**Geo-Spatial Approach for Urban Green Space and Environmental Quality Assessment: A Case Study in Addis Ababa City**

The use of urban green spaces as an indicator of urban environmental quality in Addis Ababa, Ethiopia. Rapid infrastructural growth and increasing population have negatively impacted city quality globally. To assess this, the study combines natural indicators from remote sensing data with socio-economic variables from census data.

Various parameters including land-use/land-cover, surface temperature, and vegetation index from Landsat images (1986, 2000, and 2015) were analyzed. Socio-economic factors like population density and greenhouse gas emissions (2012) were also considered. Regression, factor, and overlay analyses were conducted on these integrated variables. Four factors - greenness, crowd, heat island, and greenhouse gas emissions - were identified. Weighted factors, along with green space proportions, yielded maps for land-use, environmental risk, and environmental quality index.

Results revealed declining environmental quality in the study area. The paper suggests including more parameters in future studies for a comprehensive understanding of urban greenness changes. Addressing adverse effects of development-induced high density and reduced green areas is recommended.

Background Information

The deterioration of urban environmental quality in developing regions has become a pressing concern due to the challenges posed by increasing human-induced pressures and rapid population growth. Urban areas, particularly large cities, are struggling to manage various types of pressures associated with high human density. Achieving a sustainable urban environment relies on multiple factors, encompassing social, economic, cultural, physical, and emotional dimensions. Among these factors, the presence and extent of urban green spaces and vegetation cover play a crucial role in maintaining a balanced and high-quality urban environment.

Urban green spaces refer to outdoor areas with vegetation cover, including trees, bushes, ornamental plants, and grass. These spaces encompass a variety of settings such as parks, squares, tree-lined roads, groves, and landscaped areas within public or private properties. In many megacities globally, parks and open spaces contribute significantly to enhancing environmental quality by providing diverse green spaces. The positive effects of urban greenery extend to environmental, aesthetic, recreational, and economic benefits for city residents. Vegetation contributes to improved air quality, temperature regulation, and aesthetic appeal through processes like photosynthesis, shading, and evapotranspiration.

The presence of urban green areas has been linked to various advantages, including improved air quality, reduced noise and air pollution, and enhanced aesthetic appeal. As a fundamental component of urban ecosystems, the development of green spaces plays a pivotal role in city planning, directly impacting the environment and residents' quality of life. However, due to the multifaceted nature of urban environmental quality, a single indicator is insufficient to capture its complexity. It necessitates the integration of various elements such as greenery, built-up areas, carbon emissions, temperature, humidity, waste management, accessibility to major roads, and population density.

The challenge in assessing urban environmental quality lies in modeling and predicting the interactions among these diverse variables. The integration of Remote Sensing (RS) and Geographical Information System (GIS) techniques has emerged as a powerful approach to addressing this challenge. Remote Sensing offers the advantage of capturing spatial, spectral, and temporal data over large and inaccessible areas, facilitating the assessment and monitoring of urban greenery. Satellite imagery, equipped with multi-spectral capabilities, provides valuable insights into ecosystem components and environmental interactions. The synergy of Remote Sensing with GIS allows for the integration of remote sensing data with socio-economic variables and on-site information, enhancing the relevance of remote sensing monitoring in evaluating urban environmental quality.

The current research focuses on analyzing the distribution of urban green areas and vegetation density as key indicators for improving air quality and enhancing urban environmental quality. Simultaneously, factors such as building density, population density, temperature, humidity, waste management, road accessibility, and carbon emissions are considered as major indicators of environmental degradation within the city. Understanding the causal factors behind these dynamics is crucial for assessing and promoting sustainable urban environmental quality. The research aims to map urban green spaces and evaluate the environmental quality of ten sub-sites within Addis Ababa by leveraging remote sensing satellite imagery and secondary data sources.

Potential Data Sources

The research on urban environmental quality and the assessment of urban green areas in Addis Ababa, Ethiopia, relies on a combination of data sources that provide valuable information about both the physical and socio-economic aspects of the city. These data sources include:

* Remote Sensing Satellite Imagery: Satellite images acquired by remote sensing technology serve as a primary data source for capturing spatial information about the urban environment. The study utilizes Landsat images from different years (1986, 2000, and 2015) to observe changes in land use, land cover, and vegetation over time. The multi-spectral capabilities of remote sensing imagery enable the analysis of various environmental parameters, such as normalized difference vegetation index (NDVI) and surface temperature.
* Census Data: Socio-economic variables that contribute to the assessment of urban environmental quality are derived from census data. Population density, which provides insights into human density within the city, is an essential parameter for understanding urban dynamics. Additionally, census data can be used to analyze factors like accessibility to major roads and waste disposal patterns.
* Geographical Information System (GIS) Data: GIS data layers provide geospatial information that can be integrated with remote sensing data for a comprehensive analysis. This may include data on administrative boundaries, road networks, and other urban infrastructure, enhancing the contextual understanding of the study area.
* Environmental Parameters: Data related to various environmental parameters are utilized to assess the quality of the urban environment. These parameters may include temperature, humidity, and carbon emissions. Monitoring these factors helps identify areas with potential environmental stressors or degradation.
* Previous Studies and Reports: Existing research studies, reports, and publications related to Addis Ababa's urban environment and green spaces can contribute valuable insights and context to the current research. These sources may provide historical trends, policy information, and relevant findings that enhance the overall analysis.
* Land-Use/Land-Cover Data: Land-use and land-cover data provide information about how different areas within the city are utilized, whether for residential, commercial, industrial, or recreational purposes. These data layers are crucial for understanding the spatial distribution of urban green areas and built-up spaces.
* Green Space Inventories: Inventories of urban green spaces, parks, squares, and other vegetated areas within Addis Ababa contribute to identifying and quantifying the extent of available greenery. This information aids in evaluating the availability of green spaces for city residents.
* Climate Data: Climate data, including historical weather patterns and temperature records, can provide additional context for understanding the impact of urban greenery on local climate and temperature regulation.

By integrating these diverse data sources, the research aims to create a comprehensive and holistic understanding of urban environmental quality in Addis Ababa. The combination of physical, socio-economic, and environmental parameters allows for a robust assessment of the city's green spaces and their contribution to overall environmental well-being.

Planned Methods

The research employs a range of methods to assess and evaluate the urban environmental quality in Addis Ababa, with a specific focus on urban green areas. These methods include:

* Image Processing and Analysis: Remote sensing satellite imagery, such as Landsat images from different years (1986, 2000, and 2015), are processed and analyzed using image processing techniques. This involves the extraction of key parameters, such as the Normalized Difference Vegetation Index (NDVI) and surface temperature, to quantify vegetation cover and thermal patterns within the city.
* Data Integration: Geographic Information System (GIS) technology is utilized to integrate remote sensing data with socio-economic variables derived from census data. This integration enables the correlation of spatial patterns of urban greenery with population density, building density, carbon emissions, and other socio-economic factors.
* Regression Analysis: Regression analysis is applied to identify relationships between urban greenery (vegetation density) and various socio-economic indicators. This helps quantify the impact of factors like population density, building density, and carbon emissions on the distribution and quality of green spaces.
* Factor Analysis: Factor analysis is conducted to categorize and interpret key factors influencing urban environmental quality. Factors such as greenness, crowd (population-related factors), heat island (temperature-related factors), and greenhouse gas emissions are derived and used to evaluate the overall environmental quality of different sub-sites.
* Overlay Analysis: Overlay analysis involves layering different spatial datasets, such as greenery distribution, land-use/land-cover, and socio-economic variables. By combining these layers, the analysis identifies areas where positive or negative interactions between factors occur, contributing to a more comprehensive assessment of environmental quality.
* Weighted Analysis: Different weights are assigned to the identified factors (greenness, crowd, heat island, greenhouse gas emission) based on their relative importance. This weighted approach allows for a nuanced evaluation of the overall environmental quality index for specific sub-sites within Addis Ababa.
* Mapping and Visualization: The results of the analysis are translated into maps and visual representations that depict the spatial distribution of urban greenery, environmental risk, and environmental quality index. These maps provide a clear visual understanding of the variations across the city.
* Temporal Analysis: Changes in urban green areas and environmental quality over time (from 1986 to 2015) are examined through temporal analysis of the remote sensing data. This analysis helps identify trends and patterns of change in greenery and environmental conditions.
* Comparative Analysis: The study involves a comparative analysis of the assessed data across the ten sub-sites of Addis Ababa. This allows for a localized evaluation of environmental quality and greenery distribution within different areas of the city.
* Recommendations: Based on the findings, the research provides recommendations for urban planning and policy interventions. These recommendations aim to mitigate the adverse effects of development activities, promote sustainable urban greenery, and enhance overall environmental quality.

By employing these planned methods, the research aims to provide a comprehensive understanding of the relationship between urban green areas and environmental quality in Addis Ababa, contributing valuable insights for sustainable urban planning and development.

Expected Results

The anticipated outcomes of this study on urban environmental quality and urban green areas in Addis Ababa, Ethiopia, are multifaceted and hold significant potential for understanding and improving the city's overall well-being. The primary goal of this research is to shed light on the complex interplay between urban development, green spaces, and environmental quality in a rapidly growing and evolving urban setting.

One of the key outcomes expected from this study is the detailed spatial distribution of urban greenery across the ten sub-sites of Addis Ababa. Through the analysis of remote sensing satellite imagery, the study aims to generate comprehensive maps that highlight the varying degrees of vegetation cover within the city. These maps will not only showcase areas abundant in green spaces, such as parks, squares, and tree-lined streets, but also unveil zones with limited greenery, thus aiding in the identification of spatial patterns and potential disparities.

In addition to spatial mapping, the research endeavors to create an Environmental Quality Index (EQI) for each sub-site by integrating a range of natural parameters and socio-economic variables. This index will serve as a quantitative measure of the overall environmental quality of different areas within the city. By considering factors such as vegetation density, building density, carbon emissions, and more, the EQI will provide a comprehensive insight into the city's environmental health and resilience.

Furthermore, this study seeks to identify areas within Addis Ababa that may be experiencing a decline in environmental quality. By analyzing factors like high building density, population density, and carbon emissions in conjunction with inadequate greenery, the research aims to pinpoint zones that are potentially facing environmental degradation. This identification of areas of concern can guide targeted interventions and policies to address specific challenges.

The temporal dimension of the study is also expected to yield valuable insights. Through the analysis of remote sensing data spanning from 1986 to 2015, the research will uncover temporal trends in urban greenery and environmental quality. This historical perspective can reveal shifts and changes that have occurred over the years, providing a deeper understanding of the city's evolving environmental dynamics.

As an outcome with significant practical implications, the research is poised to offer informed policy recommendations to local authorities and urban planners. These recommendations may encompass strategies to enhance urban greenery, manage population density, control carbon emissions, and improve overall environmental quality. Such guidance can contribute to more sustainable urban development practices and foster a healthier and more livable urban environment.