



Investigating and estimating the radiation balance of climate change using Landsat satellite image series (Case study: Aslandoz Township)

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Abstract

Background and Objective: Studies show that the role of thermal remote sensing in the study and estimation of land surface temperature is very important. Land surface temperature is a very important indicator in the study of energy balance models at the land surface on a regional and global scale. Given the limitations of meteorological stations, remote sensing can be a suitable alternative for estimating land surface temperature. The main goal of this research is to monitor land surface temperature using satellite images in the years 2003, 2013, and 2023. For this purpose, the relevant images were first obtained and the necessary pre-processing was applied to each. Then, modeling and determination of the radiation and heat balance of the images were carried out. Finally, in order to monitor land surface temperature, a surface temperature map of Aslandoz Township was extracted.

Methodology: In this study, Landsat satellite images from 2003, 2013, and 2023 were used to investigate and assess the feasibility of using solar radiation energy. ENVI software was used to perform the relevant calculations, and ArcGIS software was used to prepare the map. One of the applications of thermal images is to prepare thermal maps to determine isothermal zones.

Results and Findings: The results showed that in 2003, the earth's surface temperature increased from 40.10 to 42.49 in 2013, and finally, due to climate change and rapid and severe human intervention in nature, it increased sharply to 49.92 in 2023. The results showed that areas with high vegetation cover and water areas had low temperatures, and areas without vegetation had the highest temperatures each year. This indicates that this human intervention, the destruction of forests and pastures, and the expansion of the city have also increased the concentration of heat compared to 20 years ago. Because vegetation has always been a barrier to heat, has a moderating moisture, and also has an inverse relationship with the temperature of the earth's surface.

Keywords: Radiation balance, climate change, earth's surface temperature, Aslandoz, Landsat images.

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EXTENDED ABSTRACT

Introduction

Climate change and its consequences, particularly the steady increase in land surface temperature (LST), have emerged as critical challenges for human settlements worldwide. Land surface temperature serves as a fundamental indicator for studying energy balance models at regional and global scales, providing essential information about interactions between the Earth's surface and the atmosphere. Urban and peri-urban areas experience intensified heating through the Urban Heat Island phenomenon, where built environments become significantly warmer than surrounding rural areas due to reduced vegetation cover, increased impervious surfaces, and greater absorption of solar radiation. While meteorological stations have traditionally provided temperature measurements, their sparse distribution creates fundamental gaps in understanding LST patterns across heterogeneous landscapes. Remote sensing technology, particularly thermal infrared remote sensing, has emerged as a powerful alternative for estimating land surface temperature with extensive spatial coverage and consistent temporal resolution, enabling systematic monitoring of temperature variations and their relationship with land surface characteristics. This research focuses on Aslandoz County, located in the Moghan Plain within Ardabil Province in northwestern Iran, a region characterized by Mediterranean to warm climate conditions with very hot summers and moderate winters. The county has experienced significant environmental transformations over the past two decades, making it an excellent case study for examining climate change impacts in semi-arid environments where water scarcity, agricultural dependence, and ecological sensitivity converge. The primary objective of this research is to monitor land surface temperature dynamics using multi-temporal Landsat satellite imagery for the years 2003, 2013, and 2023. Specifically, this study aims to model radiation and heat balance from Landsat thermal data, analyze spatiotemporal patterns of LST changes over the twenty-year study period, investigate the relationship between vegetation cover and surface temperature variations, and assess the implications of observed temperature trends for environmental planning and sustainable development in the region.

Methodology

Aslandoz County is situated in northern Ardabil Province between latitudes 39°25' to 39°33' N and longitudes 47°22' to 47°47' E, encompassing approximately 160 km² with the city of Aslandoz located at 160 meters above sea level along the Aras River. The region experiences extremely hot summers with temperatures frequently exceeding 35°C and mild winters, with precipitation primarily influenced by moisture from the Caspian Sea and cold air masses from northern latitudes. This study utilized Landsat satellite imagery acquired during summer months for three time periods: Landsat 5 TM for 2003, Landsat 7 ETM+ for 2013, and Landsat 8 OLI/TIRS for 2023. All images were selected based on minimal cloud coverage, downloaded from the USGS Earth Explorer portal, and subjected to radiometric calibration, atmospheric correction using the FLAASH algorithm, and geometric correction to ensure accurate spatial registration across all time periods. Land surface temperature was estimated using the radiative transfer equation method adapted for each Landsat sensor. Spectral radiance at the sensor was calculated from digital numbers, at-sensor brightness temperature was

derived using the inverse Planck function, and land surface emissivity was estimated using the Normalized Difference Vegetation Index (NDVI) threshold method. Net radiation balance components were modeled to understand the energy budget at the land surface. Spatial analysis and map production were conducted using ENVI 5.3 and ArcGIS 10.8 software packages, with LST maps classified into appropriate temperature intervals to visualize spatial patterns and temporal changes. Descriptive statistics and temperature change detection through image differencing were performed, and the relationship between vegetation cover and LST was examined through comparative analysis of temperature values in areas with varying NDVI classifications.

Results and Findings

The analysis of Landsat imagery revealed substantial and accelerating increases in land surface temperature across Aslandoz County over the twenty-year study period. In 2003, LST values ranged from 22.70°C to 40.10°C, with the highest temperatures concentrated in barren lands and sparsely vegetated areas. By 2013, LST values had increased significantly to range from 23.70°C to 42.49°C, representing a mean temperature increase of approximately 2.39°C, with particularly pronounced warming observed in peri-urban areas and rain-fed agricultural lands converted from natural rangelands. The most dramatic temperature escalation occurred between 2013 and 2023, with LST values ranging from 26.43°C to 49.92°C, representing an unprecedented increase of 7.43°C in maximum temperature over a single decade and a total increase of 9.82°C over the entire study period. Consistent patterns emerged across all three study periods regarding the relationship between land surface characteristics and temperature distribution. Areas with dense vegetation cover and water surfaces consistently exhibited the lowest LST values, maintaining temperatures 8-12°C lower than adjacent barren lands. Conversely, areas devoid of vegetation cover—including barren lands, degraded rangelands, and built-up surfaces—consistently recorded the highest temperatures each year. The urban heat island intensity increased from approximately 2.5°C in 2003 to 5.8°C in 2023. The observed LST increases reflect the compound effects of background climate change and intensive local human interventions including deforestation, conversion of rangelands to agriculture, and urban expansion, which have progressively diminished the region's natural thermal regulation capacity. The accelerating warming trajectory suggests that positive feedback loops between vegetation loss and temperature increase have become firmly established in the study area.

Conclusion

This research provides compelling evidence of substantial and accelerating land surface temperature increases in Aslandoz County, with maximum temperatures rising from 40.10°C in 2003 to 49.92°C in 2023—a warming trajectory of approximately 0.5°C per year that far exceeds global and regional background rates. The findings demonstrate unequivocally that vegetation cover serves as the primary natural mechanism for thermal regulation in this semi-arid environment, and that progressive vegetation removal through anthropogenic activities has severely compromised this regulatory capacity. Continued warming at current rates would have catastrophic consequences for

agricultural productivity, water resource availability, ecosystem integrity, and human habitability in the region, threatening food security, intensifying water scarcity, and creating increasingly challenging conditions for human settlement. Based on these findings, urgent measures are required to protect and restore vegetation cover throughout the county, including reforestation of degraded riparian corridors, conservation of remaining natural vegetation, and integration of green infrastructure into urban development. Land use planning regulations should restrict further conversion of natural and agricultural lands to built-up uses, while urban development should adopt heat mitigation strategies including cool surfaces, urban forestry, and water-sensitive design. This study demonstrates the considerable value of remote sensing technologies for environmental monitoring in data-sparse regions and provides a replicable methodology for LST assessment across similar semi-arid environments. Future research should extend this analysis to longer time series, incorporate additional environmental variables, and develop predictive models to support evidence-based climate change adaptation strategies.

Declarations

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Conflict of Interest: The authors declare no conflict of interest.

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