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Investigation of the effects of wetlands on micro-climate

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ABSTRACT

Regulation of the microclimatic structure of a region by using land use planning is one of the important strategies, which is used to fight against climate change. The climatic structures of regions are also affected by wetlands as well as land use types. In the present study, based on this information, the micro-climatic effects at the 1 km and 10 km periphery of three dam lakes and two lakes (İmranlı Reservoir, Gölova Reservoir, Dörteylül Reservoir, Lake Hafik and Lake Tödürge), which are located within the boundaries of Sivas province, were investigated. Analyses were made using GIS (geographic information systems) and remote sensing techniques.

The temperature values are obtained from the Landsat TM-5 images of 2007 summer season which belong to June 18, July 4, July 20, August 5. The calculated surface temperatures were related to the buffer areas of wetlands and land use classes. Buffer areas were formed of 2 types, for 10 km every 500 m and for 1 km every 100 m for each wetland. These buffer areas were cut by 45-degree angles within themselves and divided into 8 zones to increase accuracy by minimizing the effects of other factors (land use, topography, etc.) in the analyses. Analyses were performed separately for each circular zone and each land use. The results were statistically tested in 95% confidence interval. With the help of this study, the necessity of climate-sensitive land use planning was emphasized.

1. Introduction

The importance of fighting action plans that need to be developed in the face of urban heat island (UHI) problems, which have emerged as a result of population increase and urbanization together with global warming, is gradually increasing (Grimmond, 2007; Kirshen, Ruth, & Anderson, 2008; Lorenz, Dessai, Forster, & Paavola, 2017). The issue of climate that should be evaluated in terms of human life and life comfort needs a broad perspective as required by its complex structure (Gulyás, Unger, & Matzarakis, 2006; Hwang, Lin, & Matzarakis, 2011; Johansson, Thorsson, Emmanuel, & Krüger, 2014). This situation also requires very different disciplines to carry out research on the subject from different perspectives (Masson et al., 2014; Taleghani, Kleerekoper, Tenpierik, & Dobbelsteen, 2015).

In today's rapidly urbanized world, the heat island effect causes deterioration in the thermal comfort of cities. Therefore, this problem requires making a smart action plan to fight against it. Upon examining scientific studies, many studies and suggestions about the strategies for reducing the impacts of heat islands can be encountered in the literature (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Chen & Ng, 2012; Declet-Barreto, Brazel, Martin, Chow, & Harlan, 2013; Vardoulakis, Karamanis, Fotiadi, & Mihalakakou, 2013). As one of them, it is important to understand the cooling effects of natural resources to use them as a way to reduce the impacts of heat islands.

The cool island effect is a meteorological phenomenon in the atmospheric boundary layer like the heat island effect. For example, a lake in a desert, as compared with its surroundings, is a cold and humid source in the daytime under sunshine. Therefore, it interacts with and adjusts to its arid and hot surroundings and forms a series of special structures of the atmospheric boundary layer, which is called a cold island effect (Hu, Su, & Zhang, 1988). Therefore, the creation or the conservation of cool-island effect can improve the climatic conditions of a region and reduce the environmental stress due to heat islands. So, the facts that cool islands in the potential of a region are taken into account, and it is attempted to increase the effects of these areas through conscious planning approaches in the planning of intracity and pre-urban areas are of great importance in terms of fighting against the issue (McKendry, 2003). When the studies conducted on cool islands (UCI) are examined, parks, green spaces (Abreu-Harbich, Labaki, & Matzarakis, 2015; Chang, Li, & Chang, 2007; Jauregui, 1991; Kuşçu Şimşek, 2016; Oliveira, Andrade, & Vaz, 2011; Rehan, 2016; Rotem-Mindali, Michael, Helman, & Lensky, 2015) and water bodies (Hongyu et al., 2016; Steeneveld, Koopmans, Heusinkveld, & Theeuwes, 2014; Sun, Chen, Chen, & Lü, 2012) are shown as cool island potential. However, studies focus on green spaces and park areas (Abreu-Harbich, Labaki, & Matzarakis, 2012; Aitken, Yeaman, Holliday, Wang, & Curtis-

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McLane, 2008; Akbari, Davis, Dorsano, Huang, & Winnett, 1992, 2001; Hamada & Ohta, 2010). Nevertheless, in recent years, the cool island effect of urban wetlands has received increasing attention due to its important role in the alleviation of urban heat islands (Zhang, Jiang, & Zhu, 2014).

When it is considered from this point of view, wetlands play an important role in climate regulation with their evapotranspiration and heat storage characteristics (Gou, Qu, & Han, 2014; Nakayama & Fujita, 2010). The fact that wetlands have their own radiation, thermal and water properties leads to the formation of a micro-climate which has also its own cooling and humidifying effects (Bai, Lu, Zhao, Wang, & Ouyang, 2013; Carrington, Gallimore, & Kutzbach, 2001). According to Steeneveld et al. (2014), the rationale behind the use of water bodies originates from the enhanced evaporation of water bodies during the daytime. Assuming constant net radiation, the evaporation water costs energy at the cost of sensible heat, keeping the air temperature at a more comfortable level than without water bodies. On the other hand, the thermal capacity of water is greater than that of soil, rock, and vegetation. In comparison with land, water bodies can store more heat and decelerate temperature variation; thus, wetlands can regulate the surrounding climate (Zhang, Zhu, & Jiang, 2016). Therefore, increasing the sizes of wetlands is emerging as an effective method to reduce the effects of urban heat island (Zhang et al., 2014).

However, little information is available on individual wetlands since most UHI studies are implemented at the scale of an entire city (Sun et al., 2012). When the studies conducted in the recent period are examined, although it is observed that the studies on the cooling effect of wetlands have increased, there is still not sufficient number of scientific studies on issues such as the climatic relationships of wetlands with the land uses around them or the expression of climatic effects of wetlands at the spatial scale.

It is known that changes are also observed on micro-climate depending on the effects of land use on energy exchange between the land surface and atmosphere, biogeochemical cycle and the ecosystem structure (Wang, Zhang, Tsou, & Li, 2017). For example, wetland drainage for agriculture has significantly reduced water tables and water-storage capacity of wetlands. Wetland losses can substantially alter evapotranspiration and runoff, and thus influence heat change between land and the atmosphere (Li, Mitra, Dong, & Yang, 2017). On the other hand land cover changes also causes significant changes in micro-climate due to the changes in surface albedo, latent heat flux, and energy redistribution (Gao & Liu, 2011). Therefore, it is necessary to evaluate the micro-climatic effects of wetlands by taking into account the land uses and land cover around the region while they are investigated.

The main purpose of this study is to determine the distance at which wetlands exhibit a cooling effect and to reveal the effect of the land use change on this. In the study, which addressed 5 wetlands as the sample areas, 4 consecutive satellite images of the summer season were used. In the analyses, the cross-correlations of surface temperature information, land use information, and distance from coastline information were examined. The study emphasized that the land uses around wetlands should be decided within consciousness to increase the climate regulatory impacts of wetlands.

Furthermore, the effective use of natural resources is crucial in determining strategies to be developed against the climate change. In this respect, another purpose of the study is to draw attention to the fact that wetlands, which are our important natural resources, can be used as a tool to fight against climate change.

2. Material and methods

2.1. Study area

Sivas province, located in the east of Central Anatolia, starts on the high plateaus and rises to the east. The average altitude is above 1000 m. The large part of Sivas province is under the influence of the continental climate with hot and dry summers and cold and snowy winters. The reasons such as the fact that Sivas, one of the coldest provinces, is higher compared to its surrounding, is open to northern winds, has a rugged structure and is under changing pressure effects during the year cause it to form a unique climatic zone different from the neighbouring provinces (Governorship of Sivas, 2017). The seasonal normals of the region for the summer season (June, July, August) are as follows; the average temperature is 27.03 °C, the average humidity is 55.96%, the average rainfall is 17 mm (TSMS, 2018). The weather information for the image dates is presented in Table 1.

Table 1
Weather informations of Sivas, at the date of satellite images (TSMS, 2018).

Date	Temperature	Seasonal normals of June/July/August	Humidity	Seasonal normals of June/July/August
June 18	24.7 °C	24.2 °C	43%	%59
July 4	24.8 °C	28.1 °C	42%	%55
July 20	27.6 °C	28.1 °C	36%	%55
August 5	25.2 °C	28.8 °C	38%	%54

In this study, the Dörteylül Reservoir, Lake Hafik, Lake Tödürge, the İmranlı Reservoir and the Gölova Reservoir, which are located within the boundaries of Sivas province, were used as the study areas (Fig. 1). The attribute information of each wetland is presented in Table 2.

2.2. Data

This study was carried out on the surface temperature and land use data obtained from satellite images. The Corine data are the most accurate land use data that can be used in a study to be conducted on a regional scale since there are no numerical land use data produced in a holistic structure in our country. The fact that the Corine data have been accepted internationally by means of the ground controls has made it essential to conduct the study according to these data in terms of time efficiency and economic aspects. Due to the fact that the Corine land use data in our database belong to 2006, the study period was tried to be selected accordingly; however, since four consecutive cloudless satellite images of 5 wetlands belonging to the summer of 2006 were not available, the satellite images of 2007 were used. Land use classes were updated in order to eliminate the temporal change that occurred in this one-year period and to include the areas (smaller than 25 ha), contained in generalization in the Corine classification, in the classification. By adhering to the Corine data, considering the 2007 Spot 5 satellite image and each Landsat TM-5 image in different band combinations, the update was made by splitting the visible, apparent and non-negligible areas (settlement, forest, scrub, etc. areas where there would be no doubt as to the classification) from generalized data, or by changing their boundaries. The land use was classified upon the Spot satellite image of 2007 according to the classes given in Table 3. However, the fact that the study was carried out over the past year prevented the feasibility of ground controls. For this reason, the reliability criterion in the update made was a high-resolution satellite image and expert's comment. Verification of the obtained results was made by examining the correlations of the results obtained from 4 different satellite images with each other. Updates were made by using the ArcGIS 10.1 program.

In the study, it was preferred to use the satellite images of the same year since it was thought that the land use changes could affect the precision of the analyses. The temperature values were obtained from the Landsat TM-5 images of 2007 summer season which belong to June 18, July 4, July 20, August 5.

Buffer areas were obtained from the coastal lines drawn upon the satellite images of lakes and dams.