The Impact of Urbanization on Earth's Surface Temperature
Exploring Solutions for Sustainable Urban Planning

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Abstract

The ongoing urbanization process throughout Calgary (our study area) has led to significant changes in the Calgary's surface temperature, contributing to health risks, damage to ecosystems and overall global warming, through increased emissions of greenhouse gases, increased energy consumption, and air quality degradation. This capstone project investigates the impact of urbanization on land surface temperatures (LST) in Calgary, utilizing remote sensing data to analyze the relationship between urban landscape configurations and LST. By examining various indices such as the Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI), this research aims to highlight how urban planning can mitigate temperature increases and improve urban liveability. Preliminary findings identify significant temperature variances across different neighborhoods, underlining the importance of sustainable urban design in addressing climate change effects.

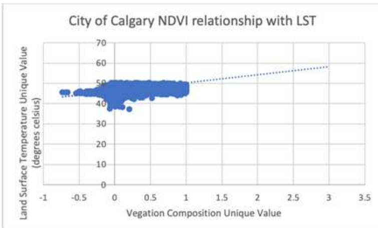
Introduction

- Urbanization leads to increased land surface temperatures (LST) locally and globally.
- Global temperature increases due to emissions of carbon dioxide and other greenhouse gasses from human energy consumption and other activities inside of urban areas, contributing significantly to global warming.
- With over half the world's population living in cities, urban planning offers a significant opportunity for temperature regulation.
- Understanding the association between built-up area urban configuration and surface temperature because it helps identify environmental problems due to increases in surface temperature and it will help with making informed decisions toward improving liveability of cities and the safety and wellbeing of citizens
- We plan on using remote sensing data to understand the role of the structure and composition of urban landscapes in determining the land surface temperature.
- Our study area is Calgary.

Results

To assist in estimating LST and analyzing and explaining its relationship to built-up areas, so far, the following data has been collected:

- Heat/intensity maps showing land surface temperatures, Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Water Index (NDWI) across Calgary
- A list of the observed "warmest neighborhoods". These include Sage Hill, Evanston, Carrington, Edgemont and more.
- A list of the observed "coolest neighborhoods". These include sub residential areas like 13° and parks such as the Alpine Park.
- Correlation plots showing the each of the correlations between LST and NDBI, NDVI, and NDWI respectively. One of these is displayed below:



Correlations between LST and NDVI [1]

Discussion

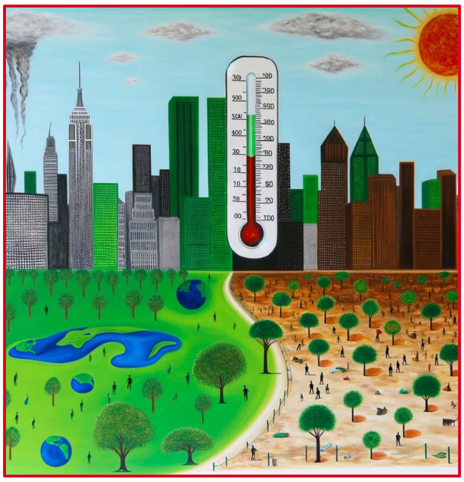
The correlation between urban configurations and increased land surface temperature (LST) is starkly evident in the temperature disparities observed across Calgary's neighborhoods. The contrast between the warmest areas, typically marked by dense built-up environments, and the cooler regions, often abundant in vegetation or water bodies, underscores the critical role of urban greenery, water features, and building materials in local climate regulation. However, this raises several questions for the broader community:

- How can urban planners more effectively incorporate green spaces within city landscapes to combat the urban heat island effect? What can communities do to reduce the urban heat island effect? Considering the cooling benefits of parks, trees, and water bodies, what innovative strategies could be employed to integrate these elements into densely built-up areas?
- What are the implications of our findings for future urban development? In light of the significant temperature variations between different urban configurations, how can new developments prioritize temperature regulation and sustainability from the outset?

The relationship between NDVI, NDWI, NDBI, and LST further illustrates the complex dynamics between urbanization and the thermal environment, suggesting that a multifaceted strategy is necessary to mitigate urban heat island effects. As cities continue to grow, the urgency for sustainable urban planning becomes ever more apparent.

Conclusions

This study conclusively demonstrates the significant impact of urbanization on local and global temperatures, with specific insights into the Calgary context. By leveraging advanced remote sensing data and GIS analysis, it identifies the stark temperature contrasts between different urban configurations, highlighting the urgent need for sustainable urban planning practices. The research emphasizes the potential of incorporating green spaces, optimizing water body distribution, and selecting appropriate building materials to mitigate the urban heat island effect. Ultimately, this study calls for an integrated approach to urban design that considers the environmental implications of development, aiming to create more liveable, cooler urban environments in the face of global warming challenges.



Methods and Materials

- Using data from USGS Earth Explorer, obtain intensity raster files, shapefiles and Landsat 8 bands for LST, NDVI, NDWI and NDBI.
- Using QGIS compute Top of Atmosphere (TOA), Brightness Temperature (BT), (NDVI), Proportion of Vegetation (Pv), Emissivity (E), LST, NDWI, NDBI and other relevant data using researched formulas.
- Generate heat maps using data obtained.
- Extract values for creating correlation plots in Excel.
- Create scatter plot combinations for LST & NDBI, LST & NDVI, LST & NDWI to visualize relationships.
- Add trendlines to these scatter plots to analyze the correlation between LST and the respective indices.
- Calculate the mean and sum of NDBI, NDVI, LST, NDWI values for each neighborhood within the study area.
- Identify neighborhoods with the highest and lowest mean temperatures and overall net temperatures.
- Determine neighborhoods containing absolute highest and lowest temperature values.

References

1. Shoro, M. Moradians, G. Onyegbutulem, A. (2024). The Impact of Urbanization on Earth's Surface Temperature [Unpublished school project]. University of Calgary.
2. I. R. Ejiagha, M. R. Ahmed, Q. K. Hassan, A. Dewan, A. Gupta, E. Rangelova et al., "Use of remote sensing in comprehending the influence of urban landscape's composition and configuration on land surface temperature at neighbourhood scale," MDPI

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