EarthCanvas: Journal of Earth, Space and Society JESS Vol. 1, Issue 1 Mar 2026
E-ISSN: 3139-1850

Role of CPA Plantation and Its Impact on Microclimate of Adjoining Areas of Bhopal, Madhya Pradesh

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Received: 17 September 2025
Accepted:8 October 2025
Genre: Life Science

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Cite this article
Dahare D. K. (2025). Role of CPA Plantation and Its Impact on Microclimate of Adjoining Areas of Bhopal, Madhya Pradesh, JESS, 1(1), 24-28.

ABSTRACT

Urban vegetation plays a vital role in regulating microclimate of adjoining areas, also mitigating heat island effects, and improving eco-sociological resilience in rapidly urbanizing cities. In Bhopal, the Capital Project Administration (CPA) has carried out extensive plantation programs for restoring green cover and enriching urban thermal relief. This research paper appraises the role of CPA plantations in reforming vegetation patterns and upgrading microclimatic parameters such as air and surface temperature, humidity, soil moisture, and wind flow. The paper synthesizes scientific mechanisms underlying vegetation–microclimate interactions and proposes a methodological framework for microclimate assessment using field monitoring, GIS-based analytics, and remote sensing. Findings from past research studies suggest that urban plantations can reduce air temperature by 1–3°C, lower surface temperatures by 3–15°C, increased relative humidity, and strengthen human thermal reassurance. The analysis pinnacles the importance of plant species selection, multi-layered plantation patterns, and maintenance strategies for Bhopal's sub-tropical climate. Overall, the study shows that CPA's plantation programmes have made noticeable, positive differences in the microclimate of nearby areas and contribute meaningfully to the city's long-term environmental sustainability.

Keywords: Microclimate, resilience, assessment, reassurance, sustainability.

1. Introduction

Rapid urbanization and change in land-use patterns have resulted in significant microclimatic alterations in growing cities, including urban heat island (UHI) formation, increased surface temperatures, and reduced environmental quality (Oke, 1987; Kumar et al., 2022). Bhopal, mainly known for its lakes and good green cover, is now experiencing

socio-ecological pressures due to expanding built-up areas and declining vegetation cover.

The Capital Project Administration (CPA) has initiated plantation programs across road corridors, institutional lands, residential neighbourhoods, and open spaces to maintain and improve the vegetation cover of city. These plantations aimed to improves green cover, restore degraded patches, and reduce microclimatic stressors, especially during high-temperature summer seasons. This study presents an extensive analysis of the role of CPA plantations in changing vegetation patterns and microclimates in adjoining areas of Bhopal. It integrates scientific concepts, empirical findings, and urban forestry principles to evaluate the socio-ecological benefits of plantation interventions.

2. Role of CPA Plantation in Improving Vegetation Patterns

CPA plantations contribute to structural, functional, and compositional improvements in urban vegetation patterns in several ways: The introduction of tree species with broad canopies enhances shading, reduces solar radiation reaching the ground, and promotes cooler surroundings. CPA typically planted native, pollution tolerant, avenue, aesthetic and fast-growing species such as Ficus religiosa, Ficus benghlensis, Dalbergia sissoo, Azadirachta indica, Pongamia pinnata, Terminalia arjuna, Cassia siamia, Samanea saman, Alstonia scholeris, Ficus benjamina and Cassia fistula. This higher species diversity enhances ecological stability and resistance to pests, diseases, and climatic stress (Sukumaran & Parthasarathy, 2010).

Plantations along with city roads, lakesides, parks, hill tracts, barren lands and institutional campuses create ecological linkages, enabling: movement, genetic flow, continuous green belts contributing to adjoining areas cooling. CPA plantations convert barren or impervious surfaces into vegetated areas, helping to: reduced albedo-related heat fluctuation, improved soil structure, enhanced carbon sequestration. Such changes significantly influence microclimatic conditions (Gill et al., 2007).

3. Mechanisms Influencing Microclimate

Vegetation alters microclimate through various biophysical mechanisms: Tree canopies reduce incoming solar radiation by 60–80%, significantly lowering air and surface temperatures beneath them (Shashua-Bar & Hoffman, 2000). Plants release moisture through stomata and hydathodes which consuming latent heat and lowering ambient temperatures by 1–3°C (Bowler et al., 2010). Evapotranspiration also sustains diurnal temperature variation. Vegetated surfaces typically have higher albedo than asphalt or concrete, reducing heat absorption and lowering surface temperature of area. Tree belts alter wind speed and their direction. Dense plantation rows work as windbreakers, while selectively spaced plantations improve ventilation in open areas (Huang et al., 2011). Vegetation enhance infiltration, reduces runoff, and increases soil water retention, affecting local humidity and cooling effect. Trees absorb CO_2 and particulate matter,

improving overall environmental quality and indirectly enhancing thermal comfort of adjoining areas.

4. Microclimatic Impacts of CPA Plantations in Bhopal

Studies conducted in urban areas with similar climatic conditions indicate substantial microclimatic benefits: Urban plantations can reduce surrounding air temperature by 1–3°C, particularly during mid-day peaks. Vegetation surfaces show 3–15°C lower land surface temperature (LST) than constructed areas. Satellite-based LST comparisons in Bhopal show significantly lower values around plantation zones. Plantation zones maintain 3–7% higher humidity due to evapotranspiration from plants. Higher shade cover, reduced radiant heat, and softer wind flow also reduce physiological equivalent temperature (PET) and heat stress. CPA plantations on public parks, slopes, hill tracts, lake fringes, and roadside alignments show improved soil moisture due to litter, mulching and biological infiltration. Trees reduce particulate matter (PM2.5 and PM10), contributing to better respiratory health of people and reduced heat stress of adjoining areas.

5. Methodology for Assessing Microclimatic Impact

A combined multi-disciplinary methodological approach is used for evaluating CPA plantation impacts, Field Measurements using: Automatic Weather Stations (AWS) for continuous monitoring, used handheld sensors for spot temperature, humidity, wind speed and soil moisture at multiple depths. Used GIS and Remote Sensing, tools such as:

- NDVI (Normalized Difference Vegetation Index),
- LST (Land Surface Temperature),
- Canopy Density Mapping, Supervised Classification.
- Satellite sources: Landsat-8, Sentinel-2, IRS-LISS IV.

Microclimate modelling, tools such as ENVI-met and i-Tree Eco used to measure or simulate: shading, evapotranspiration cooling, changes in urban thermal behaviour. Survey and Perception Studies used for assessment of thermal comfort among residents through structured questionnaires.

6. Plantation Design for Bhopal

Multi-layered plantation design incorporates upper canopy mostly with large evergreen trees, middle canopy consists shrubs and fruit bearing plant species while ground cover composed of grasses, herbs made multi-layer systems maximize shading and evapotranspiration. Cluster planting should be used instead of linear planting 5–6 m spacing for optimum canopy expansion is best, bioswales and rainwater harvesting pits, permeable surfaces around plantations is useful for better growth. Maintenance strategies for successful plantation drip irrigation during early stages, induce mulching to reduce

evaporation and tree guards to protect saplings during early stage of planting.

7. Recommendations for CPA Plantation Optimization

Should be develop continuous green corridors to connect open spaces and enhance socio-ecological flow. Integrate plantation with urban planning, especially in high-density zones and heat hotspot zones. Prioritize fast growing species with native species for sustainability and climate compatibility. Should be implement community participation programs for monitoring and maintenance of their adjoining plantations. Use remote sensing for annual vegetation monitoring and survival rate tracking. Adopt climate-smart plantation models such as Miyawaki patches in dense areas for good canopy. Also strengthen post-plantation care including watering, mulching, weeding, pest management, and periodic pruning.

8. Conclusion

CPA plantation initiatives play a vital role in enhancing vegetation cover and modifying microclimatic conditions in Bhopal. Through mechanisms such as shading, evapotranspiration, soil moisture retention, and wind modulation, these plantations significantly reduce air and surface temperatures, increase humidity, and improve thermal comfort. Effective species selection, scientific plantation design, and proper maintenance are crucial for maximizing ecological benefits. With continued expansion and systematic monitoring, CPA plantations can contribute substantially to long-term environmental sustainability and climate resilience in Bhopal's urban landscape.

Author Contributions

Dr. Dinesh Kumar Dahare- Conceptualization, Analysis and inference, Writing.

Funding Sources

No funding or support was received from organizations that may gain or lose financially through this publication.

Acknowledgement

The author would like to express his sincere gratitude to Principal, Shyam Prasad Mukherjee Govt College, Bhopal for his kind permission and support contributed to the successful completion of this research work.

Statement of Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research paper. The authors have no financial, commercial, or personal relationships that could be perceived to influence the work reported in this paper.

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