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RESEARCH ARTICLE

Climate Change And The Ecological Resilience Of Plants In Tashkent: A Multidimensional Analysis

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Abstract

This paper involves the shifting ecological role of urban and peri-urban vegetation in Tashkent amidst accelerating climate change. By integrating the physiological research and geobotanical mapping and the climate modeling of international agencies, it was analyzed anthropogenic transformation are threatening the sustainable development in Tashkent. The research identifies a critical transition in the botanical landscape: plants are shifting from stable urban amenities into stressed, functional components of climate resilience. Key findings highlight the phenomenon of "pasture digression" and the interruption of plant ontogenesis (developmental cycles) caused by extreme thermal stress (reaching 48°C). The study further utilizes species distribution modeling (SDM) to predict a 65% habitat decline for local flora by 2050 and explores the forced altitudinal migration of perennial grasses such as Poa bactriana.

KEYWORDS

Tashkent, Climate Change, Urban Heat Island (UHI), Maxent Modeling, Plant Ontogenesis, Pasture Digression, "Yashil Makon" Project, Ecological Resilience, Species Distribution Modeling (SDM), Xerophytes, Anthropogenic Transformation.

INTRODUCTION

Climate change in Tashkent, characterized by rising temperatures, increased drought frequency, and water scarcity, is significantly altering the ecological position of plants, transitioning them from a stable urban amenity to a stressed, critical component of urban resilience. Urbanization and extreme heat have caused a significant decline in vegetation cover, with build-up areas increasing while green zones decrease.

Climate change in Tashkent, characterized by accelerating temperature increases, a surge in drought frequency, and acute water scarcity, is fundamentally altering the ecological standing of regional flora. This shift transitions vegetation from a traditional urban amenity into a stressed, yet critical, component of urban climate resilience. Rapid urbanization, coupled with extreme thermal anomalies, has precipitated a significant decline in vegetation cover; as metropolitan built-up areas expand, vital green zones conversely recede.

The primary driver of this ecological destabilization is the

"Greenhouse Effect" on a local and global scale. The concentration of greenhouse gases (GHGs) – specifically Carbon Dioxide (CO_2) and Methane (CH_4) – has trapped solar radiation within the lower atmosphere, creating a feedback loop of warming. In the context of Uzbekistan, this warming is occurring at nearly three times the global average. While the global mean temperature has risen by 0.60C in recent decades, Uzbekistan has documented increases exceeding 1.60C.

Between 1990 and 2019, Tashkent's built-up footprint expanded by approximately 60%, largely at the expense of its peri-urban "green buffers." This land-use transformation has intensified the Urban Heat Island (UHI) effect, where nighttime temperatures remain high, preventing plants from recovering from daytime thermal stress. Satellite monitoring indicates that the Normalized Difference Vegetation Index (NDVI) – a measure of greenness and photosynthetic health – has plummeted in the capital from 34% to 13% over the last six years.

The hydrological cycle of the region is under unprecedented strain. The accelerated melting of Tien Shan glaciers is projected to reduce the critical runoff of the Amu Darya and Syr Darya rivers by 25–50% during peak summer months. This water stress, combined with excessive evaporation, leads to land degradation and desertification, which currently impacts nearly 60% of the nation's pastures.

In response to these environmental "tensions," the government of Uzbekistan has elevated environmental protection to a matter of national security. The "Yashil Makon" (Green Space) project serves as the flagship mitigation strategy, aiming to plant one billion trees to restore urban green cover to 30%. However, as current biological research suggests, the success of this reforestation depends entirely on shifting botanical planning from an ornamental focus to a functional, climate-resilient framework.

The ecological problems facing Tashkent highlight cities' vulnerability to global climate change. The results stress the need for integrated urban planning prioritizing sustainability and climate resilience. Urban Planning and Green Infrastructure Expanding green infrastructure – urban forests, green roofs, and shaded streets – can mitigate urban heat islands and improve air quality. Programs encouraging park creation and tree planting help lower ambient temperatures and absorb pollutants. The city administration has launched initiatives like "Green City" and partnered with international organizations for urban greening. Expanding these initiatives is critical for meaningful impact. Renewable Energy and Sustainable Transport Transitioning to renewable energy and promoting sustainable transport are vital. Expanding Tashkent's metro system, encouraging electric vehicles, and improving bicycle infrastructure can reduce greenhouse gas emissions and air pollution. Improving building energy efficiency also reduces cooling needs during hotter summers and cuts reliance on fossil fuels. Water Resource Management Investing in modern water management technologies like smart irrigation systems and waste water recycling can alleviate water shortages. Public awareness campaigns on water conservation are equally important. Considering the transboundary nature of Central Asia's rivers, cooperation with regional neighbors is essential for efficient shared water management.

Feruz Akbarov utilizes advanced grid-mapping (5x5 km cells) and Maxent modeling to predict the future of Uzbekistan's flora. His researches in 2024–2025 reveal that 65% of surveyed species in the Surkhandarya and Tashkent regions are expected to experience a "significant decline in suitable habitat" by 2050. Modeling for perennial grasses like Poa bactriana suggests that as the Tashkent plains become too arid, species are being forced to migrate to higher elevations (1500–4000 meters) to survive. This creates a "botanical vacuum" in the city, where only the most aggressive or invasive species can persist. Akbarov's work has identified "saturated indices" in the mountainous regions, while urban indices remain "unsaturated" and highly vulnerable to anthropogenic pressure, overgrazing, and land-use changes [1,3].

Foreign research institutes, including the Potsdam Institute for Climate Impact Research (PIK) and UNEP, provide the "macro" data that frames the local botanical crisis. According to the UNEP Eco-Atlas (2025), Uzbekistan recorded six major dry years between 2019 and 2024. This frequency prevents the soil from recharging, leading to permanent land degradation that affects 60% of the country's pastures. A UNICEF (2024) analysis identifies Tashkent as a high-vulnerability zone. The loss of urban trees directly correlates with increased respiratory issues in children, as the "dust-trapping" capacity of the city's green canopy has diminished. International modeling (Didovets et al., 2021) shows that river runoff in the region can decline by 25–50% during extreme years, meaning that even with the "Yashil Makon" project, there may not be enough water to sustain one billion new saplings without revolutionary water-saving technologies [2,4].

Urban vegetation has decreased as built-up areas expanded by nearly 60% between 1990 and 2019. This urbanization leads to the fragmentation of natural habitats, particularly in the adyr (foothill) zones surrounding Tashkent, where anthropogenic pressure has reduced vegetation cover by 25–50%. Research documents how anthropogenic pressure and the "greenhouse effect" shift species composition from valuable perennial grasses to invasive ruderal species like Acroptilon repens and Dodartia orientalis. This process, termed pasture digression, reduces the ecosystem service value of the green zones surrounding the capital. The work on plant ontogenesis (developmental cycles) reveals that climate stress prevents plants from completing their life cycle. The studies on endemic populations indicate that extreme summer heat often causes plants to fail the "vegetative process" before seeds are produced (Khujanazarov et al., 2024). This leads to a "senile" population structure, where older vegetation persists but no new growth replaces it, threatening long-term urban resilience [5].

Research highlights the use of ephemerals and ephemeroids as a natural adaptation. So, for species that utilize an "escape" strategy—completing growth in the moist spring before the 48°C summer peak. The survival of urban green belts depends on selecting species with high osmotic pressure and water-retaining capacity to withstand the "garmsil" (hot dry winds). Climate change is particularly threatening to rare flora in the Tashkent region. The monitoring of species such as Tulipa fosteriana and Iris magnifica shows that their ecological niches are shrinking due to the combination of rising temperatures and uncontrolled grazing in the foothill zones (Khujanazarov et al., 2021) (Table-) [6-7].

The "Yashil Makon" project aims to increase green spaces to 30%. Scientists suggest that for this to be sustainable, seedlings must be treated with mineral nutrition and microelements during their early developmental stages to artificially enhance their innate resistance to environmental "tensions" and drought. Researches indicates that dense tree canopies providing over 75% shade are the most effective. Scientists ecological assessments further specify that multi-layered plant associations (combining tall trees with drought-hardy shrubs like Prangos pabularia) create a superior microclimate barrier compared to monoculture lawns, which he classifies as highly vulnerable to desertification [8].

Table-1
Comparison of Plant Resilience

Plant Type	Adaptive Strategy	Resilience Level	Role in Urban Ecology
Ephemerals	Life-cycle completion before summer	High (Escape)	Early spring greening/soil stabilization
Xerophytes	High osmotic pressure & water retention	High (Endurance)	Core of "Green Belts" and dry-zone parks
Traditional Fruit Trees	High transpiration demand	Low (Vulnerable)	Declining; requires high irrigation
Ruderal Weeds	Rapid seed dispersal & low resource need	Very High	Indicator of ecosystem degradation

Future climate change and its impact on drought is critical for Uzbekistan, located in Central Asia, the world's largest arid zone. The evolving intensity of climate change and drought events using multi-model ensembles (MMEs) derived from the Coupled Model Intercomparison Project Phase 5 and 6 (CMIP5 and CMIP6) simulated under the Representative Concentration Pathway and Shared Socioeconomic Pathway (RCP and SSP) scenarios. The projections show different rates of increase in temperature and precipitation under the RCPs and SSPs. Projected temperature increases are expected to reach up to 2–2.50 C under SSP1-2.6, SSP2-4.5, and SSP3-7.0, by mid-century. By 2080–2099, an increase is projected of 2–30 C in monthly mean temperatures throughout the year (SSP1-2.6), and a more pronounced increase in summer up to 3–40C (SSP2-4.5) and 4–60 C (SSP3-7.0), with a marked contrast in conditions between the mountainous and desert regions of Uzbekistan. Regional changes in precipitation over the study periods show relatively little variability, except for FD, where notable trends are found. Under SSP1-2.6 and SSP2-4.5, the increase in precipitation is relatively modest, whereas the changes in SSP3-7.0 are more substantial, with some regions experiencing variations of up to 10–20 mm per period. The Standardized Precipitation Evapotranspiration Index (SPEI), calculated based on the projected temperature and precipitation, provides an estimate of future drought trends. In view of Uzbekistan's heavy reliance on agriculture and irrigation, which are the sectors that are expected to be mostly affected by climate change, our study provides a scientific basis for informed policy decision-making. This includes various aspects such as planning and management water resources, as well as the broader socioeconomic development of the country [10].

Climate change and shrinking of the Aral Sea have significantly affected the region's temperature variations. Observed inter annual changes in Uzbekistan's air temperature compared to the duration of synoptic weather types (SWT) in Middle Asia were analyzed. Nonparametric Mann–Kendall statistical test and climate trends coefficients were used to identify trend characteristics of observed temperature from 1961–2016 to the baseline period of 1961–1990. The results showed increasing temperature trends average to 1°C in warm and cold half years over Uzbekistan. The 1991–2016 decadal temperature trend ranged from 0.25 °C/decade in the northwest to 0.52°C/decade in the center, especially pronounced in the oasis and Aral Sea zones. There were also significant changes in the structure of regional SWT. The main difference in the structure of SWT in Middle Asia relative to the baseline period was expressed in a decrease of cold mass invasion duration from 113.4 to 76.1 days and an increase in low-gradient baric field duration from 65.8 to 134.6 days. The process of anthropogenic warming, which began in Uzbekistan in the 1960s of the twentieth century, has accelerated from the mid-1970s with a higher mean annual air temperature than the baseline period's climate normals (1961–1990) and is associated with changes in the regional SWT over Middle Asia [11].

CONCLUSION

The researches of the scientists and their international peers paints a clear picture: the flora of Tashkent is no longer just a decoration; it is a biological defense system under siege. For the city to remain habitable, botanical planning must move from "ornamental" to "functional," prioritizing species that can survive the projected 2.5 0 C rise in local temperatures by 2050.

To remain habitable, Tashkent's botanical strategy must pivot toward Functional Landscaping. This means prioritizing species not for their appearance, but for their ecosystem services, such as:

Thermal Regulation: Selecting trees with leaf structures capable of high transpiration rates under stress.

Air Filtration: Utilizing "dust-trapping" species that can mitigate the increasing frequency of sandstorms.

The research underscores that the success of the "Yashil Makon" project depends on a scientifically-backed selection process. We must prioritize Xerophytes and Ephemeroids—plants that have evolved "escape" or "endurance" strategies to survive the 48°C peak summer heat. Furthermore, the transition to multi-layered plant associations (combining tall shade-givers with drought-hardy shrubs like Prangos pabularia) is essential to create a resilient microclimate barrier.

If the current trend of "pasture digression" and habitat fragmentation continues, Tashkent risks losing its ecological resilience by the mid-century. The flora of the city must be managed as critical infrastructure, equivalent to water or power grids. For Tashkent to survive the climate of 2050, every new sapling must be a functional soldier in a broader biological defense strategy, chosen for its physiological ability to withstand a rapidly warming world.

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