

Microclimate Regulation as an Ecosystem Service by Mangroves: Sarovaram Biopark, Kozhikode

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Abstract

Background: The role of mangroves in regulating the microclimate at Sarovaram Biopark in Kozhikode, Kerala, is discussed in this study. The aim of the research is to test the hypothesis that mangrove habitats significantly contribute to local climate regulation or rather microclimate regulation. Field data of temperature and humidity were collected from the core mangrove area, 50 m from the core area, and from the surrounding urban areas in Kozhikode town.

Result: The results indicate that, compared with the surrounding urban agglomeration, the central zone of the mangrove forest consistently maintains lower ambient temperatures. One hundred random tourists were interviewed to assess the level of comfort within the biopark. 32% of the interviewed tourists mentioned that they had a very high comfort (91–100%), and 76% rated their entire experience as above 75%.

Conclusion: The notion that mangroves have a cooling effect and may influence microclimatic regimes is verified by this temperature difference. The findings show the value of urban mangrove patches as a source of climate resilience and sustainable urban planning, and their ecological value in mitigating the urban heat island effect.

Keywords: Mangrove, forest, environment, climate change, humidity, Temperature-humidity Index, thermal comfort, cooling effect.

INTRODUCTION/BACKGROUND

Mangroves can be found in tropical and subtropical areas between roughly 30°N and 30°S latitudes in the intertidal zone. Their worldwide range is defined by the 20°C isotherm of the sea's surface water and strong ocean currents. Latitude temperature differences affect mangroves worldwide, and soil salinity gradients are frequent locally. (Lima et al., 2021).

Along tropical shorelines, mangroves constitute an ecological group of plants and trees that have adapted to survive in intertidal environments. The loss of about 50% of global mangroves has been recorded over the past 20 years because of aquaculture, coastal development, changes in hydrology, sea-level rise, and nutrient over enrichment, even with many instances of its economic and social advantages. (Feller et al., 2010)

Vegetated coastal ecosystems such as seagrasses, mangroves, and salt marshes are considered to be among the world's most valuable and productive coastal ecosystems. Collectively known as "blue forest ecosystems," they have been discussed on the international climate and conservation agenda. As more individuals become aware of how effective blue forests are at climate regulation by sequestering carbon in the atmosphere, carbon sequestration and storage has turned out to be one of the most debated ecosystem services offered by these ecosystems. In addition, these ecosystems provide a range of important ecosystem services and benefits leading to poverty reduction and food security. Some of the most cited services are the supply of food and raw materials, opportunities for tourism and recreation, and management of extreme events. (Himes-Cornell, et al., 2018)

Since they provide noteworthy and unique ecosystem goods and services to human civilization as well as marine and coastal systems, mangrove forests are among the most productive and biologically valuable ecosystems globally. They reduce the destructive impact of natural hazards such as hurricanes and tsunamis and stabilize shores. In addition to supplying food, medicine, fuel, and construction materials for surrounding towns, they are also breeding and nursery grounds for marine and pelagic species. Mangroves and the soils that they are associated with have been estimated to sequester 22.8 million metric tons of carbon per year.

Statistics on mangrove forest extent and condition globally could provide essential data for policy-making and resource management.

Mangroves are ever evolving due to both man-induced and natural processes (e.g., erosion and aggradations). (Giri et al., 2011)

The preservation of the coastal ecology is greatly aided by mangrove forests. Recent years have seen a decline in the size and viability of these ecosystems due to human activity and global warming. (Rostami et al., 2022)

Mangroves are largely overlooked due to the impact of climate change, even though summer patchy dieback and major occurrences do happen in mangroves globally and existing alarming issues from altering climates. (Alongi, 2014; Barbier et al., 2011)

Mangrove ecosystems are very productive globally and have vital functions in marine and coastal systems. Their productivity is comparable to some of the world's most productive ecosystems, supporting a diverse range of organisms as well as breeding ground for marine organisms. (Costanza et al., 1997; Barbier et al., 2011)

In their application, preservation, and restoration, mangroves are usually undervalued in both private and public decision-making. Public decision-making in general has neglected mangrove ecosystem services due to a deficiency of knowledge and awareness regarding their role. The value of mangroves as natural capital is often undervalued when data are not available that enable comparisons of the economic value of mangrove ecosystem services to the economic value of other public expenditures.

Pollution, deforestation, fragmentation, and sea level rise are some of the problems facing mangroves all over the world (Giri et al., 2011). Coastal development and population growth, and climate change are mainly responsible for these dangers. Mangroves are being replaced by other land uses such as aquaculture ponds, urbanization, agriculture, and infrastructure. (Brander et al., 2012)

LITERATURE REVIEW

There is yet no full standardization in the valuation process of mangrove ecosystem services. The three broad categories of the economic value of mangroves are (i) direct use value, (ii) indirect use value, and (iii) non-use value, as identified by economists. The phrase "direct use values" refers to both consumptive and non-consumptive uses, such as revenue from fishing, timber, fire wood, animal feed, honey, beeswax, and recreation, that involve direct contact with the mangroves and their services. Indirect use values include ecological regulatory services like flood control, storm protection, nutrient retention, and erosion control. Existence and legacy values of mangroves are some examples of non-use values. (Mitra et al., 2020)

For the growth of tourism in safeguarded areas, it is important to use comfort climatic indices for proper planning. Planning and tourist activity development call for a clear perception of the potentialities and limitations of the climate and its attractions. As far as this is concerned, accurate knowledge of the climate of the tourist place can be a basis for intelligent local planning and management decisions. One approach to efficiently regulating human activities that can be considered for natural ecosystems, especially the developable portions of protected areas, is to monitor the comfort climate. In general terms, the climate indices indicate which months of a given year provide the most comfortable and pleasant weather for the tourists in the region of interest. (Sobhani et al., 2023)

Hazardous impacts of climate change are increasing mean daily temperatures and the intensity and frequency of summer heatwaves. Little attention has been given to mangrove systems' potential to adapt to future climates with more frequent and intense temperatures due to climate change. Mangroves are largely overlooked due to the impact of climate change, even though summer patchy dieback and large-scale events happen in mangroves globally and there are alarming issues from altering climates. (Abdulla Naseef, 2025)

Among the most ecologically productive and valuable of the world's ecosystems, mangroves provide coastal and marine systems, as well as society, ecosystem products and services that are valuable and unique. With a limited number of mangrove species found along environmental gradients, it is essential to understand how mangrove trees react ecophysiologically to these gradients. (de Lima et al., 2021)

Detailed understanding of the numerous benefits mangrove forests provide is important in keeping them in urban areas. To support ecosystem conservation, the concept of ecosystem services—the role of the ecosystem in providing various benefits to people—has gained extensive application. Mangrove forests in urban areas can be conserved through an ecosystem services approach, among other factors, by proper identification and quantification of their main ecosystem functions. It is possible to better appreciate the high worth of urban mangrove forests and the benefits of protecting mangroves by valuing ecosystem services quantitatively. Policymakers and members of the public can be encouraged to help conserve urban mangroves through the utilization of quantified information as pedagogic tools that emphasize the benefits of the ecosystems. (Sumarga E et al., 2023)

Natural ecosystems provide goods and services directly and indirectly enhancing human well-being. Land-use planning, sustainable enterprise, and integrated environmental decision-making at many geographic and sociopolitical scales all rely upon the capacity to estimate the economic value of the ecosystem's goods and services. All natural ecosystem products and services that benefit, sustain, and enhance human well-being are jointly termed as "ecosystem services" (ES). Production of food, materials for construction, medicines, prevention of diseases, regulation of microclimates, delivery of productive soil and clean water supplies, and landscape amenity for recreational and spiritual activities are a few examples of the advantages of the ecosystem. (Vo, Q. t. et al 2012)

Chow (2017) did study on Mangrove management for climate change adaptation and sustainable development in coastal zones. It suggests that Mangroves are important in developing countries because they provide various ecosystem services and support several UN Sustainable Development Goals related to climate change and the management of coastal resources. Although mangroves are at risk from climate change, they help reduce damage

by capturing carbon, stabilizing coastlines, and protecting communities from storms. They can grow quickly and help build up coastlines against rising sea levels. Chow J, (2018)

Furthermore, recent research has shown that mangrove expansion into saltmarsh areas may alter microclimatic conditions (Guo et al. 2016). Observed vegetation-microclimate feedbacks, while underinvestigated, are likely to impact the speed of climate-driven range shifts if changes in the microclimate are large enough to create biologically important differences in plant vital rates. Notably, it is yet to be determined if these microclimates offer biotic and abiotic feedback processes that alter mangrove seedling survival and, by extension, the rate at which mangroves grow in general. (Devaney et al., 2017)

MATERIAL AND METHOD

Study Area

Kozhikode district of Kerala has been known to have 200 ha of the total mangroves of Kerala **Sarovaram Biopark**: The goal of Sarovaram Biopark, an environmentally conscious park, is to preserve wetlands and mangrove forests. This park has allowed people to feel the warm embrace of nature for almost a decade. The floating rafts, boardwalk, park, musical fountain, open-air theatre, otter park, butterfly park, bird sanctuary, canal walkway, boating facilities, and aquarium serve as continual reminders of how preserving these threatened places may result in the creation of works of art. A total of 200 acre is under protection. Sarovaram, sometimes called Sarovaram Bio Park, is an environmentally conscious community in Kozhikode, Kerala, close to Kottooly. Canoly Canal is located next to the park. The project is situated in an ecosystem made up of wetlands and mangrove forests that provide home for birds, and it was constructed with an eco-friendly motif.

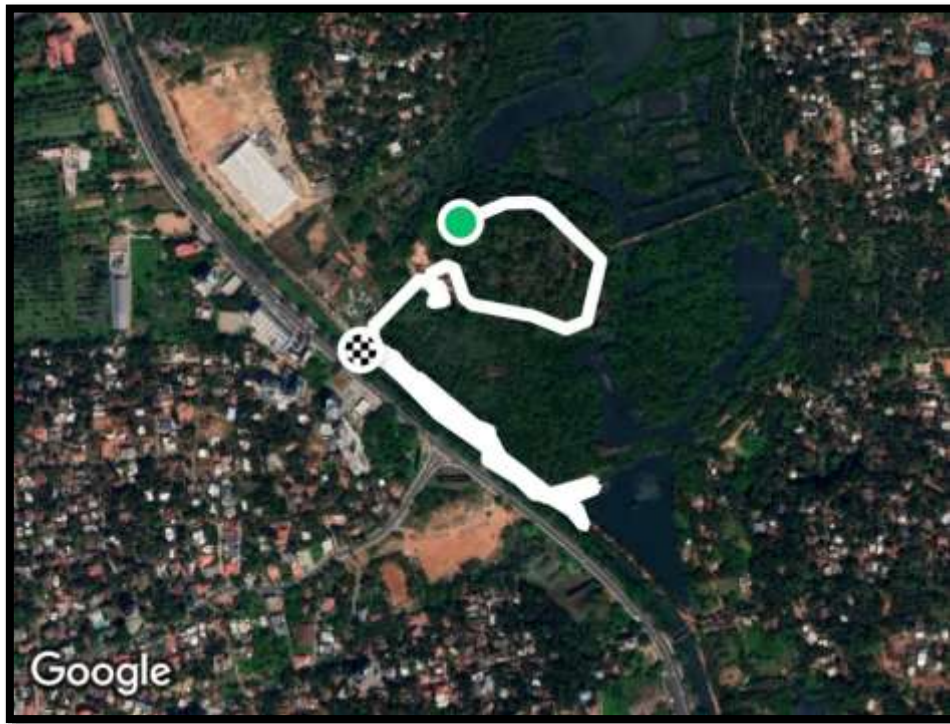


Fig.1



Fig.2 T-Z01 air quality monitor

The temperature and humidity were measured using a device that measures the air quality index. The T-Z01 air quality monitor is a high-performance device designed to assess home air quality by measuring concentrations of PM2.5, HCHO, TVOC, CO, CO₂, as well as temperature and humidity levels.

To analyse microclimate regulation, air temperature and relative humidity were measured in three locations: one within the mangrove park (under mangrove cover), one in an open area 50m away, and one in an open area 300m away. Air temperature and relative humidity were monitored three times per day for three days at each location (9-10 am, 12-1 pm, and 4-5 pm).

The THI was calculated using the following formula:

$$THI = 0.8 T + ((RH \times T)/500)$$

where:

THI = Temperature-Humidity Index.

T = Average daily air temperature (°C).

RH = Average daily relative air humidity (Nieuwolt et al., 1998)

No	Comfort Classes	THI
1	Comfortable	21–24
2	Moderate	25–26
3	Uncomfortable	>26

This study will assess visitor comfort with the microclimate within the mangrove park. 100 responders were interviewed about their experience with the mangrove park's amenities. Respondents will be requested to provide Score between 1 and 100. (%). (Sumarga, Sholihah, Srigati, Nabila, Azzahra and Rabbani, 2023)

Observations

DAY 1 Temperature Readings

Region (Temp C)	9:30 TO 10:30	12:30 TO 1:30	4:30 TO 5:30
Town	29° C	30° C	31° C
50m	28° C	28° C	30° C
Core	27° C	26° C	29° C

Table.1

DAY 1 Humidity Readings

Region (Humidity)	9:30 TO 10:30	12:30 TO 1:30	4:30 TO 5:30
Town	69	42	60
50m	73	73	61
Core	76	79	65

Table.2

DAY 2 Temperature readings

Region (Temp °C)	9:30 TO 10:30	12:30 TO 1:30	4:30 TO 5:30
Town	30° C	35° C	31° C
50m	28° C	33° C	30° C
Core	28° C	30° C	29° C

Table.3

DAY 2 Humidity Readings

Region (Humidity)	9:30 TO 10:30	12:30 TO 1:30	4:30 TO 5:30
Town	66	49	66
50m	73	60	68
Core	72	65	72

Table.4

DAY 3 Temperature Readings

Region	9:30 TO 10:30	12:30 TO 1:30	4:30 TO 5:30	Average temperature of a day
Town	29.33	31.6	30.66	30.53
50m	28.33	30	30	29.44
Core	27.33	28.33	29	28.22

Table.5

DAY 3 Humidity Readings

Region	9:30 TO 10:30am	12:30 TO 1:30pm	4:30 TO 5:30pm	Average Humidity in a day
Town	67.66	51.66	63.33	60.88
50m	71.33	65	62.66	66.33
Core	73	70.66	68	70.55

Table.6

Average Temperature of all three days

Region	9:30 TO 10:30am	12:30 TO 1:30pm	4:30 TO 5:30pm	Avg temp of a day
Town	29.33	31.6	30.66	30.53
50m	28.33	30	30	29.44
Core	27.33	28.33	29	28.22

Table.6

Average Humidity of all three days

Region	9:30 TO 10:30am	12:30 TO 1:30pm	4:30 TO 5:30pm	Avg Humidity in a day
Town	67.66	51.66	63.33	60.88
50m	71.33	65	62.66	66.33

Core	73	70.66	68	70.55
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Table.7

Region	THI (Temp-humidity Index)
TOWN	28.13
50M	27.45
CORE	26.55

Table.8

Visitor's comfort survey

Comfort Rating Range (%)	No. of Respondents (n)	Relative Frequency (%)	Comfort Category
91-100	32	32.0%	Very High Comfort
81-90	26	26.0%	High Comfort
76-80	18	18.0%	Moderately High Comfort
51-75	20	20.0%	Moderate Comfort
≤ 50	4	4.0%	Low Comfort
Total	100	100.0%	

Table.9

RESULT AND DISCUSSION

The Temperature-Humidity Index (THI) analysis in the study areas uncovered substantial microclimatic heterogeneity driven by mangrove cover. The central zone of the mangrove site had the lowest mean THI at 26.55, representing a cooler and more thermally pleasant climate. On the 50 m distance from the central zone, the THI was higher at 27.45, showing a moderate alteration of microclimatic status with declining vegetation density. Conversely, the urban surrounding area of Kozhikode municipality reported the highest THI at 28.137, indicating a warmer and stressful thermal condition.

This THI gradient unequivocally illustrates the microclimate-controlling function of mangroves, where temperature and thermal stress reduce towards the vegetative core. These observations substantiate the hypothesis that mangrove ecosystems play a role in localized climate control and deliver vital ecological services in urban settings by reducing heat stress and improving thermal comfort.

The 100 visitors to Sarovaram Biopark's central mangrove area were administered a standardized comfort perception questionnaire. On a scale of 1 to 100, the respondents rated their thermal comfort level. Based on the findings, 32% of the respondents indicated very high comfort (91-100%), and 76% of the respondents rated their experience as more than 75%. There was minimal thermal discomfort since just 4% of the respondents marked their comfort as less than 50%. This subjective assessment substantiates the result that mangrove environment improves thermal comfort considerably and is highly correlated with recorded microclimate data (e.g., reduced THI in the core zone). The results emphasize the significance of conserving and integrating mangrove patches into cityscapes to enhance human thermal well-being.

According to a study conducted by Sumarga et al., (2003), The microclimate regulation role of the urban mangrove forest at Angke Kapuk was exhibited by substantial air temperature drops and humidity increases within the park relative to nearby open spaces. The research indicated that temperatures under the mangrove canopy were about 1.7°C lower than ambient temperatures, which was mainly attributed to evapotranspiration and canopy shading. This microclimate regulation improves comfort for visitors and helps create a healthier urban climate, highlighting the critical function of mangroves as climate regulators in highly populated cities such as Jakarta. This outcome strengthens the need to preserve and restore urban mangrove ecosystems as natural climate buffers and recreational spaces. Furthermore, the

present research identified that the town area's Temperature Humidity Index (THI) was 28.13, while the central zone of the Mangrove conservation area had a THI of 26.55. As the mangrove forest at Sarovaram Biopark, Kozhikode, also serves as a recreational area, where facilities are highly required, this microclimate management contributes a valuable ecosystem service to the study area.

CONCLUSION

The findings of this research provide compelling evidence that mangrove ecosystems exert a considerable microclimatic regulating effect, particularly in urban regions. The spatial differential in the Temperature-Humidity Index (THI) values indicates the capability of mangrove cover to insulate ambient thermal conditions and reduce localized heat stress, as evidenced by the fact that the THI values are lowest in the inner mangrove zone (26.55), moderate at 50 m (27.45), and highest in the urban landscape (28.137). Perceptual information, which indicates that just 4% of visitors expressed notable discomfort and 76% gave thermal comfort ratings higher than 75%, strongly substantiates these biophysical measures.

The hypothesis that mangrove patches enhance human thermal welfare and deliver measurable environmental benefits is confirmed by agreement between objective climatic factors and subjective thermal feeling. The ecological argument for preserving residual mangrove networks in urban coastlines is reinforced by this two-pronged body of research, as it constitutes a natural strategy for urban climate adaptation besides their biodiversity function and carbon-sequestration function.

The integration of mangrove-based green infrastructure into urban planning must receive high priority, given the escalating effects of urban heat islands (UHIs) and climate vulnerabilities of tropical cities. Such conservation of ecosystems must be looked at as an important urban resilience strategy as well as an ecological conservation strategy. Future research should study seasonal dynamics, species-specific cooling potential, and long-term urban-mangrove dynamics to optimize their multipurpose use in city environments.

DECLARATION

Ethics approval and consent to participate

The ethical standards as set out by the national and/or institutional research committee were followed in carrying out this study. Ethical clearance was obtained from the Secretary of the District Tourism Promotion Council. Informed written consent was obtained from each participant prior to the start of the study.

Consent for publication

Informed consent was obtained from all participants involved in the study.

Availability of data and material

Upon reasonable request, the corresponding author can share the data sets used and/or analyzed during the current study.

Competing interests

The authors declare that there is no conflict of interest.

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Authors' contributions

All authors reviewed the manuscript

Author 1 did the primary and basic work by going to field

Author 2 and 3 did the editing work of research paper

Author 4, 5 and 6 helped in all the field work and calculations of microclimate regulation

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