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The Study of the Complexity and Capacity of Urban Floristic Diversity in Arid Zones, Exemplified by the City of Bukhara, RUz

Mukhamad I. Gulamov[α] & Saida M. Gafarova[σ]

ABSTRACT

This study examines the biodiversity of the urban flora in the arid zone of Bukhara city, Republic of Uzbekistan. The research is based on our newly proposed methods—analyzing the complexity and capacity of floral biodiversity. It also incorporates established biodiversity indices: species abundance evenness (probability of species occurrence) and the Shannon index. This is the first time that the values of complexity and power indicators for real ecological systems have been calculated. The findings reveal that the biodiversity of Bukhara's urban flora is characterized by uneven species abundance, with significant dominance of certain tree species (Pinus brutia var. eldarica (Medw.) Silba; Ulmus parvifolia L.; Platycladus orientalis (L.) Franco); shrubs (Rosa chinensis Jacq.; Yucca filamentosa L.), and herbs (Hordeum bulbosum L.; Descurainia Sophia L.; Seteria viridis (L.) P.Beauv; Coreopsis lanceolata L). A high level of complexity and low capacity in the biodiversity structure of the studied urban flora indicate weak resilience, adaptability, and regenerative capacity of the flora. These observations suggest that the general principles (lack of uniformity, unified logic, harmony, purpose, and order) governing biodiversity transformation in nature are disrupted in urban ecosystems due to the imposition of subjective logic, harmony, purpose, and order.

Keywords: urban flora; urban ecosystem; species occurrence frequency; Shannon index; biodiversity complexity; biodiversity capacity.

Author α σ: Bukhara State University, Bukhara, Uzbekistan.

I. INTRODUCTION

This paper summarizes the results of our previous studies on the biodiversity of urban flora in the arid zone of Central Asia, using the city of Bukhara as a case study. These studies employed the floristic systematic grid method. The primary objectives of this research were:

a. Based on scientific data and personal observations, study the modern physical-geographical and ecological characteristics of the city of Bukhara (Republic of Uzbekistan). The territory of Bukhara covers an area of 143 km². The climate is sharply continental and desert-like: winters are very harsh, while summers are hot and dry. The average January temperature is minus 2 degrees Celsius, and in July, it exceeds 40 degrees. The annual precipitation in the Bukhara region ranges from 90–150 mm, mostly in the form of rain. Therefore, Bukhara's territory is classified as an arid zone (Gafarova S.M., Gulamov M.I., 2021).
b. Conduct research and analysis of floral diversity in urban conditions based on field observations and literary data using the city of Bukhara, Republic of Uzbekistan, as a case study. The collected materials were used to systematize the floral diversity of Bukhara, and standard statistical data processing was performed (Gafarova et al., 2024).

Currently, the global discussion on the significance of plant biodiversity for human society is highly pertinent. Life on Earth directly depends on plant biodiversity, which serves as the foundation of existence. Considering the current pace of urbanization worldwide, any research aimed at preserving floral biodiversity is exceedingly necessary. Contemporary ecological situations on the planet confirm this necessity (A Global Standard 2016; Kate 2022; Alves 2024).

Currently, urban areas occupy a small fraction of Earth's surface; some estimates suggest less than 0.1% of the total land area. However, their impact extends over significant distances. It has been calculated that 1 m^2 of urban system consumes 70 times more energy than the corresponding area of a natural ecosystem. To provide food for an urban population of 1 million people, approximately 0.8 million hectares of arable land are required. Cities affect the environment not only as consumers of energy, organic matter, and oxygen but also as powerful sources of pollution (Conservation and Restoration of Biodiversity, 2002).

Vegetation is a fundamental component of urban ecosystems, playing a crucial role in the lives of city residents. The functions of plants in urban areas are diverse and include: Improving the urban microclimate, Food production, Regulating air composition, Absorbing dust and toxic substances, Reducing noise levels, Enhancing the aesthetic appearance of the city and Providing spaces for recreation. In ecosystems, plants play a leading role as sources of food and oxygen, creating conditions for life and shelter for other organisms (Conservation and Restoration of Biodiversity, 2002; Ceplová et al. 2017 a,b; Tretyakova et al. 2018; Jovanović, Glišić, 2021).

One of the pressing issues in this field is the development of methods to study the biodiversity of urban flora in arid zones under urban conditions, aiming to preserve and enhance its floristic structure. The biodiversity of urban flora serves as the foundation that shapes the landscape of urban planning (Christenhusz et al., 2011). Investigating the biodiversity of urban flora requires examining its elementary floristic unit at the regional level (minimum range), species composition, species density (Gafarova et al., 2024), and levels of complexity and capacity. Assessing the complexity and capacity of floristic diversity in urban zones will help determine whether the current levels and rates of urbanization are safe for the ecosystems in question. The concepts of complexity and capacity indicators in biodiversity studies were first introduced by M.I. Gulamov (2017b, 2023).

Biodiversity is a fundamental property of ecosystems, reflecting their complexity and structure. Species diversity determines the complexity of structure and the power of ecosystems (Brodsky, 2002; Lebedeva, Krivolutsky, 2002).

In natural conditions, any ecosystem strives for balance and stability. Moreover, the more complex the ecosystem—i.e., the higher its level of diversity—the more likely it is to maintain stability over time and space (Nikolaikin et al., 2003).

The level of complexity implies the presence of multiple forces in equilibrium. If there is only one force, it is meaningless to talk about its balancing. In this context, complexity is a balanced diversity or a hierarchically complex structure.

The natural increase in species diversity leads to intensified competition among species, reducing the distance between them and increasing mutual pressure. As a result, specialization occurs in biomes, ecosystems, and communities, leading to the differentiation of ecological niches.

Complexity (trade-off) is meaningful only in the presence of diversity. Without diversity, trade-offs are impossible.

Capacity refers to the rate at which work is performed, energy is transferred, or a response is made. In mathematics, the capacity of a set is a characteristic that generalizes the concept of the number of elements in a finite set. This concept is based on natural ideas about comparing sets. If we replace the set of biological species in a specific ecosystem with the concept of biodiversity in that ecosystem, it becomes quite natural to talk about the capacity of biodiversity.

Based on these concepts, the phrase "capacity of diversity (biodiversity)" can be defined as a magnitude characterizing the potential response of diversity (biodiversity) to external forces.

In the context of this work, it is appropriate to consider the capacity of biodiversity as a measure characterizing the potential response of an ecosystem to external factors. To better understand this indicator, an analogy can be drawn with the capacity of a plant.

A plant's capacity is determined by the rate at which it produces oxygen, absorbs carbon dioxide, or purifies the surrounding environment. In this context, the capacity of a tree surpasses that of a shrub or herbaceous cover.

However, when discussing the capacity of biodiversity in the plant world of a specific ecosystem, we are referring not to the capacity of an individual plant species, but rather to the indicator of the overall viability potential of the entire ecosystem. The capacity of plant biodiversity is not simply the sum of the capacities of individual species, but the ability of the ecosystem to sustain functioning, adapt, and recover.

The question of the equivalence of the capacity of biodiversity in trees, shrubs, and grasses is important and requires careful consideration. From the perspectives of physics and biology, the capacity of biodiversity in these plant groups is not equivalent, as their ecological roles and adaptation abilities differ.

Trees, shrubs, and grasses occupy different vegetation layers and perform various ecological functions. Trees form the upper layer, shrubs the middle layer, and herbaceous plants the lower layer. These differences affect their ability to perform photosynthesis, absorb carbon dioxide, and produce oxygen. For example, trees, due to their height and structure, can absorb more carbon dioxide and produce more oxygen compared to shrubs and grasses. Additionally, trees play a key role in climate formation, soil erosion protection, and creating conditions for the habitat of other organisms. Shrubs and grasses also perform important functions, but their impact on the ecosystem differs.

Thus, calculating the capacity of biodiversity for these groups of plants separately is plausible and justified, as their ecological roles and adaptation abilities differ.

The calculation of complexity and capacity indicators for biodiversity is an important tool for assessing and monitoring biodiversity in natural ecosystems. It allows for the determination of the state of the ecosystem, the exploration of its structure, and aids in the development of strategies for conserving species diversity.

This issue is of great significance, as without studying the capacity of biodiversity in the researched geographical landscape (regardless of the scale of the territory), any planning of economic activities can lead to irreversible ecological consequences. All existing ecological disasters on a global scale today are the result of such thoughtless approaches (Brodsky, 2002; Conservation and Restoration of Biodiversity, 2002).

Any activities conducted must take into account the complexity and capacity of the biodiversity of the studied landscape to avoid the emergence of new, more global ecological problems.

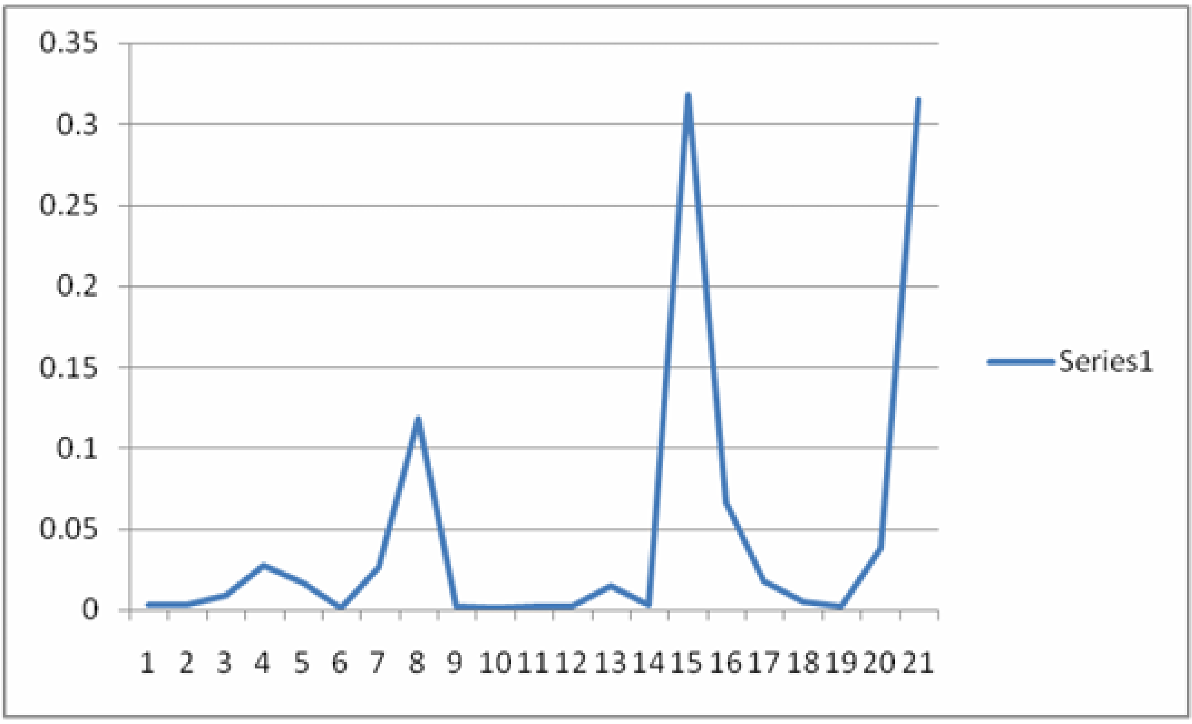

Fig. 3: Graphical representation of the frequency of occurrence of shrub species in the urban flora of Bukhara city, RUz. The evenness of species abundance is absent.

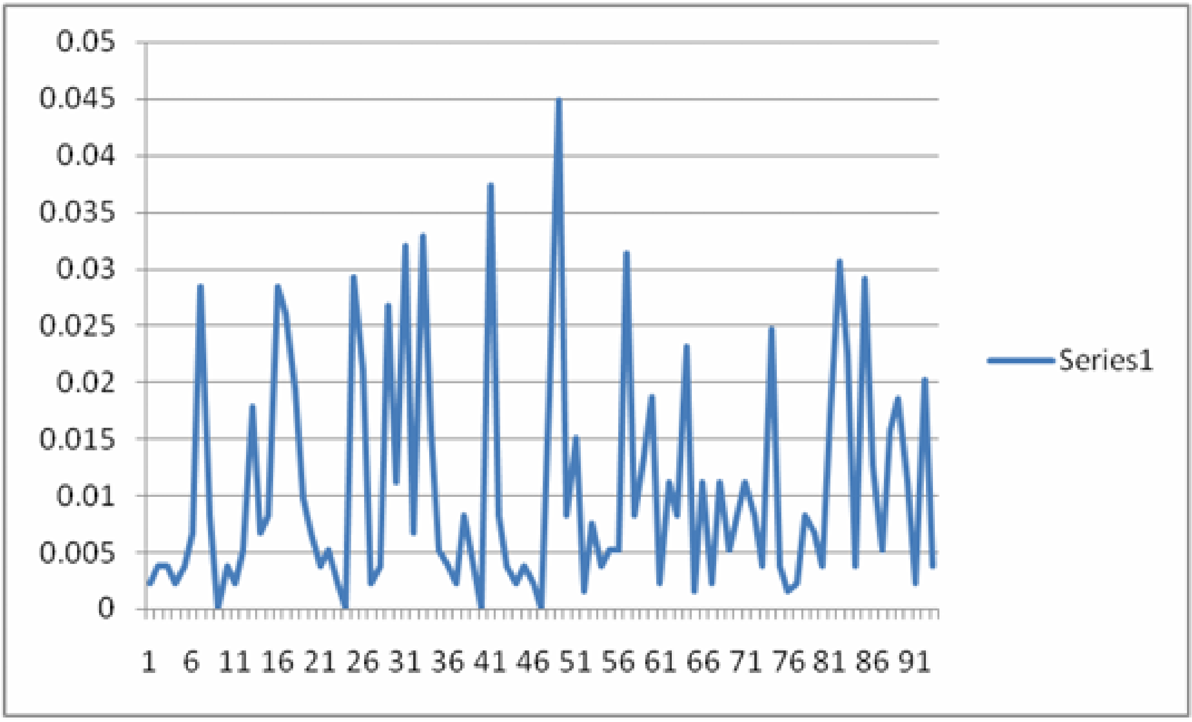

Fig. 4: Graphical representation of the frequency of occurrence of herb species in the urban flora of Bukhara city, RUz. The evenness of species abundance is absent.

III. DISCUSSION OF RESULTS

Our analysis of the biodiversity of Bukhara city's urban flora reveals:

Uneven distribution of species abundance: Dominance of several tree species (*Pinus brutia var. eldarica*, *Ulmus parvifolia*, *Platycladus orientalis*), shrub species (*Rosa chinensis*, *Yucca filamentosa*), and herb species (*Hordeum bulbosum* L.; *Descurainia Sophia* L.; *Seteria viridis* (L.) P.Beauv; *Coreopsis lanceolata* L).

Relatively high complexity index (C_d): Indicating diversity of life forms within the community.

Low Shannon index ($\overline{H}$): Suggesting a low level of biodiversity.

Low capacity (M) of biodiversity: Indicating the ecosystem's limited ability to support species diversity.

These results are presented in Tables 2, 3, 4 and Figures 2, 3, 4.

If we perceive the complexity index (C_d) as a compromise between species, then its relatively high level indicates a balanced coexistence of species in the community (Gulamov, 2017 b). This means that species are in a state of dynamic equilibrium, where each species occupies its ecological niche, minimizing competition and contributing to the stability of the ecosystem.

In addition, a high level of the complexity index indicates a low level of combination of environment-forming ecological factors. Environment-forming factors, such as various types of flora, form non-stationary scalar ecological survival fields that determine the conditions for the existence and development of species (Gulamov, 2021). In urban ecosystems, where environmental conditions are often variable and subject to anthropogenic influences, such survival fields can be unstable, which affects the structure and dynamics of vegetation.

Thus, at a low level of capacity (M) of biodiversity and relatively high values of the complexity index (C_d), an ecological tolerance zone is created. This means that there is an acceptable combination of species in this community that are able to survive and coexist in urbanized environments. However, such a situation may also indicate a decrease in the ecosystem's resistance to external influences and the need to take measures to maintain and restore it.

Table 5: The results obtained from tables 2, 3, and 4 (correspondence in ascending order) are presented in

	N	S	C_d	$\overline{H}$	M
Shrubs	22	1287	0,9524	1,9031	0,0163
Trees	43	4548	0,9767	2,8267	0,0095
Herbs	93	30081117	0,9892	4,1348	0,0000

From the data in Table 5, it is evident that the tendency of the value of the indicator M to a minimum relative to the values of $\overline{H}$ and C_d is explained by the fact that in these life forms of plants, the tendency of the ratio N/S to a minimum, that is, the tendency of the value of N to a minimum and the value of S to a maximum. This condition is especially characteristic of herbs (the value of S is too high). The convergence of the values of N and S can lead to an increase in the value of M and to the equalization of the abundance of species in all life forms of plants.

GLOSSARY

1. The capacity of an ecosystem's flora biodiversity is the ecosystem's ability for sustainable functioning, adaptation, and recovery.
2. Complexity is understood as a compromise between species, that is, an indicator of the level of species coexistence or an indicator of the combination of environment-forming ecological biotic factors.

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Author's Contributions

Mukhamad Isakovich Gulamov: Designed the project, analyzed the data and wrote the manuscript.
Saida Muhamadjonovna Gafarova: Conducted fieldwork and sample collection during the 2021-2024 field season, analyzed data and was involved in writing some parts of the manuscript.

Ethics

This material is the authors' own original work, which has not been previously published elsewhere.

Competing Interests

The authors declare that they have no competing interests.

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