



Estimation of radiant flux and radiation balance in the summer months for electricity supply to villages in Chalus Township using Landsat satellite images

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Abstract

Background and Aim : City furniture is actually a manifestation of the aesthetics and identity of a society. Therefore, functional design, appropriate location, and proper and principled use of furniture in the city context are very important. Although city furniture is one of the most important categories of a city, it is not possible to equip and improve the current situation of this important thing at a time and simultaneously in all regions of a city; therefore, a comparative comparison in this regard can be effective and help urban managers perform better and make decisions in accordance with the priority of intervention at the level of each region. On this basis, the present study has been developed with the aim of a comparative study of the regions of Tabriz metropolis based on the components of city furniture.

Methodology: For this purpose, the relevant images were first obtained and the necessary pre-processing was applied to each. Then, the images were modeled. Initially, images from the year 2023 of the Landsat 8 satellite, the OLI sensor and the TIRS sensor, and the Sebal algorithm were used to conduct this research. ENVI software was used for geometric, atmospheric and radiometric corrections of satellite images and also for performing calculations related to the SEBAL model, and ArcGIS software was used for creating a database, spatial analyses, cartographic operations and finally implementing the model.

Results and Findings: The results show that the average of the highest incoming shortwave radiation was 769 watts per square meter in September and the lowest value was in the next month of August with 730 watts per square meter. And the lowest value was in July with 555 watts per square meter. The reason for this difference in radiation power in the amount of net radiation reaching the ground in the study area is due to the difference in the angle of the sun's rays and the number of sunny hours in different months of the year. It can be concluded that solar radiation from the radiation threshold to 1000 watts per square meter is received, it can be concluded that solar radiation and radiation balance in the villages of Chalus Township have the potential to provide electricity in a suitable way

Key words Radiant flux, discrete window algorithm, land surface temperature, Chalus, Landsat images.

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EXTENDED ABSTRACT

Introduction

Access to reliable and sustainable energy sources represents one of the fundamental challenges for rural development in the twenty-first century. Solar energy, as a clean, renewable, and increasingly cost-effective energy source, offers particular promise for addressing electricity needs in rural areas with appropriate solar radiation characteristics. Land surface temperature (LST) and radiation balance components provide essential information for assessing the viability of solar energy utilization, particularly photovoltaic electricity generation. Remote sensing technology, especially thermal infrared remote sensing, has emerged as a powerful tool for estimating land surface temperature and radiation fluxes across extensive geographical areas, overcoming the spatial limitations of meteorological station networks. The Surface Energy Balance Algorithm for Land (SEBAL) and split-window algorithms enable accurate retrieval of LST and radiation components from satellite imagery, facilitating renewable energy potential assessment in data-sparse regions. This research focuses on Chalus County, located in the southern Caspian Sea region of Mazandaran Province, northern Iran. The county encompasses approximately 1,600 km² of diverse terrain spanning from Caspian coastal lowlands to the forested slopes of the Alborz Mountains. This geographical diversity, combined with the region's climatic characteristics and the presence of numerous rural settlements with limited grid connectivity, makes Chalus County an appropriate case study for assessing solar radiation potential for rural electrification. The primary objective of this research is to estimate radiant flux and radiation balance components during summer months using Landsat 8 satellite imagery and the SEBAL algorithm, with the specific aim of evaluating the feasibility of photovoltaic electricity generation in the county's rural areas.

Methodology

Chalus County is situated in the southern coastal zone of the Caspian Sea, with its northern and central portions containing the majority of settlement and economic activities connected by transportation corridors. The county is characterized by substantial forest cover on the Alborz Mountain slopes, along with rangeland and barren areas, creating diverse land surface conditions for radiation balance assessment. This study utilized Landsat 8 OLI/TIRS satellite imagery acquired during the summer months of 2023, specifically June, July, August, and September. Images were selected based on minimal cloud coverage and optimal atmospheric conditions, downloaded from the USGS Earth Explorer portal, and subjected to geometric, atmospheric, and radiometric corrections using ENVI software. Land surface temperature was retrieved using the split-window algorithm, which effectively minimizes atmospheric effects by utilizing two thermal bands. The methodology involved several sequential steps: calculation of at-sensor spectral radiance, derivation of brightness temperature using the inverse Planck function, estimation of land surface emissivity based on NDVI thresholds, vegetation fraction calculation, and final LST retrieval. Net radiation components were modeled using the SEBAL algorithm, with particular emphasis on incoming shortwave radiation as the primary parameter for photovoltaic potential assessment. Spatial analysis and map production were conducted using ArcGIS

software, with radiation flux maps generated for each summer month to characterize seasonal patterns and identify areas with optimal solar radiation characteristics for electricity generation.

Results and Findings

The analysis of Landsat 8 imagery and SEBAL algorithm implementation revealed substantial solar radiation potential across Chalus County during the summer months of 2023. Incoming shortwave radiation values demonstrated considerable monthly variation, with the highest mean values observed in September at 769 watts per square meter, followed by August at 730 watts per square meter. July exhibited the lowest mean incoming shortwave radiation at 555 watts per square meter. The spatial distribution of net radiation showed distinct geographical patterns, with the northern and central portions of the county, including the vicinity of Chalus city, receiving the highest radiation fluxes. These spatial variations are primarily attributable to differences in solar incidence angle, topographic shading effects, and the number of sunny hours across different summer months. The net radiation distribution maps revealed that during August, the predominant net radiation values ranged from 660 to 730 watts per square meter, while September demonstrated the most favorable conditions with the majority of the county receiving 700-769 watts per square meter. Even during July, the month with lowest radiation, net radiation values predominantly fell within the 491-555 watts per square meter range, with minimal areas receiving below 341 watts per square meter. Throughout all summer months, the radiation values consistently exceeded the operational threshold sensitivity of photovoltaic cells, which typically respond to solar radiation from threshold levels up to 1000 watts per square meter. This indicates that Chalus County possesses technically suitable solar radiation conditions for photovoltaic electricity generation throughout the summer season, with September representing the optimal period.

Conclusion

This research demonstrates that Chalus County receives substantial and technically viable solar radiation during summer months, with mean incoming shortwave radiation ranging from 555 to 769 watts per square meter across June through September. These values consistently exceed the minimum threshold requirements for photovoltaic electricity generation, indicating significant potential for solar energy development in the county's rural areas. The spatial analysis reveals that the northern and central portions of the county, where the majority of rural settlements are concentrated, exhibit the most favorable radiation characteristics, suggesting advantageous geographical coincidence between energy demand centers and supply potential. The SEBAL algorithm and split-window methodology proved effective for radiation balance assessment using Landsat 8 imagery, providing a replicable framework for renewable energy potential studies in other regions.

Declarations

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

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