

Rural Habitats and Land Surface Temperature: The Case of the Big Meander Delta and its Surroundings

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Abstract: The aim of this study is to map the habitats in the Big Meander Delta National Park, Bafa Lake Natural Park and its vicinity, to analyse the spatial properties of mapped habitats and the relationship between defined habitats and land surface temperature. The main materials of this study are composed of Sentinel 2A (dated 11 August 2017) and Landsat 8 (dated 26 August 2017) satellite images, soil map and digital elevation model. To achieve the purpose of this study, we employed vegetation analysis, object-based habitat classification, determination of land surface temperature (LST) values, and analysis of the relationships between habitats and their LST values. In order to determine the relationships between habitats and LST values, the Spearman correlation analysis and the Zonal statistics of the whole study area were conducted. The results show that whilst the dominant habitat types are Market gardens and horticulture, High-stem orchards and Standing fresh water; Eastern Mediterranean *Tamarix tickets*, *Sarcopoterium phryganas*, and Mud flats and sand flats constituted the rare habitats. The highest spatial connectivity was provided by Standing Fresh Water, Running water and Eastern kermes oak garrigues. Water and wetland habitat types have lower mean LST values compared to habitats with little or no vegetation and salt marshes. Our results confirmed that the presence of vegetation and water features as well as their type, abundance and coverage are effective factors in the formation of lower mean LST values in rural areas, too. However, the size of and the distance between those habitat patches were not significantly correlated with their mean LST values in our study area. So, further empirical research with time intervals might be necessary to efficiently measure the relationships between the spatial characteristics of habitat patches and their mean LST values at different times in a year. In any case, we believe that this study is important for initiating a monitoring research on the changes in habitats and the associated land surface temperatures. Such a future work can help us to provide early step for adopting suitable policies for either overcome or minimise the local climate changes and other related problems.

Keywords: *Climate change, Habitat mapping, Land surface temperature, Landsat satellite image, Sentinel 2A satellite image.*

Introduction

Ecosystems are functional units which consist of dynamic and complex interactions between living communities such as plants, animals and microorganisms and abiotic environment, and there are many services provided by healthy ecosystems for human life. These may include supporting (primary production, soil production, etc.), provisioning (fresh water, food, fuel, etc.), regulating (climate, natural cycles, etc.), and cultural (aesthetic, recreational, etc.) (MEA, 2005). However, the increasing demand for limited resources and rapid urbanisation have led to decreases in animal and plant species diversity, degradation of ecosystems and deterioration in ecosystem services, and even confronted some species with extinction. Delta systems are among the most important ecosystems that include water and wetland habitats as well as other surrounding terrestrial habitats. With these characteristics, delta systems are threatened by intensive agricultural activities as well as problems such as disruption of the water regime, loss of natural/semi-natural habitats and the excessive use of pesticides. In parallel with these environmental problems, there has been an urgent need for the development of holistic planning and management approaches from international to local scale around the world in terms of conservation and sustainability of natural areas (Lacoeuilhe *et al.*, 2018).

Water and wetland systems are one of the most efficient ecosystems that enable the transition

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between terrestrial and aquatic ecosystems. They are also important areas for the survival, sustainability and development of all living organisms. Historically concentrated around deltas, flood plains, rivers, sea and lake shores with the first settlements, the human life still depends on water and wetlands (Mitsch & Gosselink, 2000; Atalay, 2008). Evidence suggests that deltas and its surroundings are among the most important systems for biodiversity and have crucial functions in improving water quality of the region, reducing the risk of flood and drought and mitigating the negative effects of climate change (Song, 2003; MEA, 2005; Atalay, 2008; Yang & Tong, 2011). However, accurate and detailed data on the location, spatial characteristics and potential benefits of deltas and its surroundings are often scarce or difficult to access. Hence, the lack of enough data on the current status of these systems is one of the main challenges in land use planning and management. The Land Surface Temperature (LST) is an important indicator of the current status of surface energy and water balance in terrestrial and aquatic habitats at local and regional scales (Mannstein, 1987). The past thirty years have seen increasingly rapid advances in LST analysis, particularly for measuring the adverse effects of urban heat islands and local climate change in densely built-up urban areas (Saaroni and Ziv, 2003; Jin *et al.*, 2011; Klein and Coffman, 2015). On top of anthropogenic heat mainly stemming from artificial surfaces, there are also other factors affecting the formation of heat islands such as atmospheric pollution, loss of vegetation cover and water surfaces (Santamouris, 2014).

Studies on LST and urban heat islands emphasise that the presence of vegetation and water, especially their abundance and density, are one of the most important factors in reducing/eliminating the negative effects of urban heat islands (Chen *et al.*, 2006; Hathway and Sharples, 2012). The methods used for the modelling of heat islands and determining their characteristics are mainly divided into two groups. Whilst the first group studies are based on air temperature measurements, the second group studies are based on land surface temperature (LST) (Streutker, 2003). The estimations of the LST based on thermal remote sensing data (Streutker, 2002; Mathew *et al.*, 2017), is one of the important applications for addressing issues on land and water management in terrestrial and aquatic habitats. Despite that there has been little quantitative analysis of LST in rural areas, particularly the ones with important terrestrial and aquatic habitats. The aim of this study is, therefore, to identify the habitats in the delta system of the Big Menderes Delta National Park, the Bafa Lake Nature Park and its vicinity, and to analyse the relationship between spatial structural characteristics of these habitats and land surface temperature.

Material and Method

Material

This study was conducted within the Big Menderes Delta National Park, Bafa Lake Nature Park, Azap Lake and flood area, Sarıkemer flood area and their immediate vicinity. The study area, covering an area of 55165 ha, is in the province of Aydın, the Aegean Sea Region (Figure 1). The study area is in a natural basin which is shaped by the Big Meander River through time and includes two important protection areas namely, the Big Menderes Delta National Park, Bafa Lake Nature Park. There are many lagoons and swamps in the area where the Big Meander Delta flows into the sea, which has the international importance of 'Class A Wetland' (Anonymous, 2017).

Also, Bafa Lake and its surroundings, as a flood plain, share similar ecological characteristics with the Big Menderes Delta. Ecologically, including a wide variety of habitats, study area is rich in biological diversity (Figure 2). Despite having a variety of habitats and ecosystems, the study area suffers a range of issues which also changes the structure and functioning of the area (Eşbah *et al.*, 2009). These issues are mainly composed of burning the natural vegetation around wetlands, pollution and heavy grazing activities (Figure 3).

The habitat map used for analysing the spatial characteristics of the study area was obtained from 7 layers of 10 m spatial resolution including; Sentinel-2A satellite image (dated 11 August 2017) true colour bands (B02-blue, B03-green and B04-red), digital elevation model (DEM) and three main features of soil map (major soil groups, land use capability and other soil properties). In order to estimate the land surface temperature in the research area, cloud-free Landsat 8 satellite image of 26 August 2017 were used, considering the periods during which vegetation was active.

ArcGIS 10.5.1 and e-Cognition Developer64 software were used for identification, classification and mapping of habitats. For the analysis of landscape structural properties, we have used patch and class level landscape metrics in FRAGSTATS v4.2.1. Finally, statistical analyses were performed in

ArcGIS 10.5.1, and Matlab™.

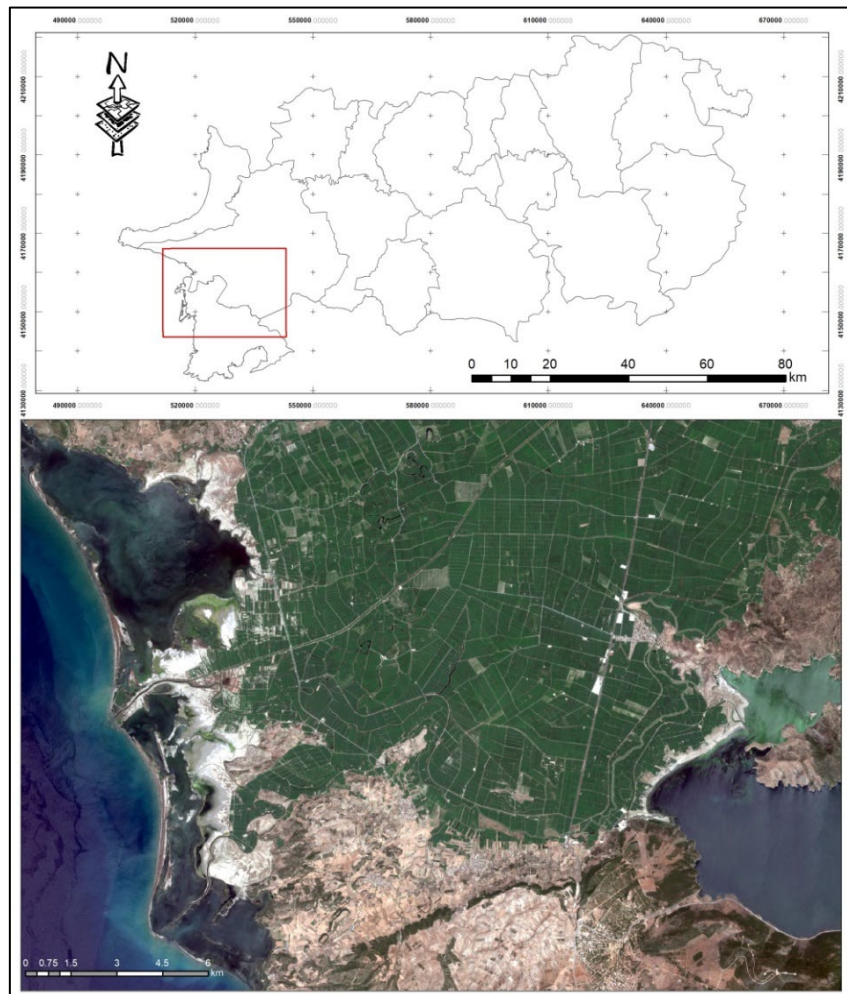


Figure 1. Study Area

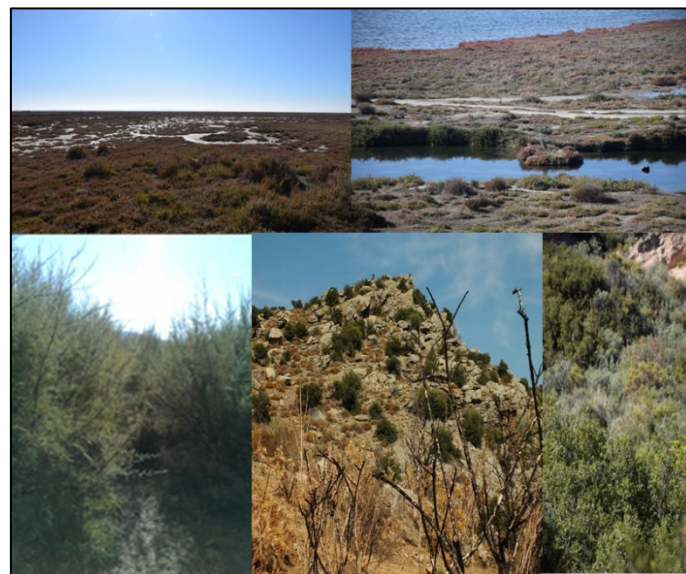


Figure 2. Different habitat types in the study area



Figure 3. Main issues in the study area⁴

Methods

Vegetation analysis

For the vegetation analyses, six-day field survey was carried out on 11.05.2017, 08.06.2017, 18.10.2017, 23.11.2017, 24.11.2017 and 14.12.2017. During field surveys, plant-species composition was recorded, and the characteristics of the recorded plant taxa were determined in terms of their community formation (values of presence, abundance-coverage, frequency and constancy). Identification of plant communities based on vegetation analysis was the baseline data for the classification of habitats in the study area. According to the findings obtained from the vegetation analysis records, the main habitat types and the associated plant communities were defined in the study area (Table 1).

Table 1. Main Habitat types in the study area

CORINE Habitat Codes	CORINE Habitat Types
11.12	Shelf and slope waters
14	Mud flats and sand flats
15.11	Glasswort swards
15.51	Mediterranean tall rush saltmarshes
15.61	Mediterranean salt scrubs
22	Standing fresh water
24	Running water
32.144	Aegean pine arborescent matorrals
32.5D	Arbutus andrachne garrigues
32.51	Eastern kermes oak garrigues
33.31	<i>Sarcopoterium phryganas</i>
42.85	Aegean pine forests
44.89133	Eastern Mediterranean <i>Tamarix tickets</i>
82.12	Market gardens and horticulture
83.1	High-stem orchards
84	Tree lines, hedges, small woods, bocage, parkland dehesa
86	Towns, villages, industrial sites

Habitat mapping

In this study, an object-based classification approach was applied by using e-Cognition Developer⁶⁴ software in order to identify different habitat types. In the object-based classification method, images are segmented according to characteristics such as criteria, colour and shape (Pillai et al. 2005; Mathieu et al. 2007). After the pre-processing of 7 selected layers in ArcGIS 10.5.1, the habitat map

was created by utilising an object-based classification using the nearest neighbour supervised classification method. The application of object-based supervised classification used in the study consists of three steps: a) the segmentation stage (multi-resolution segmentation algorithm), (b) selection of sample areas that represents different habitat types and, (c) performing supervised classification by the nearest neighbour classification method. Images are segmented according to their main characteristics like colour and shape, so the segmentation step is one of the most important stages of object-based classification. Since the size of objects defined in a satellite image varies according to the parameters used in the analysis, the parameters of segmentation is quite important to obtain an object structure that would provide the most suitable homogeneity in the satellite image. For this study, we applied the multi-resolution segmentation algorithm which works based on the parameters of scale and composition of heterogeneity criterion. In this algorithm, the larger the scale parameter, we get the larger sized objects. Whereas, the homogeneity parameters relate to the grouping of pixels, in other words the shape and density of defined objects (Pillai *et al.*, 2005; Mathieu *et al.*, 2007). In the segmentation step, each layer was equally weighted (1 value) with the value of 15 for the shape and the value of 0.3 for the compactness parameters (Figure 2).

After segmentation step, based on field surveys and GPS points, we have determined the sample areas that represent different habitat types. Next, we performed a supervised classification by the nearest neighbour classification method and the accuracy of the result map was increased by manual editing of the defined habitat classes. We also overlapped the vector data of roads and channels, which have a significant impact on habitat fragmentation, with the final habitat map. Finally, based on the Sentinel-2A satellite image, we calculated the average width of the vegetation corridors along the field boundaries and roadsides and creating a buffer of 5 m surrounding roads, channels and field boundaries, we obtained vegetation corridors along the roadsides and the borders of agricultural areas. The accuracy assessment of the habitat map was carried out by using the sample based error matrix method with the help of ArcGIS 10.5.1 software. Each habitat defined in the study area is coded using CORINE biotopes habitat codes (Devillers *et al.*, 1991).

Analysis of spatial characteristics of habitat types

The spatial and structural characteristics of habitats were analysed using patch and class level landscape metrics in FRAGSTATS v4.2.1. The selected landscape metrics are composed of 3 metrics at class level and 2 metrics at patch level (Table 2). Before running FRAGSTATS landscape metric analysis, we resampled the habitat to 30 m resolution in order to obtain spatial consistency between data layers.

Table 2. Landscape metrics that are used in this study

Landscape Metric	Abbreviation	Reason for Selection
Total class area, ha *	CA	Dominancy in the landscape
Number of patches*	NP	Together with CA and AREA_MN, fragmentation
Mean area, ha*	AREA_MN	Together with CA and NP, fragmentation
Effective MESH size, ha*	MESH	Connectivity / fragmentation
Patch area, ha**	AREA	Size of each habitat patch
Euclidean nearest neighbour distance**	ENN	The shortest edge to edge distance between each habitat

**class level metrics, **patch level metrics*

Determination of Land Surface Temperature (LST)

The retrieval of LST in an area is provided by thermal remote sensing data using satellite images (Chudnovsky *et al.*, 2004; Jin *et al.*, 2011). We applied the LST retrieval process conducted in the literature using the metadata file of Landsat 8 satellite image (see USGS, 2018a; Oğuz and Zengin, 2011; Chen *et al.*, 2014; Du *et al.*, 2016). LST data, based on thermal remote sensing, provides synchronous and continuous data set on the radiative temperature obtained from a terrain surface for larger areas (Du *et al.*, 2016). We have used thermal bands (Band 10 and 11) as well as near infrared and red bands (Band 4 and 5) of Landsat 8 satellite image for the hottest period of summertime in Aydın (dated 26 August 2017). Whilst thermal bands were mainly used for the conversion of

brightness values to spectral radiance values, spectral radiance values to reflectance values and radiance values to brightness temperature values; near infrared and red bands were used for the calculation of ground surface emissivity value (USGS, 2018b, c). For the determination of LST values and performing spatial analysis at the same spatial resolution, thermal bands of Landsat 8 satellite images were resampled to 30 m with the nearest neighbour algorithm. After that, we retrieved the LST of the study area.

The relationship between habitats and LST values

The relationship between habitats and LST values were evaluated using two approaches. The Zonal statistics tool of ArcGIS 10.5.1 was used to define minimum, mean, maximum LST values of each habitat type. On the other hand, the Spearman correlation analysis was used to quantify the effect of the habitat patch pattern on the mean LST values. The Spearman correlation analysis was performed in the Matlab™ by calculating the cross-correlation coefficients (e.g. patch area value versus mean LST value, ENN value versus mean LST value, etc.) (Matlab and Statistics Toolbox Release, 2012). Spearman's correlation coefficient (r_s) is a statistical measure of the strength of a monotonic relationship between paired data where the closer r_s is to ± 1 the stronger the monotonic relationship. The relationship between habitats and LST values were evaluated according to the Cohen standards (Cohen, 2013). According to Cohen standards, correlation coefficients between 0.10 and 0.29 are weak, correlation coefficients between 0.30 and 0.49 are moderate and correlation coefficients higher than 0.50 represent strong correlation.

RESULTS

Habitat Map and the Spatial Characteristics of Habitat Types

The resulting habitat map includes 17 habitat types with the total accuracy of 83.33% ($\kappa = 0.82$) (Figure 4). However, because the boundary of Shelf and slope waters habitat type depends on the selection of case study area and it is restricted to the area that we defined within our study, it was excluded from further analysis.

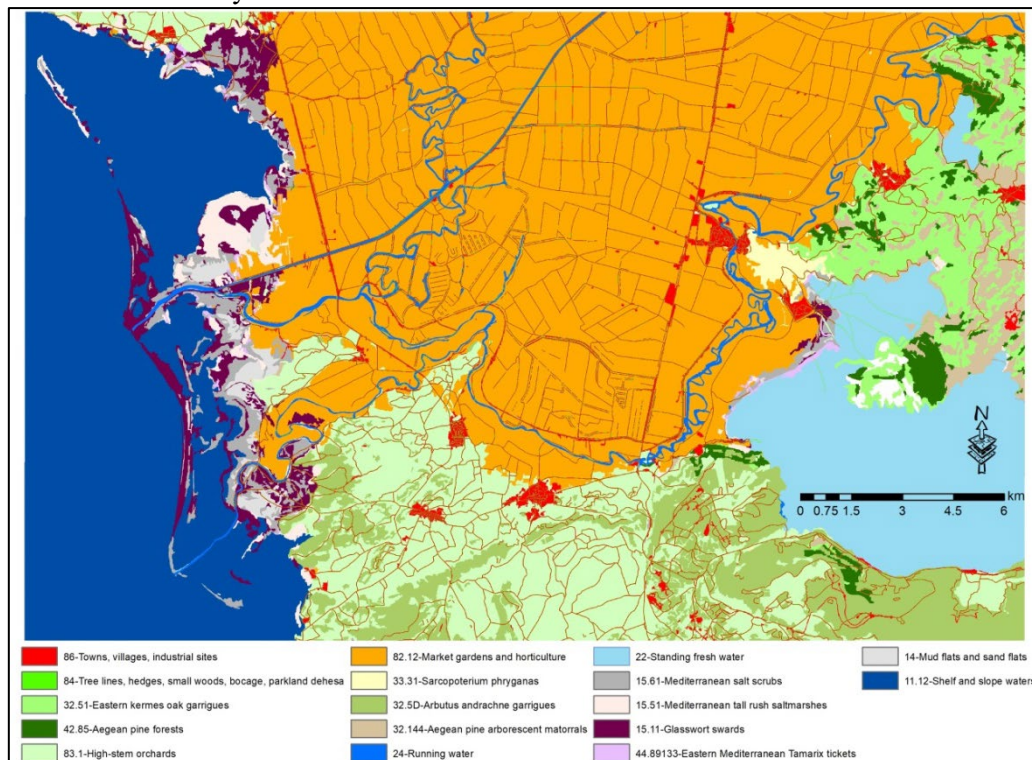


Figure 4. Habitat Map

Table 3 represents the results of landscape metrics at class level. Whilst the dominant habitat types in the study area are composed of Market gardens and horticulture (41.21%), High-stem orchards (13.29%) and Standing fresh water (10.54%), the rare habitat types are Eastern Mediterranean

Tamarix tickets (0.27%), *Sarcopoterium phryganas* (0.46%) and Mud flats and sand flats (0.80%).

Table 3. Result of the landscape metrics

Habitat Type	CA	NP	AREA MN	MESH
14- Mud flats and sand flats	355.12	34	10.44	0.27
15.11- Glasswort swards	1225.67	284	4.32	2.36
15.51-Mediterranean tall rush saltmarshes	629.03	181	3.48	1.14
15.61-Mediterranean salt scrubs	954.82	303	3.15	0.69
22- Standing fresh water	4701.38	79	59.51	376.59
24-Running water	816.12	121	6.74	7.94
32.144 - Aegean pine arborescent matorrals	1104.24	280	3.94	1.32
32.5D- Arbutus andrachne garrigues	3686.32	645	5.72	12.6
32.51- Eastern kermes oak garrigues	2100.32	214	9.81	9.42
33.31- Sarcopoterium phryganas	205.85	31	6.64	0.48
42.85- Aegean pine forests	662.80	117	5.67	0.72
44.89133- Eastern Mediterranean <i>Tamarix tickets</i>	118.42	80	1.48	0.03
82.12- Market gardens and horticulture	18376.28	1267	14.50	37.38
83.1- High-stem orchards	5924.76	1080	5.49	6.21
84- Tree lines, hedges, small woods, bocage, parkland dehesa	1253.10	1166	1.07	0.18
86- Towns, villages, industrial sites	2472.29	811	3.05	23.16

Even though the habitat types of Market gardens and horticulture and High-stem orchards dominate the study area, they demonstrate a patchier pattern in the landscape with lower mean patch area and the high number of patches. Standing fresh water represents the highest physical connectivity with the largest mean area and MESH value, and the lowest patch number. This followed by Running water, Eastern kermes oak garrigues, *Sarcopoterium phryganas*, *Arbutus andrachne garrigues*, and Tree lines, hedges, small woods, bocage, parkland dehesa. Towns, villages, industrial sites, constituting an important component of cultural habitats, cover only 5.54% of the total area with a patchier but closely positioned pattern.

The Relationships between Habitats and LST

Figure 3 represents the distribution of LST values in the study area. Whilst the areas in bright red reported the highest LST values with 42.65°C, the areas in dark blue had the lowest LSt values with 24.10°C. From Figure 5, we can clearly see that the lakes on the eastern part of the study area and the patches of Market gardens and horticulture show lower temperatures in the study area. Table 4 shows the relationship between habitat types and their min, max and mean LST values in degrees.

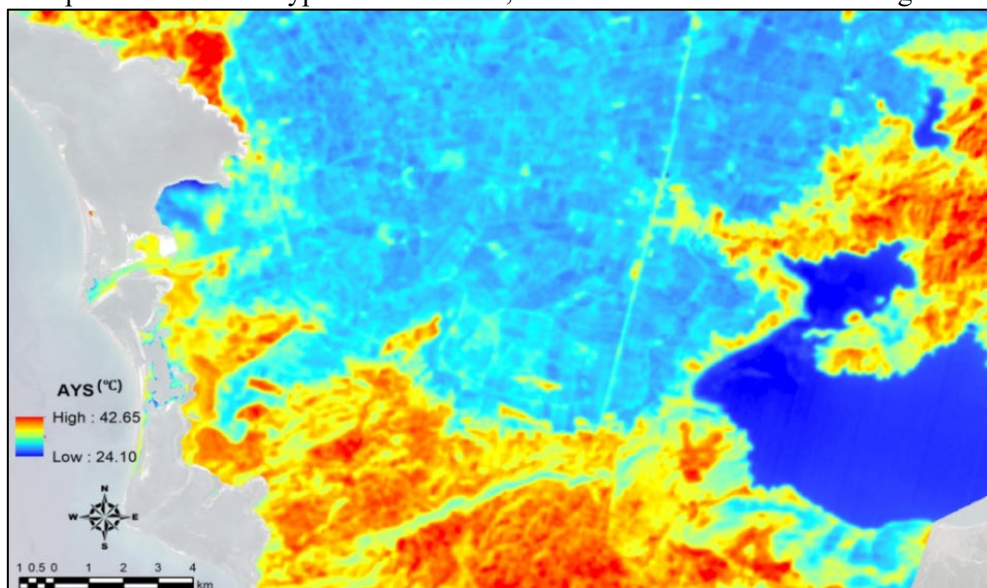


Figure 5. LST Map

Table 4. Relationship between habitat types and LST

CORINE Habitat Codes and Types	Min LST(°C)	Max LST(°C)	Mean LST(°C)
14- Mud flats and sand flats	28.86	38.24	34.72
15.11- Glasswort swards	26.71	42.65	35.15
15.51-Mediterranean tall rush saltmarshes	24.91	39.93	30.41
15.61-Mediterranean salt scrubs	26.45	40.63	35.13
22- Standing fresh water	24.10	35.20	25.57
24-Running water	27.09	37.77	29.26
32.144 - Aegean pine arborescent matorrals	25.27	41.92	35.83
32.5D- Arbutus andrachne garrigues	27.11	39.93	33.38
32.51- Eastern kermes oak garrigues	25.14	42.12	35.44
33.31- <i>Sarcopoterium phryganas</i>	29.84	39.46	35.17
42.85- Aegean pine forests	26.23	38.67	32.22
44.89133- Eastern Mediterranean Tamarix tickets	25.05	37.12	31.19
82.12- Market gardens and horticulture	26.53	38.16	28.98
83.1- High-stem orchards	27.87	41.89	36.62
84- Tree lines, hedges, small woods, bocage, parkland dehesa	24.23	40.99	31.70
86- Towns, villages, industrial sites	26.51	41.40	32.16

As expected, standing fresh water have the lowest mean LST value because of the cooling effect of water surfaces through evaporation (Hathway & Sharples, 2012; Sun *et al.*, 2012). Running water reported a higher LST value, and that result was attributed to the neighbouring patches of other habitat types (such as Mediterranean salt scrubs and Mediterranean tall rush saltmarshes towards to the coastal parts of the study area) with higher LST values. Surprisingly, Market gardens and horticulture has the third lowest LST value whilst High-stem orchards reported the highest LST value. However, this was a natural result of vegetation coverage on the soil surface at the time of the satellite image was taken. Since the density and coverage of healthy vegetation is an important factor in decreasing the LST, areas of low-density vegetation report higher LST values compared to (Gill *et al.*, 2007).

Glasswort swards, Mediterranean salt scrubs and Mud flats and sand flats reported higher LST because of their high content of salt (Orhan *et al.*, 2014; Gorji *et al.*, 2015). On the other hand, Mediterranean tall rush saltmarshes reported a lower LST value compared to abovementioned salty habitat types because of the height and density of vegetation on it at the time of LST retrieval. A similar surprising result was obtained for Aegean pine arborescent matorrals, Eastern kermes oak garrigues, *Sarcopoterium phryganas* and *Arbutus andrachne* garrigues, where they reported higher values of LST. But this was again a natural result of the scarcity and cover of vegetation on those habitats. Contrary to urban areas, the habitat type of Towns, villages, industrial sites reported moderate LST values because of the abundance and cover of vegetation patches within them (Figure 6). This result can also be explained with the fact that rural areas generally have low density of population, buildings and grey infrastructure over large areas of land compared to the urban areas (Houghton *et al.*, 2017).



Figure 6. An example of Towns, villages, industrial sites habitat type in the study area

Table 5 shows the correlation between habitat types and the area of, and distance between their patches and the mean LST values. Contrary to our expectations, the size of and the distance between different habitat patches were not significantly correlated with the mean LST values in our case study area. In general, the size and habitat patches and the mean LST were inversely correlated. In other words, the increasing size of habitat patches with fresh water, trees, shrubs and ground cover vegetation resulted in lower mean LST values.

Table 5. Relationships between landscape metrics and mean LST values

CORINE Habitat Codes and Types	Area (ha)	ENN (m)
14- Mud flats and sand flats	-0.0027	-0.359
15.11- Glasswort swards	0.1136	-0.1706
15.51-Mediterranean tall rush saltmarshes	0.1199	-0.0167
15.61-Mediterranean salt scrubs	0.1733	-0.1754
22- Standing fresh water	-0.6681	0.5387
24-Running water	-0.0701	0.0992
32.144 - Aegean pine arborescent matorrals	0.0688	0.0141
32.5D- Arbutus andrachne garrigues	-0.1571	-0.3313
32.51- Eastern kermes oak garrigues	0.0594	-0.1625
33.31- <i>Sarcopoterium phryganas</i>	-0.0183	-0.2041
42.85- Aegean pine forests	-0.217	0.302
44.89133- Eastern Mediterranean Tamarix tickets	-0.2047	0.1183
82.12- Market gardens and horticulture	-0.1689	0.1503
83.1- High-stem orchards	0.1613	-0.2882
84- Tree lines, hedges, small woods, bocage, parkland dehesa	0.0386	0.1595
86- Towns, villages, industrial sites	0.1324	-0.4827

However, if the coverage of vegetation was low or the salt content of soil and wetlands was high, the size and habitat patches and the mean LST were positively correlated. Towns, villages, industrial sites, Mud flats and sand flats, Arbutus andrachne garrigues, High-stem orchards and *Sarcopoterium phryganas* positively correlated with the distance between their patches. That means when the patches of those habitats become distant from each other, they get lower mean LST values. On the other hand, when the distance between the patches of Standing fresh water and Aegean pine forests habitats increase, they get higher mean LST vales, and vice versa.

Discussion and Conclusions

The aim of this study was the identification and spatial analysis of habitats in the delta system of the Big Menderes Delta National Park, the Bafa Lake Nature Park and its vicinity as well as the analysis of the correlations between spatial structural characteristics of these habitats and land surface temperature. This study is important in terms of defining the natural and semi-natural habitats, determining their spatial characteristics and the relationship between habitats and LST in the case of an area that includes two important protection areas within its boundaries. As a result of the analysis of spatial characteristics of habitat types in the study area, we found that the dominant habitat types were Market gardens and horticulture, and High-stem orchards as expected, because of the presence of fertile soils in the delta systems. In general, these areas thought to create barrier effects between natural and semi-natural areas (Benton *et al.*, 2003; Kerbiriou *et al.*, 2018), however, in our case study area natural and semi-natural habitats exhibit fragmented and isolated pattern with the connecting landscape components of the habitat type of Tree lines, hedges, small woods, bocage, parkland dehesa in between agricultural areas and other natural semi-natural habitats. So, whilst the habitat type of Tree lines, hedges, small woods, bocage, parkland dehesa reduce the barrier effect of agricultural areas in our case study area, it also provide strong physical connections between the most connected habitat types of Standing fresh water and Running water as well as representing high potential of supporting,

enhancing and conserving biodiversity (Lookingbill *et al.*, 2010; Zahn *et al.*, 2010; Lacoeyuilhe *et al.*, 2018). In this context, water and vegetation corridors of the habitat types of Tree lines, hedges, small woods, bocage, parkland dehesa and running between Big Meander Delta National Park and Bafa Lake Nature Park form a network in the Big Meander Delta plain and play an important ecological role in supporting biodiversity.

This study represents the results of the hottest period of summertime in Aydın (dated 26 August 2017). The estimations of the LST based on thermal remote sensing data have been widely used for monitoring water and wetland systems as well as other natural areas to obtain spatially and temporally frequent and consistent information on their environmental conditions (Guo *et al.*, 2017). The formation of high LST values, which is regarded as a reflection of the local climate change in the local environment, is a serious problem in urban areas. However, there is only scarce literature on the relationships between rural habitats and LST. The LST is an important indicator for the determination of shifts in surface temperature, presence of water and humidity, soil moisture, evaporation and salinity, for detecting the changes in the territories of ecologically important animal and plant species, and also for detecting the changes in the populations of species. Hence, retrieval of temporal LST values and its periodical evaluation through time can provide landscape planners and managers invaluable information on the changes in habitats, hydrological system and biodiversity. Local and global climate change is one of the most threatening factors for biodiversity and nature conservation since every individual reacts in a different way against to climatic factors. Our findings show that the habitat types of Standing fresh water, Market gardens and horticulture and Running water had the lowest LST values, however, the size of and the distance between those habitat patches were not significantly correlated with their mean LST values in our study area. So, further empirical research with time intervals might be necessary to efficiently measure the relationships between the spatial characteristics of habitat patches and their mean LST values at different times in a year.

It is also important to note that water and wetland systems generally accommodate a very high biodiversity and provide a series of ecosystem services, including supply, regulation, support and cultural services at regional and local scales (MEA, 2005). Besides, whilst they help to mitigate the adverse effects of global and regional climate change by regulating carbon cycle and capacity of carbon storage at global/regional scales (Song, 2003; Yang & Tong, 2011), they also play a key role in determining local climates at local scales through their cold-humid effects and energy exchange properties (Gao *et al.*, 2003; Nie & Wang, 2010). In this context, according to the principles of the United Nations Framework Convention on Climate Change (21 March 1994), measures to be taken to prevent climate change on a large scale and at minimum cost. With the development of thermal remote sensing technologies, LST retrieval using satellite images is now one of the practical ways of detecting the thermal environment of different habitats. Rapid observations of the LST values of different habitats are, therefore, important for understanding wetland systems and their surroundings.

Accordingly, this study is important for initiating a monitoring research on the changes in habitats and the associated land surface temperatures. Finally, as mentioned earlier under material section, the water and wetland system in the study area suffers from various environmental problems pollution, burning the natural vegetation around wetlands as well as heavy grazing activities (Eşbah *et al.*, 2009). Therefore, this study constitutes the base information for future monitoring work in the study area. Such a future work can help us to provide early step for adopting suitable policies for either overcome or minimise the local climate changes and other related problems (Pal & Ziaul, 2017).

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