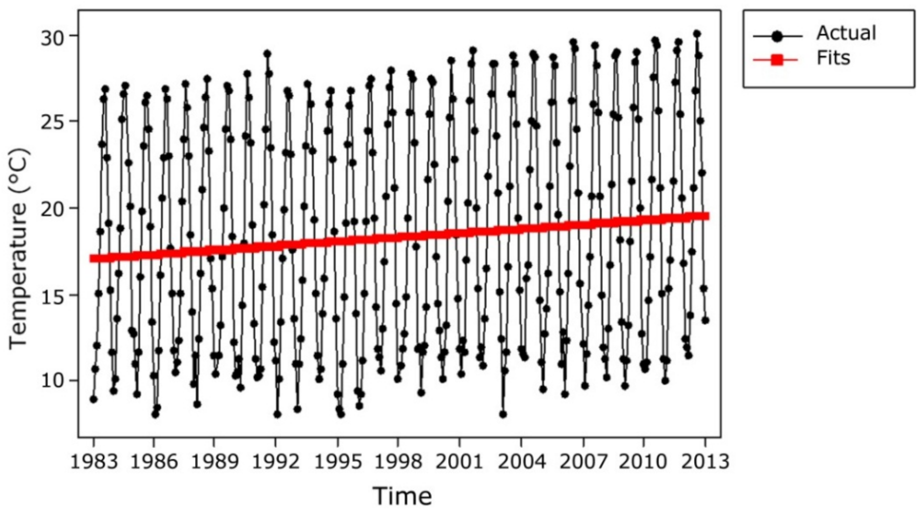

Figure 5. Trend analysis plot of mean monthly air temperature for 1983–2013 ($y = 17.028 + 0.0069x$).

The Mann-Kendall test was used to detect the trend in temperature data, which indicated an increasing trend for the mean and average maximum and minimum monthly air temperature. The mean monthly air temperature was 18.66 °C for first decade, 19.01 °C for the second decade and 20.35 °C for the last decade (Figure 5). The mean temperature difference between the first and second decade was 0.35 °C, compared with 1.25 °C between the second and last decade. The temperature increase during the 30-year period was 1.69 °C for the mean monthly values. The average monthly maximum air temperature was 24.07 °C for the first decade, 24.53 °C for the second decade and 25.43 °C for the last decade. The temperature anomaly for first decade was 0.46 °C, compared with 0.90 °C for the second and 1.36 °C for the last decade (Figure 6). The average monthly minimum air temperature was determined as 11.31 °C for the first decade, 12.05 °C for the second decade and 13.84 °C for the last decade. (Figure 7). The highest differences were observed in the night-time period, in accordance with the studies of [35–37]. The Kruskal-Wallis significance test was applied for all decadal comparisons and all differences were significant ($p < 0.05$).

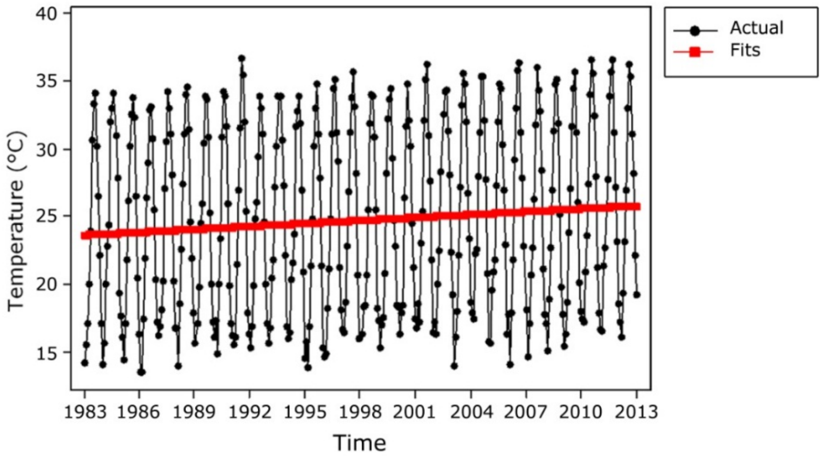

Figure 6. Trend analysis plot of average monthly maximum air temperature for 1983–2013 ($y = 23.575 + 0.0059x$).

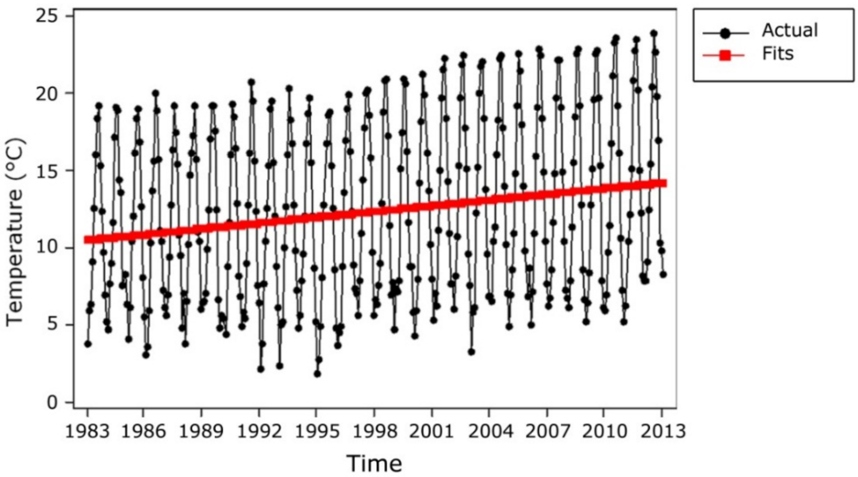

Figure 7. Trend analysis plot of average monthly minimum air temperature for 1983–2013 ($y = 10.464 + 0.0104x$).

3.3. Regression Analysis of Air Temperature Anomalies and LULC Change Data

In the last stage of the study, an additional qualitative simple linear regression model was constructed to determine the relationship between the LULC data (ha) and the air temperature anomalies (°C) for each decade (Tables 2 and 3). The correlation was significant at the 0.05 level ($p < 0.05$).

Table 2. Air temperature (T_a) anomalies according to the climatic annual means for each decades in accordance with the LULC change data.

T_a (°C)	Anomalies/Decades (°C)		
	1983–1993	1993–2003	2003–2013
Monthly Mean T_a	0.35	1.25	1.60
Monthly Average of Maximum T_a	0.46	0.90	1.36
Monthly Average of Minimum T_a	0.74	1.43	2.17

Table 3. Temporal LULC change values (ha).

CORİNE Land Cover Diversities	1984–1995 Change	1995–2003 Change	2003–2011 Change	1984-2011 Total Change
Water bodies	−83	+16	−17	−84
Forest	+838	−468	−373	−3
Shrubs	+604	−1799	+1093	−102
Permanent crop	−1456	+73	+22	−1361
Urban fabric	+112	+806	+918	+1836
Arable lands	−265	+821	−820	−264
Other	+250	+551	−823	−90

An applied qualitative simple linear regression model (using Minitab-17 software) demonstrated significant correlations between the LULC change of urban fabric, forest, permanent crop, water bodies and air temperature anomalies during the examined period. The other land use classes of arable lands, shrubs and other class types, which generally contain open spaces with little or no vegetation and beach, did not indicate any relationship for the air temperature anomalies in the statistical analysis. This can be explained by the sudden increases and decreases in the values in the examined period.

Air temperature anomalies for the mean and average maximum and minimum monthly temperatures were evaluated to determine significant relationships with LULC change. The most interesting and important correlations were obtained for the mean monthly temperature values. The reason is that different regression coefficients were explained by high RMSE values of the maximum and minimum air temperature anomalies in the regression analyses with the LULC values. Urban fabric, forest, permanent crop, and water body land uses were strongly correlated with the mean monthly air temperature anomalies, with low RMSE values of 0.087, 0.184, 0.166 and 0.312, respectively.

For example, the urban fabric land use class has an R-sq value of 97.4% for the mean monthly air temperature anomalies of the examined decades, while the correlation coefficient was 84.3% for the average monthly maximum air temperature anomalies and 83.7% for the average monthly minimum air temperature anomalies. Another interesting correlation was observed for the forest land cover type. The R-sq value of the mean monthly air temperature anomaly was 88.5% for forest land cover change, compared with 60.9% for the average monthly maximum air temperature and 67.3% for the average monthly minimum air temperature. This research has highlighted the importance of the relationship between the mean air temperature and increasing artificial land uses (Table 4 and Figure 8).

In most of the latest scientific studies of [34–37], increasing air temperature anomalies were observed over recent decades in Mediterranean basin. When the least-squares linear regression model was applied to determine the correlation between LULC change values and air temperature anomalies, significant results were obtained between mean monthly air temperature anomalies and urban land uses, forest, permanent crop land cover, and changes in water bodies.

Table 4. Mean monthly T_a anomalies for selected decades in accordance with the LULC change data.

Months	Mean T_a (°C) Anomalies/Decades		
	1983–1993	1993–2003	2003–2013
January	0.40	1.30	1.66
February	0.38	1.28	1.60
March	0.34	1.27	1.57
April	0.32	1.22	1.55
May	0.32	1.20	1.55
June	0.28	1.20	1.57
July	0.30	1.24	1.60
August	0.32	1.23	1.59
September	0.35	1.25	1.61
October	0.36	1.25	1.62
November	0.38	1.27	1.63
December	0.42	1.28	1.65

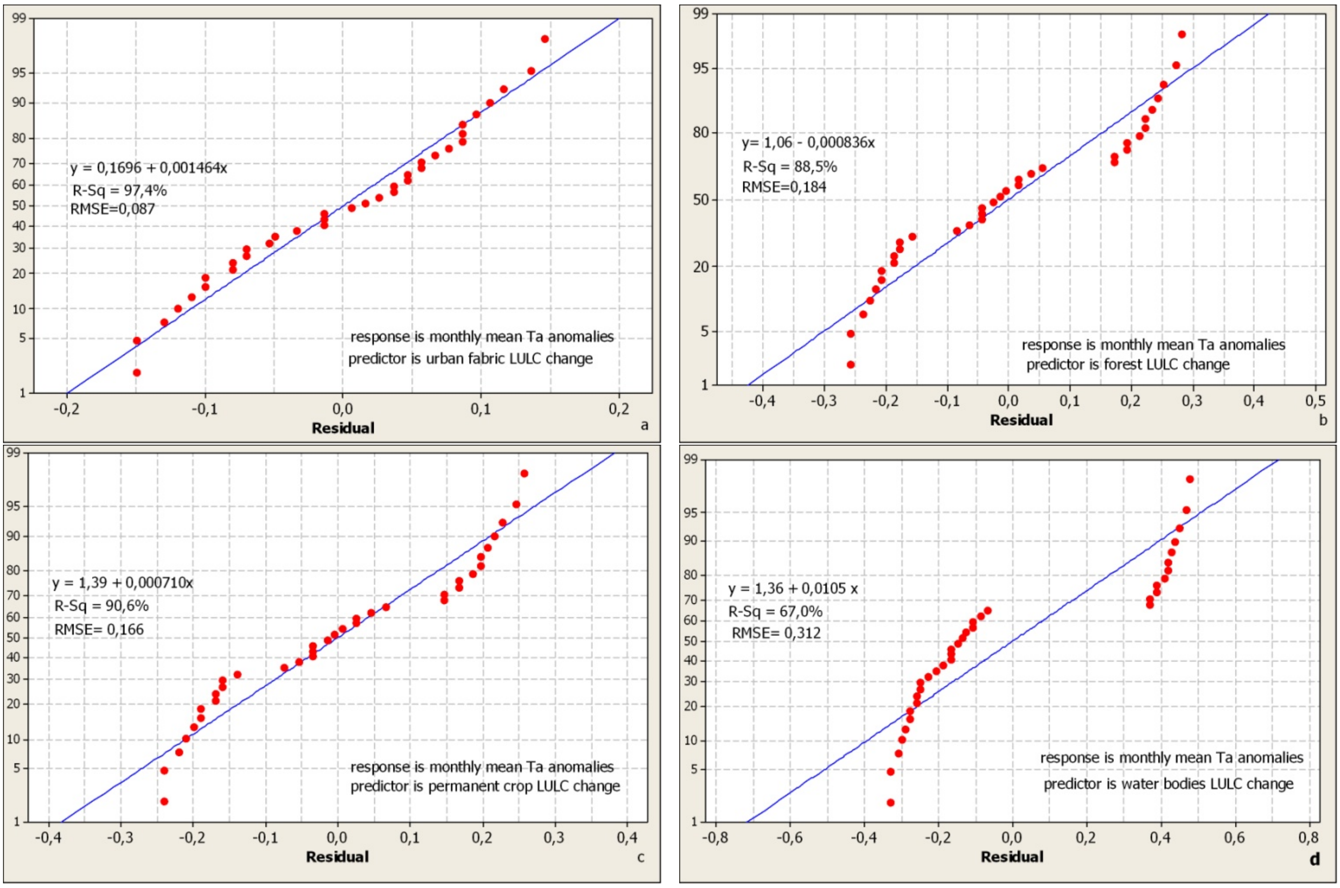

Figure 8. Regression analysis of decadal mean air temperature anomalies and LULC change values for (**a**) urban fabric; (**b**) forest; (**c**) permanent crops and (**d**) water bodies.

I obtained a positive correlation for urban fabric land use in accordance with many of the latest studies, such as [38–40]. Agricultural and natural land uses that were converted into generally urban areas (built-up residential areas and touristic buildings with paved roads) were represented by increasing air temperature anomalies as reported by [41,42] for examined periods. Forest land cover based on the vegetation canopy shade was negatively correlated with air temperature anomalies in this study, similar to other scientific research (e.g., [43–48]). A lower but significant correlation was obtained for the water surface that was associated with the coastal sea surface and permanent crop cover. In the first decade (Figure 4) the area of permanent crops decreased about 60% as a result of conversion to greenhouses, especially those constructed using plastic materials for out of season vegetable production, which resulted in high income while that of fruit production was decreasing. This artificial land cover conversion increased the urban fabric land use and therefore also increased the air temperature anomalies. The coastal sea surface of the study area on the western side was filled artificially and was constructed for recreational uses by local governmental authorities. The amount of this change was not that large but exhibited a high correlation with increasing anomalies. Arable lands were negatively correlated with shrub lands as depicted in Figure 4. When arable lands were not used for agricultural activities, they were converted into natural shrub lands. However, land cover diversity of arable lands and shrubs has not demonstrated any statistically significant correlation for temperature anomalies in the regression analysis. The most significant LULC change was recorded for urban fabric and permanent crop lands. Urban development was constructed in permanent crop lands of olive and orange trees in the study area for the examined period of the last three decades.

The population of Fethiye is increasing and has accelerated to 140,000 as a small touristic and agricultural town of the country. Urbanization rates are increasing globally as more people are moving to cities and this trend is expected to continue well into the 21st century. Increased urbanization results in an increase in urban temperatures compared with the rural countryside, causing the phenomenon known as climate change that is observed in cities worldwide. This fact is consistently emphasized by all working groups in the IPCC assessment reports [1].

4. Conclusions

The objective of this research was to investigate the effect of LULC change on the air temperature of the biosphere in coastal Mediterranean cities in decadal periods since the 1980s. In this respect a pilot study was conducted in Fethiye, Turkey where agricultural activities are decreasing because of lower income, while tourism and urban development are increasing due to population explosion and tourism activities.

In the study, significant results were obtained between the mean monthly air temperature anomalies and urban land uses, forest, permanent crop land cover, and change in water bodies. I obtained a high positive correlation coefficient for urban fabric land use and mean monthly air temperature anomalies per decade. Forest land cover based on the vegetation canopy shade indicated a negative correlation between air temperature anomalies, which is in accordance with other scientific researches. The most significant LULC change was recorded in the conversion of permanent crop lands to artificial surfaces, *i.e.*, greenhouses constructed of plastic materials for out of season vegetable production. Another interesting result was urban development on permanent crop land of olive and orange trees in the study area for the examined period of the last three decades. Important conversions of arable lands were not observed during the examined period; therefore no significant correlations were obtained with mean air temperature anomalies. When arable lands were not used for agricultural production, they were converted into natural shrub lands. Small changes in the water bodies of the sea surface along the coast were observed as a result of filling the sea surface with constructional materials for recreational uses like cafes and restaurants. These small changes were strongly correlated with increasing mean temperature anomalies as result of artificial land cover conversion.

The results from this research have expanded the scientific understanding of the effect of converting natural or semi-natural surfaces to artificial land uses on global warming by deforestation, urban expansion and ecosystem changes in the Mediterranean basin. The latest Assessment Report (AR5) of the IPCC meeting, which was held on 23 February 2015 in Nairobi has predicted global warming of 2 °C using 65% of the world's carbon budget. This report represents climate change with increases in warm temperature extremes, decreases in cold temperature extremes, and increases in sea level and the number of heavy precipitation events with extreme weather actions. The potential impact of climate change caused by global warming was listed in this report as food and water shortages, increased poverty, increased displacement of people and coastal flooding.

The results obtained in this study should be used to support better urban landscape plans and architectural designs to improve human thermal comfort for sustainable urban life in Mediterranean cities. Street geometry and orientation to wind breeze, the H/W ratio of buildings and the sizes of open and green spaces should be examined carefully in urban planning and design for climate adaptation.

For future studies in the Mediterranean basin aiming to evaluate the relationship between LULC change and atmospheric temperature, I recommend studying RS images with high spatial resolution (e.g., Ikanos, QuickBird) around the observation site, *i.e.*, not in a small area, because in this type of study, a large periphery would have a stronger impact on climatic parameters.

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Conflicts of Interest

The author declares no conflict of interest.

References

1. IPCC. *Climate Change 2001: Impacts, Adaptation and Vulnarability*; Contribution of Working Group II to the Third Assesment Report of the Intergovernmental Panel on Climate Change; McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S. Eds.; Cambridge University Press: Cambridge, UK, 2001.
2. Mahmood, R.; Foster, A.; Logan, D. The GeoProfile metadata, exposure of instruments, and measurement bias in climatic record revisited. *Int. J. Climatol.* **2006**, *26*, 1091–1124.
3. Govindasamy, B.; Duffy, P.B.; Caldeira, K. Land use changes and northern hemisphere cooling, *Geophys. Res. Lett.* **2001**, *28*, 291–294.
4. Osborne, T.M.; Osborne, D.M.; Lawrence, J.M.; Slingo, A.J.; Challinor, T.R. Wheeler, Influence of vegetation on the local climate and hydrology in the tropics: Sensitivity to soil parameters. *Clim. Dynm.* **2004**, *23*, 45–61.
5. Gibbard, S.; Caldeira, K.; Bala, G.; Phillips, T.J.; Wickett, M. Climate effects of global land cover change. *Geophys. Res. Lett.* **2005**, *32*, 705–714.
6. Alberti, M.; Marzluff, J. Ecological resilience in urban ecosystems: Linking urban patterns to ecological and human function. *Urban Ecosyst.* **2004**, *7*, 241–265.
7. Ackerman, B. Temporal march of the Chicago heat island. *J. Clim. Appl. Meteorol.* **1985**, *24*, 547–554.
8. Voogt, J.; Oke, T. Thermal remote sensing of urban climates. *Remote Sens. Environ*. **2003**, *86*, 370–384.
9. Song, C. Spectral mixture analysis for subpixel vegetation fractions in the urban environment: How to incorporate endmember variability? *Remote Sens. Environ*. **2005**, *95*, 248–263.
10. Masek, J.G.; Huang, C.; Wolfe, R.; Cohen, W.; Hall, F.; Kutler, J.; Nelson, P. North Amercan forest disturbance mapped from a decadal Landsat record. *Remote Sens. Environ*. **2008**, *112*, 2914–2926.
11. Su, W.; Zhang, Y.; Yang, Y.; Ye, G. Examining the impact of greenspace pattern on land surface temperature by coupling LİDAR DATA with a CFD Model. *Sustainability* **2014**, *6*, 6799–6814.
12. Stone, B. Land use as climate change mitigation. *Environ. Sci. Technol.* **2008**, *43*, 9052–9056.
13. Willems, E.; Vandevoort, C.; Willekens, A.; Buffaria, B. Landscape and land cover diversity index. Available online: http://ec.europa.eu/agriculture/publi/landscape (accessed on 15 May 2013).
14. Gulinck, H.; Mugica, M.; Lucio, J.V.; Atauri, J.A. A framework for comparative landscape analysis and evaluation based on land cover data, with an application in the Madrid region (Spain). *Landsc. Urban Plan.* **2001**, *55*, 257–270.
15. Han, K.S.; Champeaux, J.L.; Roujean, J.L. A land cover classification product over France at 1 km resolution using SPOT4/VEGETATION data. *Remote Sens. Environ.* **2004**, *92*, 52–66.
16. Vancutsem, C.; Ceccato, P.; Dinku, T.; Connor, S. Evaluation of MODIS land surface temperature data to estimate air temperaturein different ecosystems over Africa. *Remote. Sens. Environ.* **2010**, *114*, 449–465.
17. Carlson, T.N.; Arthur, S.T. The impact of land use-land cover changes due to urbanization on surface microclimate and hydrology: A satellite perspective. *Glob. Planet. Chang.* **2000**, *25*, 49–65.

18. Chen, X.L.; Zhao, H.M.; Li, P.X.; Yin, Z.Y. Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. *Remote. Sens. Environ* **2006**, *104*, 133–146.
19. Xiao H.L.; Weng, Q.H. The impact of land use and land cover changes on land surface temperature in a karst area of China. *J. Environ. Manag.* **2007**, *85*, 245–257.
20. Weng, Q.H.; Lu, D.S.; Schubring, J. Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *Remote. Sens. Environ* **2004**, *89*, 467–483.
21. Klok, L.; Zwart, S.; Verhagen, H.; Mauri, E. The surface heat island of Rotterdam and its relationshipwith urban surface characteristics. *Resour. Consery. Recycl.* **2012**, *64*, 23–29.
22. Dong S.; Yan, X.; Xiong, Z. Varying responses in mean surface air temperature from land use/cover change in different seasons over northern China. *Acta Ecol. Sin.* **2013**, *33*, 167–171.
23. Li, J.J.; Wang, X.R.; Wang, X.J.; Ma, W.C.; Zhang, H. Remote sensing evaluation of urban heat island and its spatial pattern of the Shanghai metropolitan area, China. *Ecol. Complex.* **2009**, *6*, 413–420.
24. Owen, T.W.; Carlson, T.N.; Gillies, R.R. An assessment of satellite remotely sensed land cover parameters in quantitatively describing the climatic effect of urbanization. *Int. J. Remote Sens.* **1998**, *19*, 1663–1681.
25. Araya, Y.H.; Cabral, P. Analysis and modeling of urban land cover changes in Setubal and Sesimbra, Portugal. *Remote Sens.* **2010**, *2*, 1549–1563.
26. Weng, Q. Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications and trends. *ISPRS J. Photogramm. Remote Sens.* **2009**, *64*, 335–344.
27. Schwarz, N.; Schlink, U.; Franch, U.; Grobmann, K. Relationship of land surface and air temperatures and its implications for quantifying urban heat island indicators—An application for the city of Leipzig (Germany). *J. Ecol. Indic*. **2012**, *18*, 693–704.
28. Cheng, K.S.; Su, Y.F.; Kuo, F.T.; Hunh, W.C.; Chiang, J.L. Assesing the effect landcover changes on air temperature using remote sensing images—A pilot study on northern Taiwan. *Landsc. Urban Plan.* **2008**, *85*, 85–96.
29. Turkish Statistical Institute. Avaiable online: http://www.turkstat.gov.tr (accessed on 20 March 2013).
30. Kruscal, W.H.; Wallis, W.A. Use of ranks in one-criterion variance analysis. *J. Am. Stat. Assoc.* **1952**, *47*, 583–621.
31. Altınsoy, H.; Öztürk, T.; Türkeş, M.; Kurnaz, M.L. Projections of Future Air Temperature and Precipitation Changes in the Mediterranean Basin by Using the Global Climate Model. In Proceedings of the National Geographical Congress with International Participitation (CD-R), İstanbul, Turkey, 7–10 September 2011. (In Turkish)
32. Sen, B.; Topçu, S.; Türkeş, M.; Sen, B.; Warner, J.F Projecting climate change, drought conditions and crop productivity in Turkey. *Clim. Res.* **2012**, *52*, 175–191.
33. Türkeş, M. *Global Warming and Kyoto Protocol: Scientific, Economical, and Political Analysis of Climate Changes*; Bağlam Publishing: İstanbul, Turkey, 2011; pp. 21–57.
34. Türkeş, M. *Physical Science Basis of the Climate Change: Physical Climate System, Enhanced Greenhouse Effect, Observed and Projected Climate Variations. 5th Atmospheric Science Symposium Proceedings Book*; Istanbul Technical University: Istanbul, Turkey, 2011; pp. 135–151.

35. İyigün, C.; Türkeş, M.; Batmaz, İ.; Yozgatlıgil, C.; Purutçuoğlu, V.; Koç, E.K.; Öztürk, M.Z. Clustering current climatic regions of Turkey by using a multivariate statistical method. *Theor. Appl. Climatol*. **2011**, *114*, 95–106.
36. Türkeş, M.; Sümer, U.M; Demir, I. Re-evaluation of trends and changes in mean, maximum and minimum temperatures of Turkey for the period 1929–1999. *Int. J. Climatol.* **2002**, *22*, 947–977.
37. Türkeş, M.; Sümer, U.M Spatial and temporal patterns of trends and variability in diurnal temperature ranges of Turkey. *Theor. Appl. Climatol.* **2004**, *77*, 195–227.
38. Feng, X.Y.; Luo, G.P.; Li, C.F.; Dai, L.; Lu, L. Dynamics of ecosystem service value caused by land use changes in Manas River of Xinjiang, China. *Int. J. Environ. Res.* **2012**, *6*, 499–508.
39. Odindi, J.O.; Mahangara, P. Green spaces trends in the city of Port Elizabeth from 1990 to 2000 using remote sensing. *Int. J. Environ. Res*. **2012**, *6*, 653–662.
40. Barati, A.A.; Asadi, A.; Kalantari, K.; Azadi, H.; Witlof, F. Agricultural land conversion in Northwest Iran. *Int. J. Environ. Res*. **2015**, *9*, 281–290.
41. Saptoma, S.K.; Nakona, Y.; Yuge, K.; Haraguchi, T. Observation and simulation of thermal environment in a paddy field. *Paddy Water Environ*. **2004**, *2*, 73–82.
42. Tian, Y.; Yin, K.; Lu, D.; Hua, L.; Zhao, Q.; Wen, M. Examining Land Use and Land Cover spatiotemporal change and driving forces in Beijing from 1978 to 2010. *Remote Sens.* **2014**, *6*, 10593–10611.
43. Bernatzky, A. The contribution of trees and green spaces to a town climate. *Energ. Buildings* **1982**, *5*, 1–10.
44. Georgi, N.J.; Dimitriou, D. The contribution of urban gren spaces to the improvement of environment in cities: Case study of Chania, Greece. *Build. Environ*. **2010**, *45*, 1401–1414.
45. Chen, Y.; Wong, N.H. Thermal benefits of city parks. *Energy Build.* **2006**, *38*, 105–120.
46. Zhang, X.; Zhong, T.; Feng, X.; Wang, K. Estimation of the relationship between forest patches urban land surface temperature with remote sensing. *Int. J. Remote Sens*. **2009**, *30*, 2105–2118.
47. Jenerette, G.D.; Harlan, S.L.; Stefanov, W.L.; Martin, C.A. Ecosystem services and urban heat riskspace moderation: Water, green spaces and social inequality in Phoenix, USA. *Ecol. Appl*. **2011**, *21*, 2637–2651.
48. Shashua-Bar, L.; Pearlmutter, D.; Erell, E. The influences of trees and grass on outdoor thermal comfort in a hot-arid climate enviroment. *Int. J. Climatol*. **2011**, *31*, 1498–1506.