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Estimation of Land Surface Temperature of Khost Province, Afghanistan, using Satellite Remote Sensing Technologies

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ABSTRACT

One particularly important metric for examining the thermal flux and heat energy balance of land surfaces is land surface temperature (LST). It can be used for developing models of urban heat transmission, managing water resources, simulating climate change, and conducting environmental studies. This investigation focuses on determining the surface temperature of Khost province in Afghanistan, with an additional goal of assessing the correlation between the Normalized Difference Vegetation Index (NDVI) and the city's ground temperature. Utilizing data from the Landsat 8 Thermal Infrared Remote Sensor (TIRS), this study employs the Top of the Atmosphere Radiance method to estimate surface temperature. The findings indicate that the surface temperature exhibits a relatively low range of 10 to 48 °C in June 2023. Notably, areas abundantly covered with forest and vegetation manifest lower temperatures, while industrial or vegetation-deprived regions demonstrate higher temperatures, reaching up to 48 °C. The study leveraged NDVI to explore the relationship between thermal behavior and the extent of vegetation cover. Employing a regression technique, the investigation establishes a negative correlation between NDVI and LST, with the regression coefficient from NDVI to LST also being negative. In conclusion, the study determines that there is a negative correlation between NDVI and LST, highlighting the cooling effect of vegetation on surface temperatures.

Keywords: Remote Sensing, Geographical Information Systems, Land Surface Temperature, Climate Change

INTRODUCTION

The continuous loss of plant cover on Earth's surface is mostly caused by human activity (Sahana et al., 2016). As noted by (Song et al., 2021), this decrease in vegetation contributes to the rise in land surface temperature (LST). According to Song et al., one of the primary variables influencing LST is vegetation, which is a measure of the Earth's surface temperature, is an essential indicator of the ecological health of the ecosystem. (Phan et al., 2018) have underlined the importance of this component for regional and global studies on land surface processes. Land use and land cover conversion are the main causes of the rising land surface temperature (LST) seen worldwide (Moisa et al., 2022). Many investigations carried out in different parts of Ethiopia consistently support the finding of a significant rise in land surface temperature (LST) linked to modifications in land use and land cover. (Moisa et al., 2022; Wolteji et al., 2022).

The study of land surface temperature (LST) has been transformed by remote sensing technologies, which have also given researchers important new insights into the dynamics of the Earth's surface (Hussain et al., 2023). (Yang et al., 2017) provided evidence of the usefulness of thermal infrared sensors for accurate LST analysis, allowing scientists to efficiently track temperature changes at various spatial scales. The Normalized Difference Vegetation Index (NDVI) is a crucial indicator of the quantity and health of vegetation (Tucker, 1979). The negative correlation between NDVI and LST in urban settings has been the subject of research. (Yang et al., 2017) emphasized the cooling impact of plants on urban heat islands, drawing attention to this correlation. The study emphasizes how crucial green areas are to reducing localized temperature rises in urban settings. Regional studies explore the geographic-specific elements impacting the link between NDVI and LST. (Marzban et al.,2018) paper is one instance of this type of research. (Weng, 2009) talk about how surface temperature measurements can be made more reliable by integrating several sensors and techniques, such the Top of the Atmosphere Radiance approach. The observed variation in surface temperatures across different land cover types aligns with previous studies that have emphasized the impact of land use and land cover changes on local thermal behavior (Yang et al., 2017). Furthermore, the identification of a negative correlation between the

Normalized Difference Vegetation Index (NDVI) and LST is consistent with findings in various regions globally, highlighting the cooling effect of vegetation on surface temperatures (Marzban et al., 2018).

MATERIALS AND METHODS

Study Area

Khost is situated in the southeastern region of Afghanistan, sharing its borders with Pakistan to the east and south. It has a population of approximately 1.4 million people, and the total area of Khost Province is roughly 4,152 square kilometers. The average elevation varies between 1,000 to 1,500 meters above sea level. The city's geographical coordinates are approximately Latitude: 33.3336° N, and Longitude: 69.9222° E. The study area of Khost province is depicted in (Figure 1).

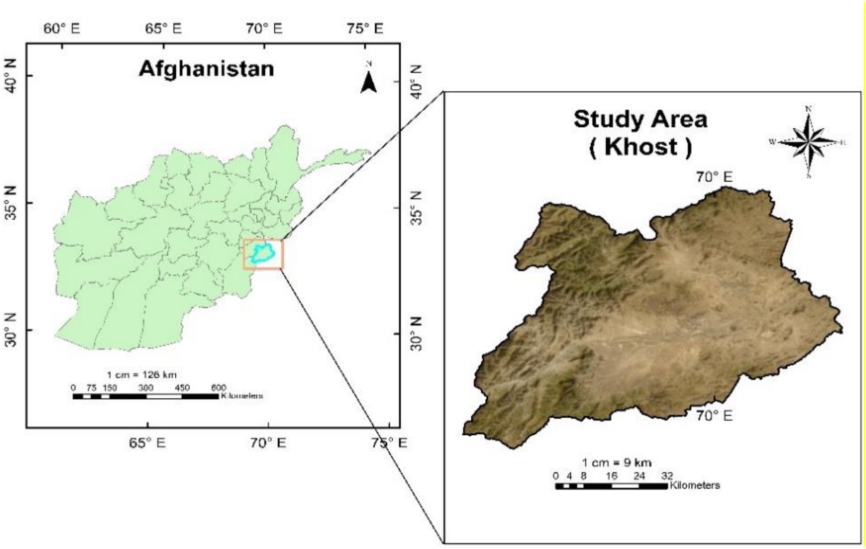

Figure 1. Shows the Study Area of Khost province, Afghanistan

Data

The current investigation employed a methodology comprising the creation of NDVI maps, retrieval of land surface temperature maps, and subsequent correlation analysis. Initial images were obtained from USGS explorer and using Landsat 8 OLI and TIRS imagery scenes were downloaded. Administrative boundaries of Afghanistan and Khost province were obtained from OCHA Afghanistan which served as the primary data sources for this research.

Normalized Difference Vegetation Index (NDVI)

A standardized algorithm called the Normalized Difference Vegetation Index (NDVI) was developed to measure how green vegetation is. The resulting NDVI values fall between -1 and 1, where a value of -1 denotes non-existence and a value of 1 denotes existence. (Figure 2) shows the NDVI image generated for the research area.

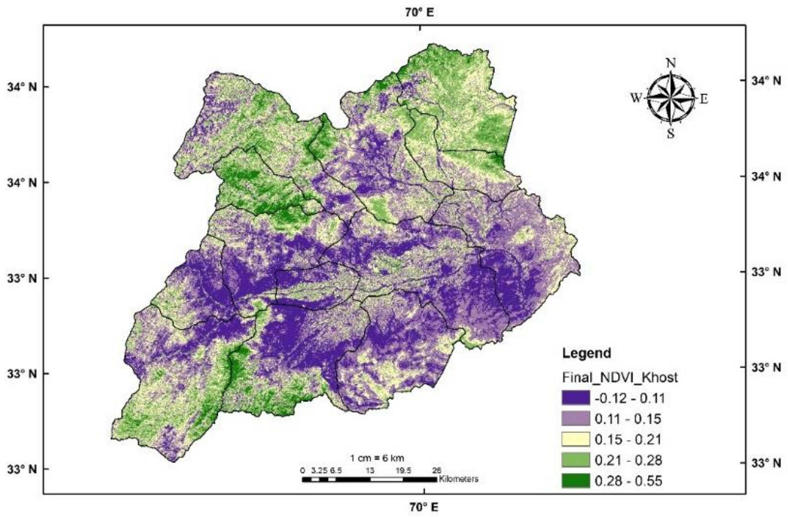

Figure 2. Shows the (NDVI) map of Khost province as of 06-29- 2023

Land surface temperature (LST) Analysis

The image processing steps using ArcMap software involved a systematic approach to derive the final map. The first crucial step was the conversion of Top of Atmosphere (TOA) reflectance values to Brightness Temperature (BT) through the formula BT = (K2 / (ln (K1 / L) + 1)) − 273.15. This conversion is vital for obtaining accurate temperature values from the satellite data. Subsequently, the proportion of vegetation (Pv) was computed using the formula Pv = Square ((NDVI – NDVImin) / (NDVImax – NDVImin)), allowing for the quantification of vegetation cover within the study area. Additionally, emissivity (ε) was determined with the formula ε = 0.004 * Pv + 0.986, which plays a crucial role in temperature estimation. Finally, the Land Surface Temperature (LST) was computed using the formula LST = (BT / (1 + (W * BT / 1.4388) * Ln (ε))), where W is set to 10.8 for Landsat 8 data. After following the above steps the final map of LST for Khost province is derived.

RESULT

The suburban areas of Khost province, which are distinguished by a lack of vegetation cover, had the highest temperatures, according to an examination of Land Surface Temperature (LST) images. experienced high temperatures in its arid regions which is shown in red color, having temperature values from 39 to 48 °C as depicted (Figure 3). On the other hand, places with vegetation cover tend to have the lowest land surface temperatures shown in dark green to light green colors ranging from 10 to 36 °C. The temperature trends in the region are significantly impacted by changes in land use, as illustrated in **(**Figure 3). The Land Surface Temperature (LST) values are higher in places with no vegetation cover, like urban or suburban areas, while the LST values are lower in places with flora, like woods and farmland in Khost province.

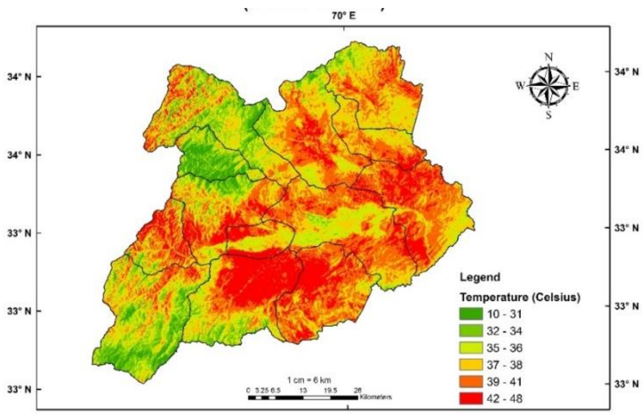

Figure 3. Shows the Land Surface Temperature map of the study area dated 06-29- 2023

There is a negative correlation between NDVI and LST, it means that where NDVI is lower, the surface has higher land surface temperature and where NDVI is higher the temperature of the surface is low. Values above 0.0 signify active vegetation, while negative values denote inactive vegetation, residential land cover, highway roads, and bare soil.

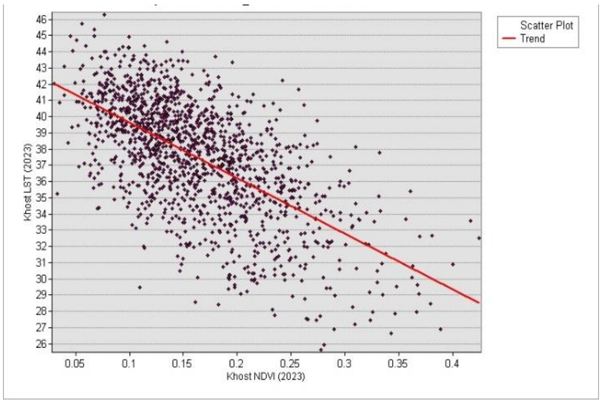

Figure 4. Shows the Correlation graph between LST and NDVI

DISCUSSION

The examination of Land Surface Temperature (LST) images, different temperature patterns may be observed in Khost province. Suburban areas with no vegetation cover have the greatest temperatures (39 to 48 °C), whereas places with vegetation cover have lower temperatures (10 to 36 °C). The cooling effect of vegetation is shown by the found negative association between the Normalized Difference Vegetation Index (NDVI) and LST, where lower NDVI values correlate with higher land surface temperatures and vice versa. Notably, urban and suburban regions exhibit higher LST values than places with dense flora, demonstrating the influence of land use on temperature trends. The study's conclusions highlight the significance of taking land cover into account when analyzing the local climate and offer insightful information for Khost's urban development and climate resilience.

CONCLUSION

This research conducted a comprehensive examination of land surface temperature (LST) in the Afghan province of Khost, utilizing information from the Landsat 8 Thermal Infrared Remote Sensor (TIRS). In June 2023, the study revealed a significant temperature range of 10 to 48 °C, showcasing diverse thermal patterns associated with different land cover types. The negative correlation found between the Normalized Difference Vegetation Index (NDVI) and LST underscored the cooling effect of vegetation on surface temperatures. The study employed cutting-edge methods, to enhance the accuracy of surface temperature estimation and deepen our understanding of how vegetation influences regional climate conditions. However, to gain a more comprehensive understanding of land surface temperature variations over the years, conducting a temporal analysis considering land use and land cover changes for the past twenty or more years would be valuable.

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Authors Contributions: Haider conceived and designed the study, conducted data collection and analysis, and preparing the draft. Hassan contributed to data interpretation, and actively participated in critical discussions.

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