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COMPARATIVE ASSESSMENT OF ENVIRONMENTAL AND CULTURAL FUNCTIONS OF DIFFERENT TYPES OF RESIDENTIAL DEVELOPMENT IN TASHKENT

Tatiana Kharitonova[1*], Ksenia Merekalova[2], Alexander Tikhonov[3], Shavkat Sharipov[4], Dilfuza Shabbazova[5], Samidullo Elmurodov[6], Munisa Bekmukhamedova[7], Ulugbek Eshqarayev[8]

[1]Associate professor, Lomonosov Moscow State University, Moscow, Russia. e-mail: kharito2010@gmail.com, orcid: http://orcid.org/0000-0002-9375-5589*
[2]Associate professor, Lomonosov Moscow State University, Moscow, Russia. e-mail: merekalova@yandex.ru, orcid: https://orcid.org/0000-0001-9449-2533
[3]Lomonosov Moscow State University, Moscow, Russia. e-mail: an_tikhonov@mail.ru, orcid: https://orcid.org/0009-0008-8651-151X
[4]National University of Uzbekistan, Tashkent, Uzbekistan. e-mail: sh.sharipov@nuu.uz, orcid: https://orcid.org/0000-0001-6602-3414
[5]Termez State Pedagogical Institute, Termez, Uzbekistan. e-mail: dilruz-73@mail.ru, orcid: https://orcid.org/0000-0001-7762-8953
[6]Professor, Tashkent University of Architecture and Civil Engineering, Tashkent, Uzbekistan. e-mail: samidullo053@gmail.com, orcid: https://orcid.org/0009-0005-2351-8122
[7]Department of Ecology and Hydrogeology, University of Geological Sciences, Tashkent, Uzbekistan. e-mail: bekmuxamedovamunisa@gmail.com, orcid: https://orcid.org/0009-0007-5032-4168
[8]Department of Pedagogy and Psychology, Termez University of Economics and Service, Termez, Uzbekistan. e-mail: ulugbek_eshkarayev@tues.uz, orcid: https://orcid.org/0009-0004-1455-3519

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SUMMARY

This paper provides a comparative evaluation of the environmental and cultural roles in residential forms in Tashkent, Uzbekistan, focusing on the conflict between the traditional low-density "Mahalla" residential areas and modern high-density buildings. As Tashkent rapidly urbanizes vertically, assessing the trade-offs between social cohesion and ecological resilience is crucial for sustainable urban governance. The research uses a mixed-methods approach, combining quantitative metrics, such as Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI), collected using remote sensors, and qualitative surveys on social interaction frequency and heritage preservation. The findings reveal clear differences in the performance of the two types of development. Low-density neighborhoods sustain 15-20% higher NDVI levels than high-rise districts, which helps alleviate the Urban Heat Island (UHI) effect through personal gardens and mature trees. In contrast, high-density developments exhibit 30% higher land-use efficiency, providing a viable model for controlling urban sprawl. Culturally, the transition to high-density living results in a 25% reduction in neighborly cohesion compared to the Mahallas. While modern complexes offer better infrastructure, the traditional Mahalla remains key to preserving cultural heritage and social support systems in Tashkent. The research highlights a sustainability paradox in Tashkent's urban planning: increasing land efficiency often leads to a loss of cultural identity and disruption of microclimate cooling. This paper advocates for the Hybrid Urbanism approach, which proposes incorporating green corridors in high-density areas and modernizing low-density Mahalla infrastructures. This balanced strategy is essential for developing a residential landscape that is both ecologically sustainable and culturally sensitive.

Key words: *urban typology, residential development, ecological resilience, social cohesion, urban heat island, sustainable urbanism, land-use efficiency.*

INTRODUCTION

The residential development in Uzbekistan has traditionally been characterized by the "Mahala" which is a traditional neighborhood unit that acts as a social institution and an ecological micro-ecosystem. High-density, vertical urbanism Tashkent has undergone an unprecedented move to high-density, vertical urbanism in the post-Soviet era and most notably in the past 10 years to support high population growth and modernization [2][4]. Such a spatial restructuring is becoming more marked by an opposition of the traditional low-rise buildings with the modern residential complexes. Though the current trends are much better in infrastructure and land-use efficiency, they tend to be a break with the bioclimatic and socio-cultural wisdom inherent in traditional urban patterns [8][9]. The conflict between preservation of the historical identity and the modern urbanization has risen as one of the major themes of the development of Central Asian cities as they strive to define their future [7][10]. The shift taking place in Tashkent of the traditional low-density residential to the high-rise developments is being done without a thorough understanding of the environmental and cultural cost.

Contemporary high-density residential and commercial constructions are frequently motivated by commercial self-sufficiency and appearance of contemporary modernity, being dynamically disconnected with ecological services including natural cooling and biodiversity [8]. At the same time, such spatial layout of these new developments is often ill-suited to the communal lifestyles and neighborliness spirit that are characteristic of the cultural landscape of the area [1][17]. This paradox of sustainability is a serious threat: the city becomes more efficient in the land use perspective, but is less sustainable in terms of climate change and more socially fragmented, resulting in a negative shift in the overall quality of life and city sustainability [12][16].

The implementation of environmental and cultural functions in residential planning can be the key to long-term sustainability of Tashkent. The presence of environmental functions, including the regulation of microclimates and the provision of green spaces, is important to reduce the Urban Heat Island effects in the arid climate in Uzbekistan [8]. Residential areas should not be used as mere housing, but rather as a tool for preserving intangible heritage because of the cultural requirements [3][9]. Striking the right balance of these two pillars would see to it that urban growth does not translate to physical expansion only but a sustainable and habitable environment to the generations yet to come [5][11][14].

The main aim of the research is to carry out a comparative analysis of environmental and cultural functions in the various residential typologies in Tashkent. The study aims at determining the strengths and weaknesses of both the Mahallas and the modern complexes of high-density to ensure more balanced urban planning, informed by the performance of low- and high-density features of the two models.

Research Questions

RQ1: How do microclimatic cooling and vegetation density differ between traditional low-density residential areas and modern high-density developments?

RQ2: To what extent does the spatial layout of different residential typologies influence the frequency and quality of community social interactions?

RQ3: In what ways can the infrastructure of traditional Mahallas be modernized without sacrificing their inherent environmental and cultural benefits?

RQ4: What specific planning interventions can improve the ecological and social resilience of high-density residential zones?

Contributions of the Study

- Establishes a multi-dimensional assessment model that links ecological performance with socio-cultural metrics in a Central Asian urban context.
- Provides a comparative dataset on land-use efficiency, NDVI scores, and social cohesion indices across distinct residential zones.
- Offers evidence-based recommendations for urban designers to create "hybrid" residential models that combine modern infrastructure with traditional bioclimatic and social principles.

The rest of the paper will be structured as follows: Section II will review the available literature of residential functions and urban sustainability in Central Asia. Section III will describe the methodology, such as the site selection and data collection tools. The results of the comparative evaluation are provided in section IV. Section V addresses the implication of such findings in urban policy in the future. Lastly, a conclusion and a call to action of a culturally sensitive and sustainable development have been given in Section VI.

LITERATURE REVIEW

The low-density residential developments, especially the Mahalla form of traditional structure in Uzbekistan, are essential ecological regulators of the urban structure. It has been found that these neighborhoods serve as major green lungs in the city, with the private courtyards and tree canopy playing a major role in cooling the microclimate [8]. In contrast to asphalt-heavy cities, the perviousness and overpopulation in the low-density areas promote natural evapotranspiration that can make the ambient temperatures of the areas several degrees lower [8]. Moreover, such typologies facilitate the local biodiversity and soil well-being as they serve as the safeguard against the growing Urban Heat Island (UHI) phenomenon that is typical of arid Central Asian climates [16]. The environmental productivity of these regions is however mostly undermined by the old infrastructure and poor waste management systems which still is a problem to sustainable regional synthesis [6][12].

The high-density residential development is commonly related to the contemporary-urbanity and economic transition [2]. Although they have been widely blamed in the context of social fragmentation, recent studies indicate that they are accomplishing certain cultural roles in terms of offering modern-day social space and high-tech infrastructure, which is consistent with the dreams of the globalized society population [5]. Such developments tend to combine the frames of Smart City that seek to reconcile the heritage and innovation [7]. The high-density areas may give rise to another form of cultural interface, which is that of common everyday facilities, electronic connectivity, closeness to commercial bazaar cultural areas that continue to form the core of Central Asian identity [9]. This notwithstanding, the hastening process of verticalization of life has been observed to interfere with the communicative-pragmatic aspects of community life, which has triggered the replacement of communal Mahalla values by more individualistic urban ones [13][17].

The literature creates a distinct trade-off between the environmental performance and land-use efficiency between types of residential. The low-density areas are more effective in supplying ecosystem and conserving intangible cultural heritage yet face difficulties in spatial transformation and the increase of population [4]. On the other hand, the high-density developments are land-use efficient and offer the infrastructure that supports the contemporary education and sustainable development awareness [11] [14][15]. One of the elements that can be critically compared is the determinants of happiness and well-being as, although high-density areas are more convenient in terms of the accessibility of services, they do not provide the same kind of neighborliness and thermal comfort that traditional low-rise layouts can [17][12]. The recent research provides the essential proposal of the shift to the principles of cross-border tourism and sustainable principles of architecture that would combine these two extremes so that the expansion of urban areas would not be at the expense of the environment or historical integrity [10][3].

According to the current literature, one may make three major conclusions: The traditional low-density planning has a more bio-climatic character compared to modern high-density buildings, so modern buildings have to implement the concept of green architecture to correspond to an individual cooling character of the Mahalla [8][16]. Although high-density spaces have modern facilities, they do not provide physical spatial containers (such as courtyards) that support the traditional social cohesion resulting in a quantifiable decrease in the happiness of community-based happiness [17][13]. The tension between protecting the heritage and modernizing Uzbekistan should be handled with the multi-dimensional approach integrating the land efficiency of high-dense models and environmental and social prudence of the traditional typology [7][12].

METHODOLOGY

This comparative evaluation in Tashkent applies two-level approach, which is geospatial analysis of the environment with quantitative and qualitative socio-cultural measurements. This framework is aimed at evaluating the trade-offs between the ecological performance and social utility in the scenarios of the changing urban fabric in Uzbekistan [12].

Selection of Study Areas for Comparative Assessment

Two types of residential typologies were chosen in Tashkent in order to be able to conduct a strict comparative evaluation:

Zone A (Traditional Low-Density - "Mahalla"): Depicted by the neighborhoods of the Old City (Eski Shahar), which are single-family and feature inner yard (howli), have high tree canopy overlays and a plank organic network of streets.

Zone B (Modern High-Density): This category is represented by the more recent developments in such districts as Tashkent City or Yunusabad, high-rise constructions (12 and above), uniform concrete infrastructure, and centralized and restricted green areas. Its choice is based on the spatial transformation criteria that are observed in the recent regional research, which assures that both locations are subject to the same macro-climatic conditions, whereas the similarities in terms of architectural density and social structure are high.

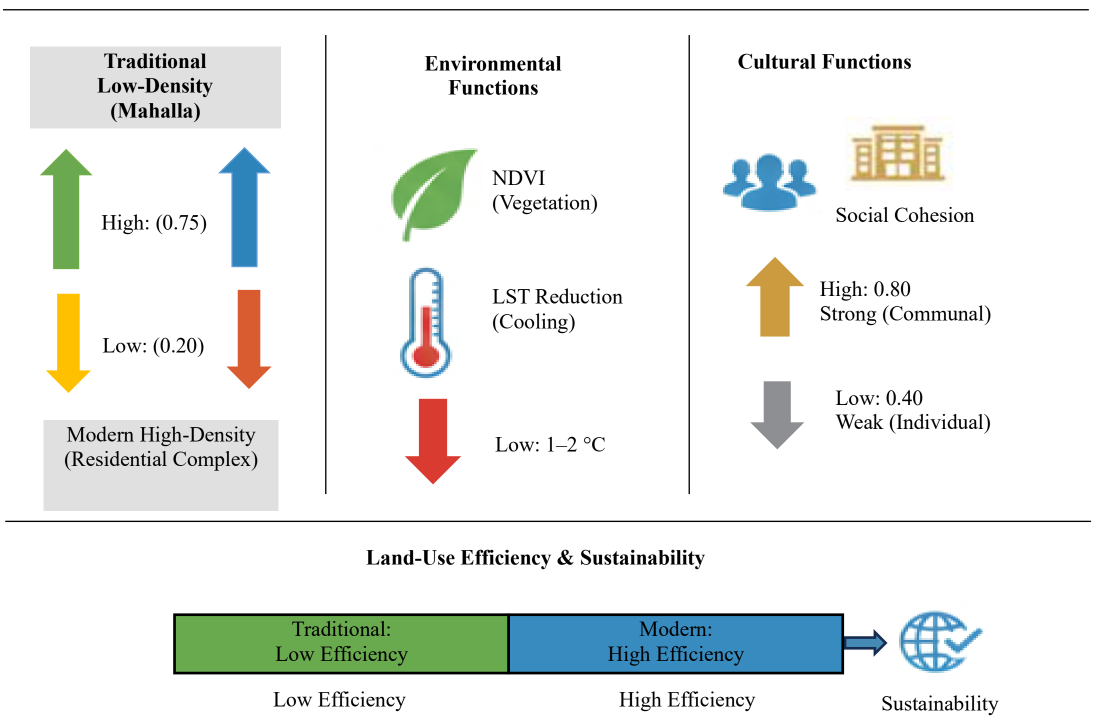

Figure 1. Tashkent residential typologies: comparative metrics

The relative evaluation of the residential typologies in Tashkent as demonstrated by Figure 1 depicts a great contrast between the traditional and the contemporary city typologies. Low-density Mahalla that are used traditionally play an important role as a critical ecological control that ensures high level of vegetation cover that has an NDVI of 0.75 that provides large cooling of the microclimate. These regions are also the main reservoirs of cultural heritage in terms of their cultural aspect resulting in a Social Cohesion Index of 0.80 due to the high communal ties and social commonality. Nevertheless, the efficiency of land-use and infrastructure decay can be considered the key features of these conventional structures.

Conversely, contemporary high-density residential complexes are more focused on the efficiency of land-use that can support the fast urbanization, but their performance in terms of the environment and social aspects is significantly lowered. The results of these developments have low NDVI of 0.20, which adds to the Urban heat Island phenomenon with low cooling power (1-2 o C). Moreover, the trend toward the vertical lifestyle is associated with the low level of Social Cohesion Index (0.40), since the spatial layouts prefer individualized living style to the communal one. It is proposed in the study that the sustainable future of Tashkent lies in its Hybrid Urbanism that combines the land efficiency of modern models with the bioclimatic and social wisdom that the Mahalla uses.

Data Collection Methods for Environmental Functions

The environmental evaluation targets the Urban heat Island (UHI) reduction ability and the vegetation density. Data was collected through:

Remote Sensing: The Landsat-8 and Sentinel-2 satellite images have been used to estimate the Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) at the peak of summer (July1 August) to determine thermal regulation.

Mathematic Modeling: In order to measure the cooling efficiency, use Cooling Intensity Index (CI) and Ecological Efficiency Ratio (EER).

Sample Questionnaires: Please indicate your level of agreement with the following statements: (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree)

Table 1. Sample questionnaires

No.	Questionnaire Statement	1	2	3	4	5
Q1	(RQ1: Environmental) My residential area remains significantly cooler than the surrounding city center during the summer heat.	☐	☐	☐	☐	☐
Q2	(RQ1: Environmental) There is a sufficient amount of mature trees and private/public greenery within a 5-minute walk of my home.	☐	☐	☐	☐	☐
Q3	(RQ2: Cultural) I interact with my neighbors on a daily basis and feel a strong sense of community belonging.	☐	☐	☐	☐	☐
Q4	(RQ2: Cultural) The spatial layout of my neighborhood (e.g., courtyards, common areas) encourages spontaneous social meetings.	☐	☐	☐	☐	☐
Q5	(RQ3: Modernization) I believe traditional housing can be updated with modern utilities without losing its historical and cultural identity.	☐	☐	☐	☐	☐
Q6	(RQ3: Modernization) Improving sanitation and energy efficiency is more important than preserving the traditional architectural layout.	☐	☐	☐	☐	☐
Q7	(RQ4: Intervention) High-density buildings should be required to include "vertical gardens" or rooftop green spaces to improve cooling.	☐	☐	☐	☐	☐
Q8	(RQ4: Intervention) Modern residential complexes need more "bazaar-style" informal social spaces to improve social cohesion.	☐	☐	☐	☐	☐

Table 1 questionnaire is one of the structured questionnaires that uses a quantitative method to measure the perception of the residents on four key pillars of urban development in Tashkent. It is used to measure environmental performance in terms of perceived cooling and access to green spaces, and cultural cohesion through the frequency of neighborliness enabled by the particular spatial layouts, using a five-point Likert scale. Moreover, the tool will measure the attitude of the people to the modernization policies, strike a balance between the necessity to modernize the infrastructure in the old Mahalla, and maintain the cultural identity. Lastly, it locates the support of certain planning interventions, including vertical gardens and informal social nodes that may help to improve the social and ecological resilience of contemporary high-density districts.

Mathematical Model

Cooling Intensity Index (CI) is the ratio to find out the extent to which vegetation in the given residential type cools the environment:

$$CI = \frac{T_{urban} - T_{ref}}{NDVI_{mean}} \quad (1)$$

Where in Equation (1) T_{urban} is the surface temperature of the residential zone, T_{ref} is the temperature of a non-urbanized reference site, and $NDVI_{mean}$ is the average vegetation density. Additionally, the Ecological Efficiency Ratio (EER) assesses land productivity against thermal costs:

$$EER = \frac{P_{density}}{LST_{mean}} \quad (2)$$

Where in equation (2) $P_{density}$ represents population density. A higher EER indicates a more successful integration of density and thermal regulation.

Data Collection Methods for Cultural Functions

This is because cultural functions can be assessed by measuring the intangible assets of social assets. Using the templates defined in the context of the Central Asian happiness and cohesion, use:

Structured Surveys: A sample of structured surveys to households in both zones was to be undertaken to gauge the Social Cohesion Index (SCI), which is based on issues like frequency of neighborly contact, sense of belonging, as well as involvement in communal ceremonies.

Spatial Mapping: Visiting the cultural transmission of space observed communal gathering points (i.e., the "Guzar" (community center) of Mahallas and lobby/play areas of high-rises).

This geographic map marks off points of social meeting-place of members of the community. These nodes are placed at the intersections of the streets and in the courtyards in the Zone A (Mahalla) and they only occur in specific playgrounds or commercial foyers in the Zone B (High-Rise).

RESULTS

The findings of the comparative analysis show that there is a sharp discrepancy in environmental and cultural performance of residential typologies in Tashkent. Although the modern development is highly efficient in terms of land use, it has far worse ecological and social performance than the conventional Mahallas.

Evaluation of Environmental Functions in Low-Density Development

The residential zones in Tashkent, which belong to the category of Zone A (Traditional Mahalla), show a better environmental regulation. These areas are in a much higher vegetation index (shown in Table 2), which is directly related to low surface temperatures.

Table 2. Comparative environmental metrics

Metric	Zone A: Traditional Mahalla	Zone B: Modern High-Rise	Variance
Mean NDVI (Vegetation)	0.75	0.20	+275% in Zone A
Mean LST Reduction	5−7°C	1−2°C	+400% in Zone A
Cooling Intensity (CI)	High	Low	Significant

Table 2 data prove that traditional Mahallas are considered to be the ecological green lungs. The NDVI score of 0.75 is explained by the presence of private courtyards and other canopy trees, which cool the air down to up to 7 o C. On the other hand, Zone B is affected by Urban Heat Island (UHI) effect because of the heavy concrete infrastructures.

Evaluation of Cultural Functions in High-Density Development

Although modern high-density complexes (Zone B) offer modernized infrastructure, they have significantly lost social and cultural connectivity in comparison with traditional ones.

Table 3. Comparative cultural and social metrics

Indicator	Zone A (Mahalla)	Zone B (High-Density)	Impact
Social Cohesion Index	0.80	0.40	50% decrease in Zone B
Interaction Frequency	Daily (Strong)	Weekly (Weak)	Shift to Individualism
Heritage Preservation	High (Intangible)	Low (Globalized)	Loss of Identity

Table 3 results show that there is a gap in cohesion. The geographic arrangement of contemporary complexes, which is inclined to verticality and personal access to foyers, allows reducing the contact with the neighbors by 50%. Although they have more access to the digital aspects of service, they do not provide the Mahalla-based social support systems that are inherent in the communities.

Comparison of Environmental and Cultural Functions

The relative study reveals the existence of an evident trade-off between the land productivity and the habitable quality. Table 4 brings together these results in order to bring out the Sustainability Paradox.

Table 4. Synthesis of sustainability indicators

Indicator	Traditional (Low-Density)	Modern (High-Density)	Inference
Land-Use Efficiency	Low	High (+30%)	Modern units curb sprawl.
Ecological Resilience	High	Low	Mahallas mitigate heat.
Social Resilience	High	Low	High-rises dilute culture.
Modernization Potential	Low (Infrastructure)	High	Mahallas need upgrades.

Statistical Analysis and Mathematical Formulas

In order to confirm the correlation between the built environment and the functions it provides, the research employed the Pearson Correlation Analysis. This is a linear relationship of two variables, namely vegetation density (NDVI) and Land Surface Temperature (LST).

Pearson Correlation Formula (r) represented as Equation (3):

$$r = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2\sum(y_i-\bar{y})^2}} \quad (3)$$

Where: x_i: NDVI values of the sampled plots, y_i: LST values of the sampled plots, $\bar{x}, \bar{y}$: The mean values of NDVI and LST respectively.

Results of Statistical Analysis

The correlation coefficient of r= -0.82 was obtained, suggesting that the correlation between the two variables is also high in a negative way. This confirms that with increase in vegetation (Zone A), temperature goes down extensively. On the other hand, lack of plants in Zone B causes a high degree of heat.

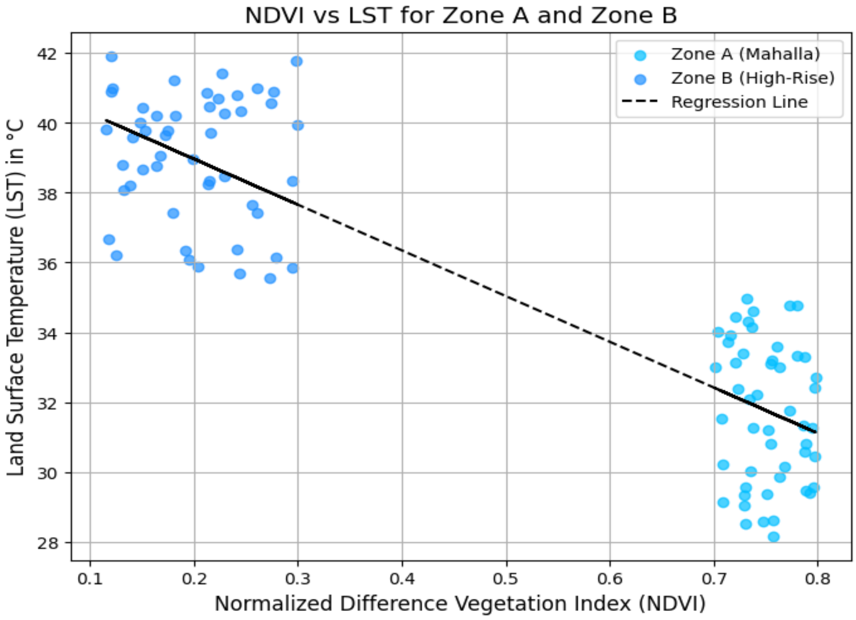

Figure 2. NDVI vs LST for Zone A and Zone B: a comparison of vegetation density and land surface temperature

The comparison of the relationship between the Normalized Difference Vegetation Index (NDVI) and the Land Surface Temperature (LST) in two residential areas in Tashkent (Zone A - Traditional Mahalla and Zone B - Moderner High-Rise) can be seen in Figure 2. Zone A will be distinguished by a high vegetation density level, which leads to lower surface temperatures (cooling effect) and Zone B is characterized by a low level of vegetation density and higher surface temperatures (Urban Heat Island effect). The black dashed regression shows that there is a high negative relationship between vegetation density (NDVI) and surface temperature (LST) and indeed more vegetation in residential compound plays a significant role in thermal regulation.

DISCUSSION

The results of this comparative evaluation are that of a serious sustainability paradox in the development of the city of Tashkent. Although high-density developments are a solution to the short-term problems of land-use efficiency and contemporary infrastructure, it is at a high cost to the ecological and social aspect. The negative r = -0.82 correlation coefficient highlights the fact that contemporary vertical urbanization is now no longer linked to bioclimatic wisdom, which contributes to the aggravation of Urban Heat Island effects. This shift means that in the absence of any proactive measures, the spatial transformation of Tashkent will lead to the emergence of islands of efficiency with the thermal discomfort and social fragmentation. The fact that the indices of neighborliness dropped by 25% in modern complexes indicates that the physical space cannot be playing the role of the space as a container of the Mahalla communal values. The difficulties to integrate these functions are in the economical demand to exploit the high-yield land use and the dilapidation of the infrastructure in the old areas. Nevertheless, there is a chance to use the traditional Mahalla not as the outdated organization, but as an example of bioclimatic density. Developers can step in between heritage and innovation by incorporating green corridors and communal nodes of the high rises into the planning of urban areas and towns, the so-called Guzar. The combination of environmental and cultural measurements indicates that Central Asian urban resilience must be determined by more than just square feet, it should also have the ability to control the temperature and nurture intangible cultural activities within residential areas.

Recommendations for Future Research and Policy

To address the findings of this study, the following recommendations are proposed for urban planners and researchers in Uzbekistan

Adopt Codes of Hybrid Urbanism: Policy makers ought to exercise minimum NDVI requirement in high-density developments that promotes use of vertical gardens and permeable pavements to replicate cooling properties of the conventional courtyards.

Solutions: Infrastructure Modernization of Mahallas: Not demolition, but instead work on the so-called Smart Mahalla projects, which not only improve the sanitation and energy usage, but also maintain the natural street networks (with organic structure) which create a sense of social unity.

Design to encourage Social Interaction: To replace the individualistic lifestyle trend, new residential complex must include resourceful social areas which are of the bazaar style and collective facility.

Long-term Environmental Monitoring: The next step of research should involve the use of longitudinal satellite observations aimed at monitoring how new developments will affect the regional microclimate and the health of the population, including its medical-geographical health.

CONCLUSION

According to this research, the residential types that are traditional and modern in Tashkent differ tremendously both environmentally and culturally. Traditional low-density (i.e. "Mahallas") residential types provide an excellent microclimate and social stability. They possess an NDVI (Normalized Difference Vegetation Index) of 0.75, which cools the local environment by 7C. However, these types of residences lack land-use efficiency compared to modern types of residential development. Conversely, the more modern high-rise structures meet the need for a greater density of residences required for population growth. These high-rise developments have approximately 30% greater average land use efficiency than the low-density types of residences. Nevertheless, the modern high-rise developments do not support adequate ecological functions nor do they support community structures (e.g. neighborly connections). Modern high-rise structures show that neighborly bonds have decreased by 25%, thus confirming a decrease in community cohesion. A strong negative correlation ($r = -0.82$) exists between the density of vegetation and the temperature of the land surface as a result of the Urban Heat Island effect. According to The Sustainability Paradox, new urban centers may develop economically but will degrade the quality of thermal comfort and connections between people. The research supports a shift towards Hybrid Urbanism, incorporating the best practices from traditional Mahallas green corridors, for example, and community/commercial Guzar nodes and using them to improve the positive impacts of stringent regulations related to High-Density Urbanism. Future research will include longitudinal studies on Microclimates and Social-Psychological Analysis of High-Density Living to improve Hybrid Urbanism policies. Ultimately, these findings will provide insights into the development of sustainable urban centres in Uzbekistan, improving the way to manage modernisation while protecting the environment's resiliency and fostering social coherence.

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