

Sustainable Urban Development Model (Example of Resort Akhtala)

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Abstract The article presents the results of dissertation research on anthropogenic processes within the natural-territorial complex of Akhtala resort. This interdisciplinary study employed remote sensing methods to assess the extent of environment changes occurring within the framework of urban development.

By synthesizing research methods from various disciplines and adapting them to the specific context of Akhtala, we developed essential documentation, a geodatabase, a comprehensive planning guide, development strategies, and monitoring mechanisms.

The findings from this approach can be applied to similar complexes. The integration of advanced technologies facilitated the acquisition of detailed information about the research area.

Depending on the researcher's objectives, these methods can be utilized to create strategic development plans, implement action plans, or ongoing monitoring processes.

The research aimed to analyze the dynamics of natural and anthropogenic changes in the Akhtala resort area, by applying sustainable urban development principles. The goal was to mitigate or limit factors contributing to global challenges.

The anthropogenic landscape has intensified due to rapid urbanization over the past decade. The research focused on developing strategies to counteract the negative impacts of urbanization, driven by population growth. This issue has emerged as a significant obstacle to sustainable urban development.

Key words: Anthropogenic, Urbanization, Green space, Land use, Resort Akhtala,

Natural-territorial complex, Satellite photos, Information digitization, Buffer, Environment, Degradation, Erosion, Territorial planning, Creative planning, Rational land use.

Introduction

The research was conducted to fulfill the requirements for a Ph.D. at Georgia Technical University. A dissertation titled "Urban Green Spaces Dynamics (Example of Gurjaani City)" was produced within the scope of this study. The primary objective was to analyze the dynamics of anthropogenic factor changes within the natural-territorial complex and evaluate the growing environment challenges posed by anthropogenic impacts in the context of urban development.

Given the varied conditions and small scale of similar complexes, acquiring and processing suitable information presents challenges. To address this, satellite imagery and maps should be digitized and integrated into an electronic database for easy interpretation and accessibility.

Emerging challenges in sustainable urban development highlight the critical need for rational and purposeful land use as a fundamental problem-solving tool. Rational land use is a key strategy for mitigating the negative consequences of urbanization. Effective urban planning, including the arrangement of green spaces, is essential for optimizing the use of natural resources. The creation of green spaces is identified as both a tool and outcome of sustainable urban development, presents as a buffer against environmental degradation.

The research incorporated the global sustainable development strategy, which aims to create ecologically clean, socially just, and economically viable urban spaces. Integrating

green spaces into urban areas, protecting natural spaces and resources, and effectively planning land use are crucial elements for achieving this goal.

Main Part

Natural Green Space and Data Analysis

The Akhtala resort complex exemplifies a natural green space. Research information was integrated into a comprehensive database. This data was then deciphered and analyzed. The dynamics of urban and anthropogenic processes were documented through step-by-step observations.

Spatial Overview and Boundaries

While nature lacks defined boundaries, a separate object or transitional state can be represented as a limit. Accordingly, the Akhtala resort complex, borders presenting not only natural areas, but also anthropogenic ones. Therefore, its volume and distribution area can be determined.

Classification System and Object Identification

A classification system was developed during the research. Using the NDVI index, the complex was divided into nine distinct objects (see image 1).

These categories include:

1. Water (swamp) surfaces;
2. Pseudo-volcanic craters;
3. Low vegetation;
4. Parking/Ground surface;
5. Path;
6. Building;
7. Road;
8. Evergreen vegetation;
9. Mixed vegetation.

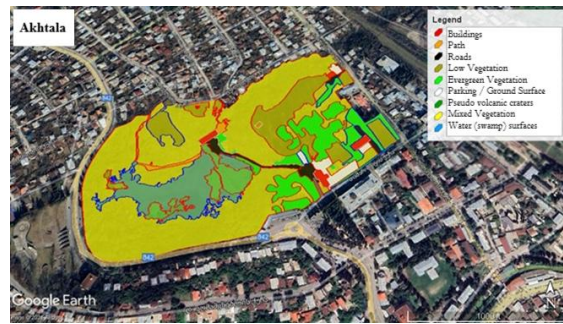


Image 1. Akhtala Resort's Clusters according to the Classification Table.

Buffer Zone and Anthropogenic Impact

The clusters within the Akhtala complex, based on their distribution area and location, warrant particular attention. These clusters function as a natural buffer zone, mitigating anthropogenic impact within the complex and its surrounding areas. Anthropogenic factors are most prominent along the road leading into the complex; their influence diminishes towards the central areas but remains visible.

Plant Health Assessment and NDVI³ Index

Remote sensing methods were employed to assess plant health using a dedicated information base. The NDVI index was used to categorize plant zones, and their areas were calculated based on the classification table. Objects with varying NDVI indexes were identified (see image 2). Lighter red colors represent areas with sparse vegetation cover or water surfaces.

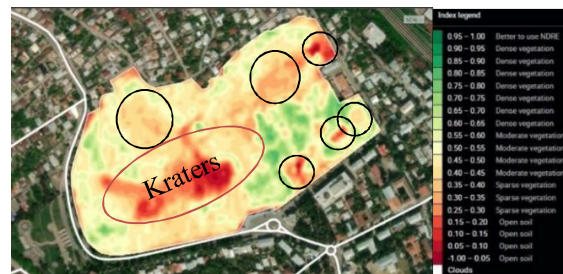


Photo. 2. The resort of Akhtala clusters, according to the NDVI index of the vegetation cover.

Long-Term Monitoring: For to the discovery

from the difference between near-infrared (NIR) and red (R) reflectance values of a surface.

³ NDVI is a widely used index in remote sensing to estimate vegetation health and density. It's calculated

of dynamics for anthropogenic factors, To fully understand how human activities change this area over time, we need to keep observing the Akhtala complex. This means studying it not only in different places but also over many years.

Localized object in time (chronological overview)

A Brief Historical Excursion

Akhtala is a mud-healing resort located in Gurjaani city, 122 kilometers from Tbilisi, at an elevation of 392 meters. The region has a moderate continental climate characterized by hot summers, warm winters, and an annual precipitation of 700 millimeters. The resort's primary asset is its healing mud. Pseudo-volcanic mud has been used for baths, applications, and tampons since the 18th century, as mentioned by historical figures such as Vakhushti Batonishvili, P. Yoseliyan, and Doctor A. Meskhisvili.

Thorough scientific research into the healing properties of Akhtala mud began in 1928 at the D. Javakhishvili Institute of Spa Therapy and Physiotherapy. Historically, Akhtala was a separate village where mud ore was extracted. In 1785, a significant robbery occurred, resulting in the theft of large quantities of money, silver, and copper. Mud ore production resumed in 1786, and in 1934, Akhtala was incorporated into the newly formed city of Gurjaani.

While historical sources, video, and photo archives from 1960 provide valuable information, this research relied primarily on spectral data analysis due to the challenging terrain. Remote sensing methods and various satellite platforms we used it to overcome the difficulties of physical access to this dangerous environment.

Despite the low resolution of early satellite images, it was possible to identify the general location and extent of the large-scale object. However, accurate evaluation based solely on this data was limited. Although the 1985 image lacks detail, it reveals a uniform green space. you can see (Image 3).



Image. 3. Akhtala resort satellite photo Google Earth 1984 - 2023 year.

Akhtala, a natural territorial complex, consists of:

The territory bordered by the roads encompasses a total area of 246,600 square meters.

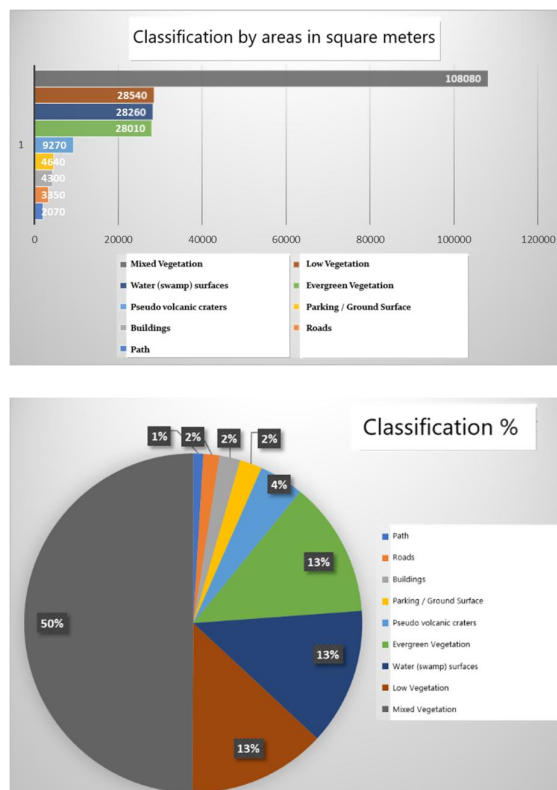


Image. 4. resort Akhtala clusters, area by %.

According to the classification system, it is crucial that the largest area within the entire complex be covered by vegetation (Image 4). However, the most critical focus is on areas with low vegetation cover. These surfaces are threatened by desertification, often caused by human activities. In addition to human impact, erosion and soil washing-out processes are also progressing.

Therefore, without in-depth research, determining the exact causes is impossible. Our objective is to assess the extent of the current situation rather than seeking its origins.

For accurate calculations, we considered that low vegetation cover has a low self-recovery capacity and proportionally produces minimal oxygen. Consequently, we focused solely on mixed and evergreen vegetation. After that, we removed marked objects (with varying NDVI indices) from the electronic base and the entire territory-complex system, and we used modern technologies in order to calculate the oxygen produced by the mentioned area in one day. This Volume is sufficient for 8,180 people.

**Possible Factors of Complex Formation:
Organic Systems in Urban Design**

Example: The Natural Territorial Complex of Akhtala

Time and Development: Organic systems evolve gradually under various influences. Akhtala exemplifies a complex where natural and human-made processes have concurrently shaped a unique landscape.

Interconnection: System elements are connected and interdependent. Consequently, complex development should be harmonious and interconnected.

Structure without a Central Plan: Natural complexes often exhibit distinct zones that function as an integrated whole. Akhtala demonstrates this by revealing definable functional zones that interact with the surrounding territory.

Examples of Natural Organic Systems: - The Akhtala Natural-Territorial Complex's

River Systems. Rivers in the complex dynamically change over time, creating channels, floodplains, and diverse ecosystems. The main river in the complex is a Vedziruli river potentially at risk of diffuse pollution. It is in the listed among 25 water bodies under threat (European Union Water Initiative Plus East Partnership for Countries - Vedziruli (Ved302) - Image 5).

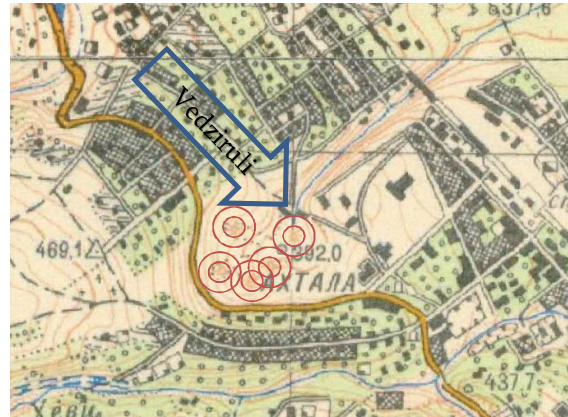


Image. 5. topographic map from Napr.gov.ge map base.

Forests: Forests are complex ecosystems where trees compete for sunlight, water, and nutrients. Diverse species create intricate habitats. Notably, desertification and slope collapse are evident within the complex, requiring further investigation to identify underlying causes.

Canyons and Craters: These geological features result from natural processes like erosion and volcanic activity, which have shaped the landscape over vast periods. Satellite images from 2000 show five crater's cones, while only four remain in 2007. (Image 6) Determining the cause of this disappearance, such as erosion or human intervention, requires detailed study. A topographic map also confirms the presence of five crater cones. The complex represent a dynamic natural system continually influenced by human activities and inversely proportionally. Additionally, a river's origin cannot be in a depression unless it's a specific pseudo-volcanic water source. The complex's internal structure is constantly evolving, affecting its current state.



Image. 6. Akhtala resort 2000-2007; disappearance of the 5th crater.

Natural Organic System's Formation Factors

Volcanic Activity: Volcanic activity is crucial in shaping the complex's landscape characteristics. However, naturally formed landscapes typically lack the infrastructure necessary for urban development.

Natural Erosion: Natural erosion also significantly contributes to the complex's formation but does not create a suitable environment for an urban network.

Anthropogenic Activity: While human influence cannot be disregarded due to the presence of resources, it is important to note that volcanic activity and natural erosion are the primary factors in shaping the Akhtala complex.

Sustainable Urban Development Criteria: The Akhtala Complex

Sustainability encompasses social, economic, and environmental impact. The Akhtala complex should align with sustainable

urban development principles, creating healthy and vibrant spaces while minimizing environmental harm. It's essential to consider the local population's needs and integrate them into spaces planning, ensuring ecological and economic stability.

Land Use Planning: This involves categorizing land for specific purposes like residential, commercial, industrial, and green spaces. For Akhtala, determining the functional purpose of different territories is crucial. Prioritizing green spaces, recreational zones, and scientific research areas is essential to avoid expanding unwanted marked areas (Image 7, based on Image 1 & 2).



Image 7. Akhtala resort 2007-2024; disappearance of the objects.

Infrastructure - While infrastructure development falls outside the scope of this research, it's essential to note that over the years, the number and size of infrastructural facilities in the complex have been changed, in the future residential and other structures should adhere to sustainability standards. Geological, water supply, and energy systems require in-depth investigation, especially if considering the region's earthquake activity.

Society Participation - Public involvement is crucial for successful development. Residents should contribute through public consultations, hearings, and feedback mechanisms.

Economic Development - Economic development strategies should prioritize job creation and economic opportunities. The resort should be developed to maximize benefits for the local population.

Aesthetics and Design - Urban spaces should be visually appealing and enhance the community's well-being. To preserve the complex's natural beauty, many objects and materials should be removed from the territory.

Processes to Ensure Compliance with Criteria

Planning: This stage involves analyzing existing conditions, setting goals, and developing a comprehensive plan. Detailed research is crucial, especially given the area's seismic activity and pseudo-volcanic terrain. Satellite imagery, orthophotos, and topographic maps are essential tools.

Zoning: Determining appropriate land use for different zones is critical. Local regulations must be considered. A classification table can be used, or new micro-zones can be identified based on territory-oriented and sustainable urban planning principles (refer to Photo 1, based on Photos 2 & 7).

Construction, Financing, Management, and Care: These responsibilities primarily lie with the resort owner and local authorities. Successful implementation depends on the preceding planning and zoning stages.

Conclusions

Natural attractions like the Akhtala Complex often embody principles of organic systems. Their unplanned evolution, characterized by interconnected elements and emergent order, creates unique and dynamic environments. Traditional urban planning

systems may not be suitable for such complexes, highlighting their distinct nature. Sustainable urban development, a model that fosters a partnership with nature, could be particularly relevant for Akhtala. Balancing environmental and economic interests is crucial. The means to achieve this are explored in the part of the article, section: "Criteria for Sustainable Urban Development: The Akhtala Complex."

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