MAUN Mühendislik-Mimarlık Fakültesi Dergisi,5(1),15-25,2024/MAUN Journal of the Faculty of Engineering and Architecture, 5(1),15-25,2024
Araştırma Makalesi/Research Article

Evaluating the Correlation Between Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI)

Erkan KARAKOYUN

Muş Alparslan University, Faculty of Engineering and Architecture, Deparment of Architecture, Muş/Turkey.
ORCID: 0000-0003-2821-9103

Corresponding Author: e.karakoyun@alparslan.edu.tr

Arrival Date: 02.05.2024 Acceptance Date: 20.05.2024

Abstract

Climate change and its effects, which are increasing day by day, and adversely affect the human life. The world's average temperature trend is tend to increase and the precipitation regime is changing with the effects of climate change. In this study, changes in Land Surface Temperature and Normalized Difference Vegetation Index were calculated and mapped in Mus province for the years 2013-2018 and 2023. The obtained NDVI and LST results were compared and correlation analysis was performed. The highest values of LST were obtained in the year 2018. It was observed that the study area had more vegetation, especially in the southwest and northwest, according to NDVI values. It was observed that LST values demonstrated parallel results with the change in average temperature. For example, the average temperature increased in 2018, and decreased in 2023 and the same results were observed for the LST values. When the spatial-temporal maps were examined, it was observed that LST values were higher in regions where NDVI values were low, but a strong correlation between NDVI and LST was not observed during the study period. With this study, changes in vegetation and land surface temperature in Mus province can be examined on a regional scale and will be useful in taking necessary precautions.

Keywords: Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Remote Sensing, Landsat 8

Yer Yüzey Sıcaklığı (LST) ve Normalleştirilmiş Fark Bitki Örtüsü (NDVI) Arasındaki İlişkinin Değerlendirilmesi

Özet

Gün geçtikce artan iklim değisikliği ve etkileri hayatı olumsuz etkilemektedir. Dünya ortalama sıcaklığı artmakta ve yağış rejimi iklim değisikliği etkileri ile değişmektedir. Bu çalışmada 2013-2018 ve 2023 yılları için Muş ili özelinde yer yüzey sıcaklıklarındaki (LST) değişimler ve normalleştirilmiş fark bitki örtüsü indeksi (NDVI) hesaplamaları yapılmış ve haritalandırılmıştır. Elde edilen NDVI ve LST sonuçları karşılaştırılmış ve korelasyon analizi yapılmıştır. 2018 yılında en yüksek LST değerleri elde edilmiştir. Çalışma alanının özellikle güneybatısı ve kuzeybatısında NDVI değerlerine göre daha fazla bitki örtüsüne sahip olduğu görülmüştür. LST değerlerinin ortalama sıcaklıktaki değişimle paralel sonuçlar gösterdiği, örneğin ortalama sıcaklığın 2018 yılında arttığı, 2023 yılında ise düştüğü, LST değerlerinde de aynı sonuçların gözlendiği görülmüştür. Oluşturulan uzay mekansal haritalar incelendiğinde NDVI değerinin düşük olduğu bölgelerde LST değerlerinin daha yüksek olduğu gözlense de, NDVI ve LST arasında çalışma periyodu süresince güçlü bir korelasyon gözlenmemiştir. Bu çalışma ile Muş ilindeki bitki örtüsü ve toprak sıcaklığındaki değişimler bölgesel ölçekte incelenebilecek ve gerekli tedbirler alınmasında faydalı olacaktır.

Anahtar Kelimeler: Yer Yüzey Sıcaklığı (LST), Normalleştirilmiş Fark Bitki Örtüsü (NDVI), Uzaktan Algılama, Landsat 8

1. INTRODUCTION

The global average temperature has been increasing, especially in recent years, due to the increasing human population and industry and the resulting increase in greenhouse gases in the atmosphere (Korkmaz, 2022). For example, 2023 has been recorded as the warmest year since 1850, when records began to be kept. While this situation negatively affects sea water level rise, access to clean water resources and biodiversity, especially on a global scale, it also leads to an increase in disasters such as floods, drought and forest fires and loss of life and property on a regional scale. Besides, climate change on a worldwide scale is diminishing water reserves in numerous regions (Acar, 2024). Due to high temperatures and decreasing rainfall caused by climate change, fertile agricultural lands are decreasing and desertification is increasing. Emigration from rural areas to urban areas is increasing due to increasing industrialization, human population and the impact of climate change. This situation causes urbanization to increase and green areas to decrease. Some of the sun's rays are reflected back after reaching the surface. While this reflection is less in urban areas where urbanization is intense, it is more in green areas. Therefore, sunlight is absorbed in urban areas and reflected as heat around it, generating an urban heat island (UHI) (Oke, 1982). However, many studies have shown that intense urbanization increases urban heat island effects, while green and wetlands reduce this effect (Amiri et al., 2009; Song et al., 2014). Increasing temperatures negatively affect human health, cause excessive energy consumption and change biodiversity (Mercan, 2020). For these reasons, detecting and mapping land surface temperature (LST) changes on an annual scale becomes important.

Land surface temperature is a very important parameter used to understand climate change and various chemical and physical parameters (Tomlinson et al., 2011). It reflects the transfer of energy and water between the Earth's surface and the atmosphere, impacting seasonal occurrence of plant development (Z. Li et al., 2022) Especially in mountainous areas, the spatio-temporal distribution of land surface temperature is effected by the topography of the area, land use types and vegetation (Ullah et al., 2023), and this creates a change between land use changes and land surface temperatures (W. Li et al., 2017). Normalized Difference Vegatation Index (NDVI) is a method that determines the vegetation density in a region to be observed using remote sensing methods. NDVI introduces the vegetation density and health. By employing NDVI data for the region, we can observe alterations in vegetation cover within the area (Sruthi & Aslam, 2015). Researchers frequently use NDVI analysis in areas such as agricultural drought (Sruthi & Aslam, 2015), land degradation (Eckert et al., 2015), land use and land cover change (Jung & Chang, 2015; Sahebjalal & Dashtekian, 2013). However, in recent years, many studies have been conducted to examine the effect of changing vegetation on LST through NDVI analysis (Julien et al., 2011; S. & C.R., 2016; Sara Afrasiabi et al., 2013; Sun & Kafatos, 2007; Tan et al., 2012; Ullah et al., 2023). For example, Sara Afrasiabi et al. (2013) conducted a study in the Mashhad, Iran region to examine the relationship between NDVI and LST, and obtained low NDVI values in regions with low vegetation cover. They also detected a negative correlation between NDVI and LST through their correlation analysis. Sun & Kafatos (2007) in their study in North America, in the correlation analysis they conducted to determine the relationship between NDVI and LST, they obtained positive values in the winter months and negative correlation values in the warm periods (May-September).

LST is an important parameter used by research to analyze drought, climate change, agriculture and environmental changes. Therefore, in order to measure LST, stations are established in the fields and spot measurements are made. However, since these measurements are on a direct and point scale, they do not represent large areas. Therefore, data obtained from satellites are often used in the literature to make LST maps, as they can examine larger areas and obtain images (Z. Li et al., 2013; Z. Li et al., 2022; Wang, 2010). In Turkiye, both NDVI analysis and LST analysis are used by researchers using the remote sensing method (Mercan, 2020; Yücer, 2023, Orhan et al., 2014, Balcik, 2014; Sekertekin & Kutoglu, 2016). The list and the details of the previous studies and this study are indicated in Table 1.

Table 1. List and details of previous studies

Author(s)	Study Area	Data Used	Method used
Ullah et al. (2023)	Himalayan region	Landsat 8	LST, NDVI, LULC
W. Li et al. (2017)	China	Landsat 8	LST
Sruthi & Aslam (2015)	India	MODIS	LST, NDVI
Eckert et al. (2015)	Mongolia	MODIS	NDVI
Jung & Chang (2015)	Korea	MODIS	NDVI, LULC
Sahebjalal & Dashtekian (2013)	Iran	Landsat ETM+	NDVI, LULC
Jullien et al. (2011)	Iberian Peninsula	NOAA	NDVI, LST
Anbazhagan & Paramasivam (2016)	India	Landsat 5, Landsat 7	NDVI, LST
Tan et al. (2012)	Malaysia	Landsat 5, Landsat ETM+	NDVI, LST
Sun & Kafatos (2007)	North America	GOES-8, GIMMS	NDVI, LST
Mercan (2020)	Muş	Landsat 5, Landsat 8	LST
Yücer (2023)	Safranbolu	Landsat 7, Landsat 8	Albedo, LST, NDVI
Orhan et al. (2014)	Salt Lake Basin	Landsat 5	LST, NDVI, VCI, TVX
Balcik (2014)	Istanbul	Landsat 5	LST, NDBI, NDVI
Skercetin & Kurtoglu	Zonguldak	Landsat 5, Landsat 8	LST, NDVI
This study	Muş	Landsat 8	LST, NDVI

This study was conducted specifically in the province of Muş, which is located in the Euphrates-Tigris basin, which is the largest and highest water potential basin in Turkey. Within the scope of the study, NDVI analysis and then LST analysis were performed for the years 2013-2018 and 2023, and the relationship between them was examined by correlation analysis. This study, conducted for the province of Muş, which has significant water potential and agricultural production potential, as well as one of the largest plains in Turkey, will show the NDVI and LST changes over the region for years.

2. MATERIAL AND METHODS

2.1. Study Area

Muş province is located in the Eastern Anatolia region of Turkey and within the Euphrates-Tigris basin. Two important rivers, Murat and Karasu, pass through it, feeding the Euphrates River. It borders Erzurum in the north, Van in the east, Diyarbakır in the south and Bingöl in the west (Figure 1). The annual average temperature (1964-2023) is 9.8^{0}C and the annual average total precipitation is 759.6 mm (https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A&m=MUS). Its average altitude is 1829 m.

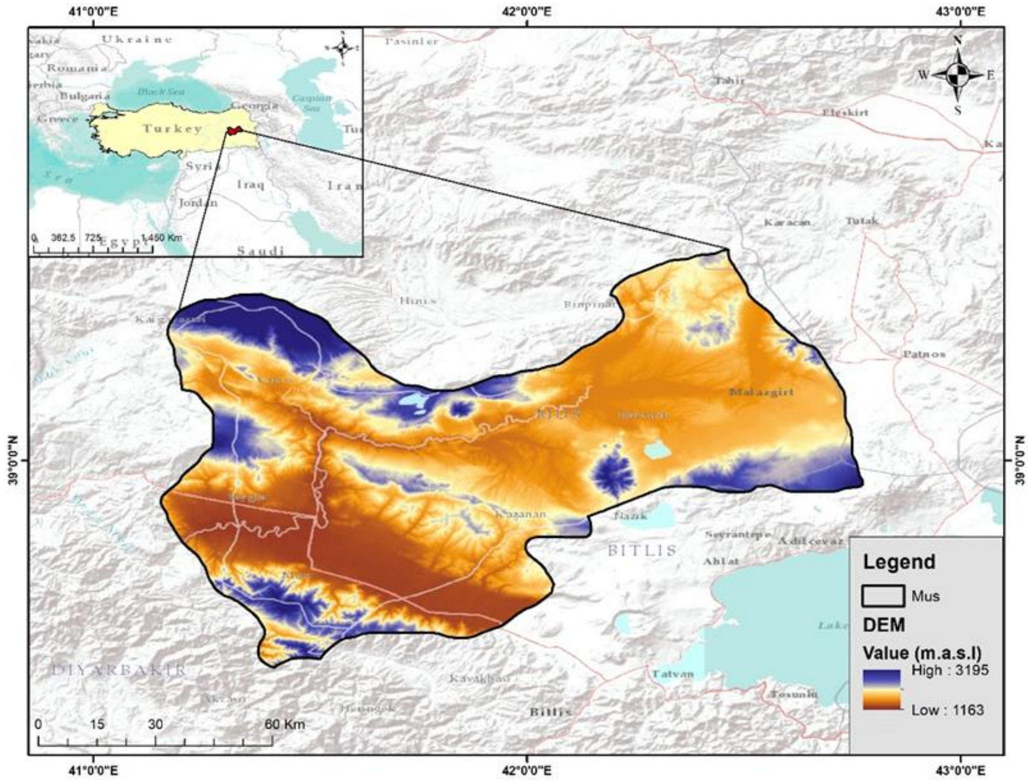

Figure 1. Study area

2.2. Methods

The Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) data has been used in this study. It has been downloaded from United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/). The generation of NDVI and LST involves utilizing the red, near-infrared, and thermal infrared spectral bands. Three images in total have been gathered between the studied period in the Landsat and the details of those are given in Table 1. Satellite images were taken with 5 years interval (2013-2018-2023). All images have almost no cloud cover that can be used as a clear image. Satellite images were selected from dates close to each other for comparison purposes and investigate the temporal changes in LST and NDVI. ArcGIS 10.8 and MS-Excel have been used for image processing and analyzing statistical analysis. The initial image size exceed those of the study area; therefore, they are modified using a Mus City shapefile after pre-processing. The downloaded and excracted landsat data as study are then used for the calculation of NDVI and LST maps as illustrated in Figure 2.

Table 2. Spesifications of landsat satellite sensors

Date of acquisition	Satellite Sensor	Path/Row	Cloud Cover (%)
08/16/2013	Landsat 8 OLI/TIRS	171/33	0.08
08/30/2018	Landsat 8 OLI/TIRS	171/33	0.00
08/20/2023	Landsat 8 OLI/TIRS	171/33	0.25

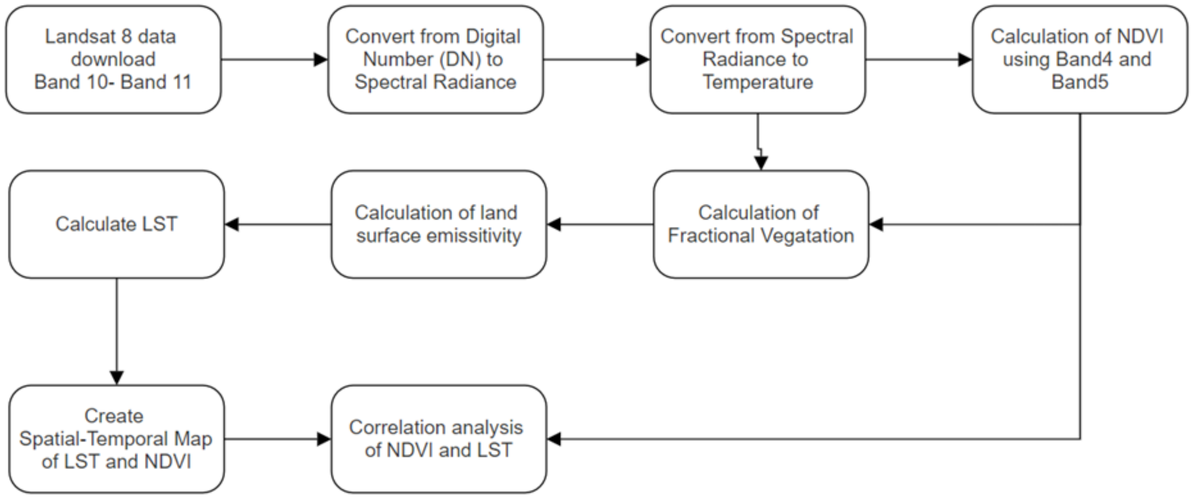

Figure 2. Flow chart of methodology

2.2.1. Calculation of LST and NDVI

Advancements in satellite technology allow for the computation of surface temperatures using thermal bands present in satellite imagery.

First step of the calculation of LST is the conversion of the digital number (DN) to spectural radiance (Lλ) for Landsat 8 and the procedure is given in the equation 1.

$$L_\lambda = \text{RadianceMultiBand} * \text{Digital Number} + \text{RadianceAddBand} \quad (1)$$

In equation 1, L_λ is spectral radiance.

After the conversation of DN to L_λ, next step is the conversation of spectral radiance to temperature given in the equation 2.

$$T_b = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)} \quad (2)$$

In equation 2; T_b= sensor brightness temperature in Kelvin, K_2 and K_1 are the calibration constant for Band 10 and Band 11 in Landsat 8 satellite. Next step is to find fractional vegetation (Fv) by using equation 3 below.

$$F_v = \left(\frac{NDVI-NDVI_{min}}{NDVI_{max}-NDVI_{min}}\right)^2 \quad (3)$$

Where $NDVI_{min}$ is minimum value of NDVI and $NDVI_{max}$ is the maximum value of NDVI.

NDVI is can be calculated by using Band 4 (Red) and Band 5 (Near infrared) for Landsat 8 satellite. It is calculated by following equation 4.

$$NDVI = \left(\frac{Band\ 5-Band\ 4}{Band\ 5+Band\ 4}\right) \quad (4)$$

Next, the land surface emissivity can be calculated with the equation 5.

$$\varepsilon = 0.004 \times F_v + 0.986 \quad (5)$$

After all procedure above LST can be calculated as equation 6.

$$LST = \frac{T_b}{1+\left(\lambda * \frac{T_b}{\alpha}\right) * ln\varepsilon} \quad (6)$$

Where λ is effective wavelength, $\alpha = h * \frac{c}{s}$ =14388 µm K, his Plank's constant, c is speed of light, ε is land surface emissivity.

3. RESULTS and DISCUSSION

3.1. Spatial-Temporal Distrubiton of LST and NDVI

LST and NDVI are important parameters used to describe the change in land surface. The LST and NDVI analysis are conducted in this study by using Landsat 8 sattellite in the years 2013-2018-2023. First, the spatial-temporal maps were created for both LST and NDVI and then the correlation analysis was made between them. Besides the average temperature changing between the years 2013 to 2023 and LST for study area are given in Figure 3. As can be detected from the Figure 3, the highest average temperature (13.5 ^{0}C) was observed in 2018 and the lowest average temperature (9.8 ^{0}C) was observed in 2023. In parallel with these values, the highest LST values (40.3) were seen in 2018 and the lowest (39.08) in 2023.

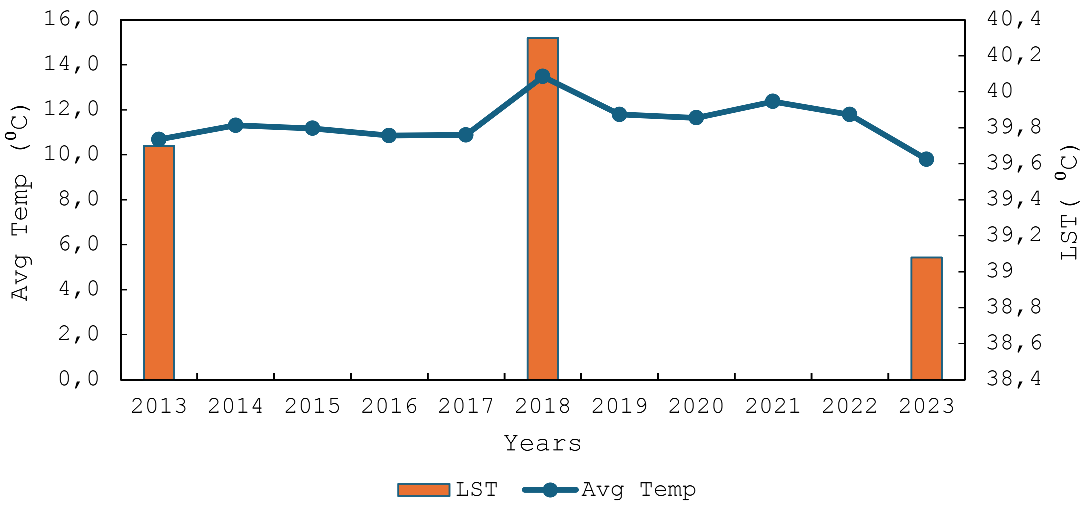

Figure 3. Average temperature and LST of Muş in studied period

The spatial-temporal maps of NDVI and LST for the years 2013-2018 and 2023 are created and given in Figure 4. With the help of Figure 4, temporal changes on a regional scale can be observed. The NDVI values ranges between -1 to 1. The highest values mean more vegetation. The scales regarding NDVI values and land surface features are given in Table 2.

Table 3. Land surface features based on the values of NDVI (Jafari & Hasheminasab, 2017)

NDVI values	Land Surface Feature
NDVI < -0.185	Water
-0.185 ≤ NDVI ≤ 0.156	Soil and very poor vegatation
0.156 ≤ NDVI ≤ 0.46	Medium vegatation
NDVI > 0.46	Dense vegatation

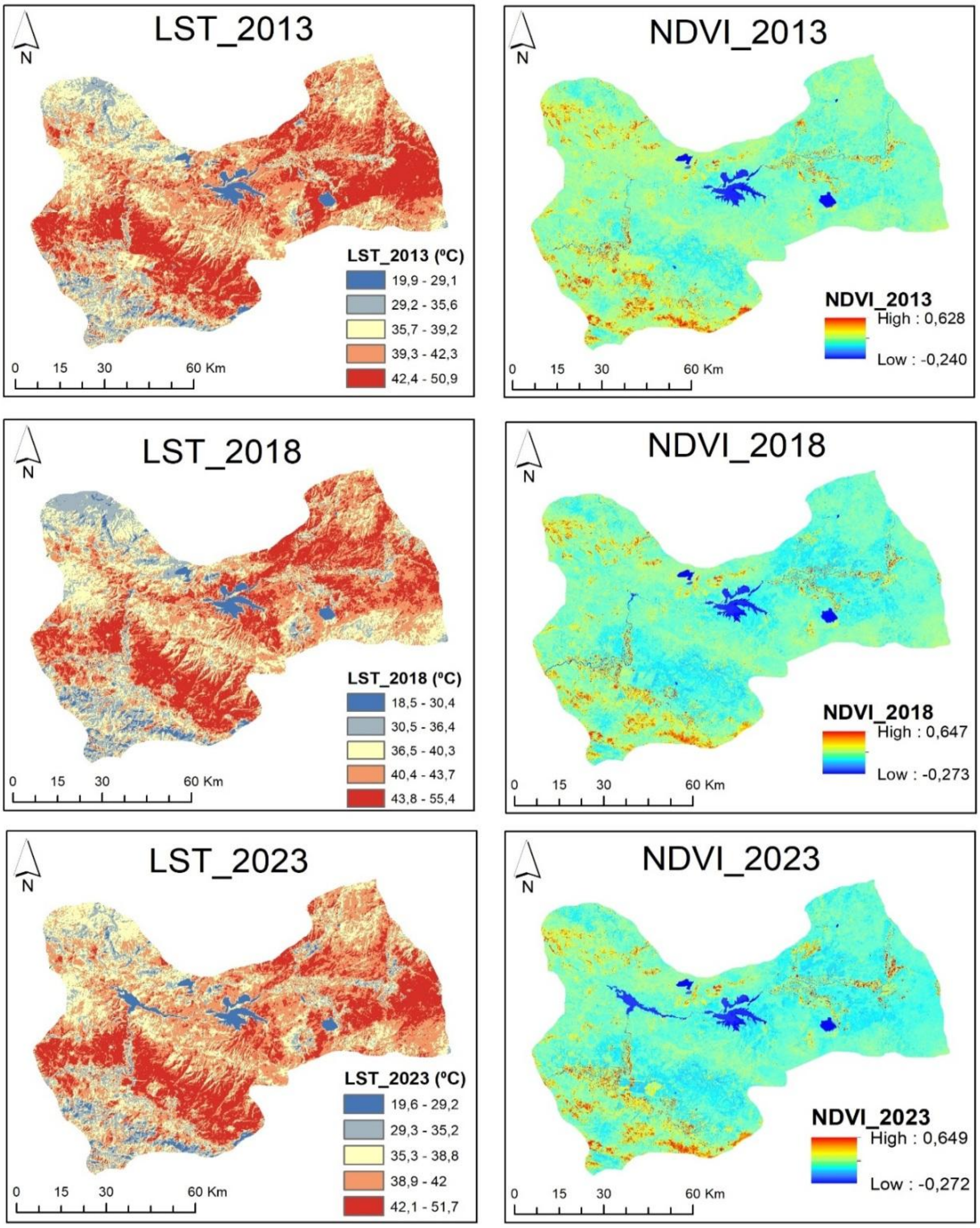

Figure 4. Spatial distribution maps of LST and NDVI

As aspected lowest NDVI values seen in water areas. The dense vegetation area mostly was observed in the southwest and northwest part of the study area. It can also seen that, the NDVI ranges from the years 2013 to 2023 didn't change alot. The NDVI values range the lowest from -0.240 to -0.272 while the highest from 0.628 to 0.649 for the years 2013 and 2023 respectively. Same observations also seen for the LST. Only the maximum LST values reached to 55.4 in 2018 while 50.9 in 2013 and 51.7 in 2023. When the LST spatial map is compared, it is seen that the LST values that observed in the northwestern part of the study area tend to decrease especially in the map of 2023. There is opened the Alparslan-2 dam in 2022. It may be the effect of the dam lake to decrease of the temperature.

3.2. Correlation analysis of LST and NDVI

Statistical spesification of LST and NDVI values for the years 2013-2018 and 2023 are given in the Table 3. The lowest NDVI value (-0.181) was observed in the year 2018 while the lowest average NDVI value (0.153) was also determined in 2018. In addition, it can be also seen from the Table 3 that the maximum LST value is 50.9 □C while the lowest LST seen in 2013 and 2023 with 21.1 □C. The average LST in 2018 is 40.3, which means a higher value than the values in 2013 and 2023.

Table 4. Statistical values of LST and NDVI

Years	**Minimum**		**Maximum**		**Mean**	
	NDVI	**LST**	**NDVI**	**LST**	**NDVI**	**LST**
2013	-0.162	21.100	0.541	47.300	0.161	39.698
2018	-0.181	21.200	0.555	50.900	0.153	40.299
2023	-0.160	21.000	0.560	48.400	0.162	39.084

A spatial distribution map of LST and NDVI was made, and then point values were determined on the map by using create fishnet section in ArcGIS. Then all values were exported into the Excel to determine the correlation. Figure 5 shows the results of the correlation between LST and NDVI. The correlation results between LST and NDVI were evaluated based on the Cohen standarts (Cohen, 1988). According to Cohen standards, correlation coefficient values between 0.10 and 0.29 indicate a weak relationship, correlation coefficient values between 0.30 and 0.49 indicate a moderate relationship, and correlation coefficient values above 0.50 indicate a strong relationship (Tonyaloğlu, 2019). It is found that, the correlation coefficient between LST and NDVI as 0.07, 0.09 and 0.07 which is weak relationship, in the years 2013, 2018, and 2023, respectively. Although, the areas where the NDVI values are low, the LST values are high (Figure 4) there is no significant correlation found between LST and NDVI values. The reason might be the seasonal changes in the LST and NDVI. (Guha, 2021) also found that seasonal changes affect the relationship between LST and NDVI. Their study also showed that dry season produced the weak correlation on the LST and NDVI. Marzban et al., (2018) studied the seasonal analysis on LST and NDVI correlation. Their findings indicated that the correlation in LST and NDVI are influenced by factors such as the season, the time of day, and the type of land cover. In addition, Sun & Kafatos, (2007) determined that there is a positive correlation between LST and NDVI in winter, whereas it becomes negative during warmer seasons.Besides, the negative correlation between LST and NDVI found in the study of (J. Tan et al., 2020; Guha & Govil, 2021).

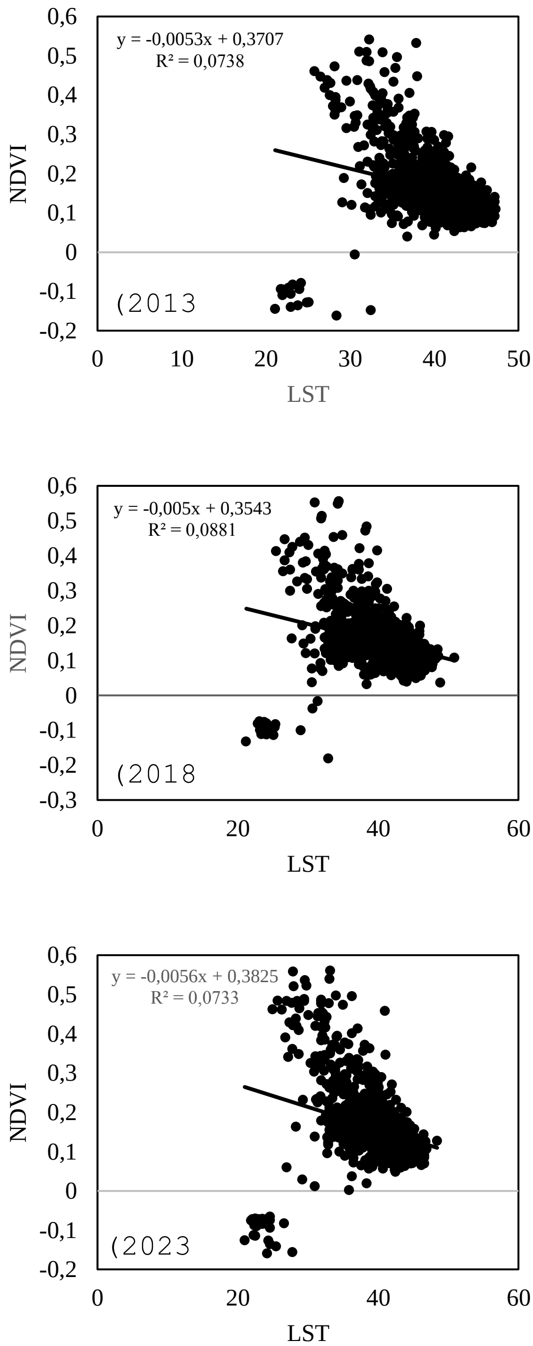

Figure 5. The scatter plot of NDVI and LST for the years 2013,2018, and 2023.

4. CONCLUSION

The spatial-temporal map of the NDVI and LST for the years 2013, 2018, and 2023 were determined using Landsat 8 satellite images for the city of Mus. When the LST changes calculated between 2013 and 2023 were examined, the regions where the changes occurred could be determined with the spatial map created. When compared the statistical results of the LST, the year 2018 produced the highest LST values than the years 2013 and 2023. In the year 2018, the lowest average (0.153) and the lowest minimum (-0.181) NDVI values has determined. The southwest and northwest part of Mus has more vegetation according to spatial map of NDVI. Although the partly areas that have low NDVI values have higher LST, overall there is no significant correlation determined between LST and NDVI. Since the correlation can not be found strong, it might be the seasonal affect. Because of this, determining the LST and NDVI with seasonal can be effective for the future study. In addition, the affect of land use land cover change over the LST and NDVI can be a recommendation for studing.

REFERENCES

1. Acar, R. (2024). Evaluation of Susurluk Basin Flows Using Trend Analysis Methods. Firat University Journal of Experimental and Computational Engineering, 3(1), 65–74. https://doi.org/10.62520/fujece.1421090
2. Amiri, R., Weng, Q., Alimohammadi, A., & Alavipanah, S. K. (2009). Spatial-temporal dynamics of land surface temperature in relation to fractional vegetation cover and land use/cover in the Tabriz urban area, Iran. Remote Sensing of Environment, 113(12), 2606–2617. https://doi.org/10.1016/j.rse.2009.07.021
3. Anbazhagan., S., & Paramasivam., C. . (2016). Statistical Correlation between Land Surface Temperature (LST) and Vegetation Index (NDVI) using Multi-Temporal Landsat TM Data. International Journal of Advanced Earth Science and Engineering, 5(1), 333–346. https://doi.org/10.23953/cloud.ijaese.204
4. Balcik, F. B. (2014). Determining the impact of urban components on land surface temperature of Istanbul by using remote sensing indices. Environmental Modelling and Assessment, 186, 859–872. https://doi.org/10.1007/s10661-013-3427-5
5. Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Lawrence Erlbaum Associates. https://doi.org/https://doi.org/10.4324/9780203771587
6. Eckert, S., Hüsler, F., Liniger, H., & Hodel, E. (2015). Trend analysis of MODIS NDVI time series for detecting land degradation and regeneration in Mongolia. Journal of Arid Environments, 113, 16–28. https://doi.org/10.1016/j.jaridenv.2014.09.001
7. Gorgani Sara, A., Panahi, M., & Rezaie, F. (2013). The Relationship between NDVI and LST in the urban area of Mashhad, Iran. International Conference on Civil Engineering Architecture & Urban Sustainable Development, November. https://www.researchgate.net/publication/265601825_The_Relationship_between_NDVI_and_LST_in_the_urban_area_of_Mashhad_Iran
8. Guha, S. (2021). Dynamic seasonal analysis on LST-NDVI relationship and ecological health of Raipur City, India. Ecosystem Health and Sustainability, 7(1). https://doi.org/10.1080/20964129.2021.1927852
9. Guha, S., & Govil, H. (2021). An assessment on the relationship between land surface temperature and normalized difference vegetation index. Environment, Development and Sustainability, 23(2), 1944–1963. https://doi.org/10.1007/s10668-020-00657-6
10. Jafari, R., & Hasheminasab, S. (2017). Assessing the effects of dam building on land degradation in central Iran with Landsat LST and LULC time series. Environmental Monitoring and Assessment, 189(2). https://doi.org/10.1007/s10661-017-5792-y
11. Julien, Y., Sobrino, J. A., Mattar, C., Ruescas, A. B., Jiménez-Muñoz, J. C., Sòria, G., Hidalgo, V., Atitar, M., Franch, B., & Cuenca, J. (2011). Temporal analysis of normalized difference vegetation index (NDVI) and land surface temperature (LST) parameters to detect changes in the Iberian land cover between 1981 and 2001. International Journal of Remote Sensing, 32(7), 2057–2068. https://doi.org/10.1080/01431161003762363
12. Jung, M., & Chang, E. (2015). NDVI-based land-cover change detection using harmonic analysis. International Journal of Remote Sensing, 36(4), 1097–1113. https://doi.org/10.1080/01431161.2015.1007252
13. Korkmaz, M. (2022). Yozgİlinin Kuraklik Araştirmasi Ve TrenAnalizi. Engineering Sciences, 17(3), 21–34. https://doi.org/10.12739/nwsa.2022.17.3.1a0479
14. Li, W., Cao, Q., Lang, K., & Wu, J. (2017). Linking potential heat source and sink to urban heat island : Heterogeneous effects of landscape pattern on land surface temperature. Science of the Total Environment, 586, 457–465. https://doi.org/10.1016/j.scitotenv.2017.01.191
15. Li, Z., Tang, B., Wu, H., Ren, H., Yan, G., Wan, Z., Trigo, I. F., & Sobrino, J. A. (2013). Remote Sensing of Environment Satellite-derived land surface temperature : Current status and perspectives. Remote Sensing of Environment, 131, 14–37. https://doi.org/10.1016/j.rse.2012.12.008
16. Li, Z., Wu, H., Duan, S., Zhao, W., Ren, H., & Liu, X. (2022). Satellite Remote Sensing of Global Land Surface Temperature : Definition , Methods , Products , and Applications. Reviews of Geophysics, 61, 1–77. https://doi.org/10.1029/2022RG000777.

17. Marzban, F., Sodoudi, S., & Preusker, R. (2018). The influence of land-cover type on the relationship between NDVI–LST and LST-Tair. International Journal of Remote Sensing, 39(5), 1377–1398. https://doi.org/10.1080/01431161.2017.1402386
18. Mercan, Ç. (2020). Yer Yüzey Sıcaklığının Termal Uzaktan Algılama Görüntüleri ile Araştırılması: Muş İli Örneği. Türkiye Uzaktan Algılama Dergisi, 2(2), 42–49. https://dergipark.org.tr/tr/pub/tuzal
19. Oke, T. R. (1982). The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society, 108(455), 1–24. https://doi.org/10.1002/qj.49710845502
20. Orhan, O., Ekercin, S., & Dadaser-Celik, F. (2014). Use of Landsat Land Surface Temperature and Vegetation Indices for Monitoring Drought in the Salt Lake Basin Area , Turkey. The Scientific World Journal, 2014. https://doi.org/http://dx.doi.org/10.1155/2014/142939
21. Sahebjalal, E., & Dashtekian, K. (2013). Analysis of land use-land covers changes using normalized difference vegetation index (NDVI) differencing and classification methods. African Journal of Agricultural Research, 8(37), 4614–4622. https://doi.org/10.5897/AJAR11.1825
22. Sekertekin, A., & Kutoglu, S. H. (2016). Evaluation of spatio-temporal variability in Land Surface Temperature : A case study of Zonguldak , Turkey. Environmental Monitoring and Assessment, 188. https://doi.org/10.1007/s10661-015-5032-2
23. Song, J., Du, S., Feng, X., & Guo, L. (2014). The relationships between landscape compositions and land surface temperature: Quantifying their resolution sensitivity with spatial regression models. Landscape and Urban Planning, 123, 145–157. https://doi.org/10.1016/j.landurbplan.2013.11.014
24. Sruthi, S., & Aslam, M. A. M. (2015). Agricultural Drought Analysis Using the NDVI and Land Surface Temperature Data; a Case Study of Raichur District. Aquatic Procedia, 4(Icwrcoe), 1258–1264. https://doi.org/10.1016/j.aqpro.2015.02.164
25. Sun, D., & Kafatos, M. (2007). Note on the NDVI-LST relationship and the use of temperature-related drought indices over North America. Geophysical Research Letters, 34(24), 1–4. https://doi.org/10.1029/2007GL031485
26. Tan, J., Yu, D., Li, Q., Tan, X., & Zhou, W. (2020). Spatial relationship between land-use / land-cover change and land surface temperature in the Dongting Lake area , China. Scientific Reports, 10(9245), 1–9. https://doi.org/10.1038/s41598-020-66168-6
27. Tan, K. C., Lim, H. S., MatJafri, M. Z., & Abdullah, K. (2012). A comparison of radiometric correction techniques in the evaluation of the relationship between LST and NDVI in Landsat imagery. Environmental Monitoring and Assessment, 184(6), 3813–3829. https://doi.org/10.1007/s10661-011-2226-0
28. Tomlinson, C. J., Chapman, L., Thornes, J. E., & Baker, C. (2011). Remote sensing land surface temperature for meteorology and climatology: A review. Meteorological Applications, 18(3), 296–306. https://doi.org/10.1002/met.287
29. Tonyaloğlu, E. E. (2019). Kentleşmenin Kentsel Termal ÇevrÜzerindekEtkisiniDeğerlendirilmesi, Efeler İncirliova (Aydin)Örneği. Turkish Journal of Landscape Research, 2(1), 1–13.
30. Ullah, W., Ahmad, K., Ullah, S., Tahir, A. A., Javed, M. F., Nazir, A., Abbasi, A. M., Aziz, M., & Mohamed, A. (2023). Analysis of the relationship among land surface temperature (LST), land use land cover (LULC), and normalized difference vegetation index (NDVI) with topographic elements in the lower Himalayan region. Heliyon, 9(2), e13322. https://doi.org/10.1016/j.heliyon.2023.e13322
31. Wang, Y. (2010). Dynamics of Land Surface Temperature in Response to Land-Use / Cover Change. Geographical Research, 49(1), 23–36. https://doi.org/10.1111/j.1745-5871.2010.00686.x
32. Yücer, E. (2023). Albedo, Yer Yüzey Sıcaklığı Ve Ndvı Arasındaki İlişkinin Landsat-7 Ve Landsat-8 Uydu Verileri Kullanılarak İncelenmesi: Safranbolu Örneği. Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi, 26(1), 177–190.