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COMFA MODEL APPLICATION FOR REAL-TIME ASSESSMENT OF URBAN HEAT ISLAND EFFECTS ON OUTDOOR THERMAL COMFORT

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ABSTRACT
The cooling outcomes of inexperienced infrastructure (GI) had been thoroughly researched because of the extended hobby in decreasing urban warmth islands (UHIs). despite its importance, little studies has been carried out on how GI complements pedestrians' avenue-degree outside thermal comfort (OTC). by investigating how city greenery and water bodies mitigate out of doors Thermal consolation-derived city heat Islands (OTC-UHIs), this have a look at fills this knowledge hole. in step with the findings of our observe, GI extensively reduces OTC-UHIs for the duration of hot, muggy summers. due to the excessive warmth potential of pavement and buildings, distinctly advanced urban areas have smaller day-to-night time versions in land surface temperature, resulting in a tropical nighttime phenomenon. higher plant life cowl increases the cooling results of GI, which reduces the intensity, frequency, and period of OTCUHI. The flowers cowl ratio and sky view factors have a huge effect on cooling, and the connection between OTC-UHIs and concrete morphology adjustments throughout the day. moreover, parks have an extended cooling impact distance than rivers, in particular at night time, in step with a energy curve dating for GI's cooling impact distance. Our results show that by means of addressing the weather-brought about UHIs, the green use of GI can substantially increase pedestrians' avenue degree OTC.

Keywords:
OTC (Outdoor thermal comfort), UHI (Urban heat island), Comfa model, Urban Heat Exposure, Internet of Things (IoT), Urban Microclimate.

INTRODUCTION

Urban heat islands (UHIs) are a sizeable task in city areas, in which ambient or floor temperatures are drastically better than surrounding areas due to human activities and synthetic systems. these islands of warmth are mainly due to immoderate heat and radiation accumulation all through the sunlight hours, resulting in behind schedule middle of the night cooling of city regions in comparison to surrounding regions. The depth of UHIs is determined by using various factors, together with neighborhood weather situations, geographical context, and concrete morphological features like density and geometry. inexperienced infrastructure, consisting of urban greenery and water bodies, can play a critical role in mitigating road-degree UHIs and enhancing outside thermal comfort. The examine aims to investigate street-stage microclimate statistics to recognize the relationship between outside Thermal comfort-derived UHIs (OTC-UHIs) and inexperienced infrastructure, focusing at the cooling outcomes of vegetation and water our bodies. via leveraging city IoT sensor massive information, this research goals to offer insights into the effectiveness of green infrastructure in reducing warmth stress and mitigating street-level UHIs. The take a look at develops a changed COMFA (consolation formulation) version to guide the use of green infrastructure in decreasing warmth stress and mitigating street-level UHIs. This model is designed to assist urban planners and policymakers make knowledgeable decisions approximately the location and design of green infrastructure to maximise its cooling results and enhance out of

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doors thermal consolation. by way of integrating city IoT sensor information with superior modeling strategies, this research aims to provide a complete information of the position of inexperienced infrastructure in mitigating UHIs and improving city livability.

LITERATURE REVIEW

Estimating Outdoor Thermal Comfort Using a Cylindrical Radiation Thermometer and an Energy Budget Model (R. D. Brown and T. J. Gillespie).
A mathematical model to estimate outdoor thermal comfort for humans from micrometeorological data has been formulated using the energy balance concept and the simultaneous satisfaction of four criteria for comfort from the literature: (a) a comfortable perspiration rate, (b) a comfortable core body temperature, (c) a comfortable skin temperature, and (d) a near-zero energy budget. A cylindrical modification of the globe thermometer is proposed as a simple monitor of outdoor radiation absorption for a person, and the effect of windspeed on the thermal resistance of clothing is considered. Results show a correlation coefficient of 0.91 between model output and subjective comfort ratings of 59 different situations with a variety of temperatures, insolations and windspeeds.

A Synthesis of Disaster Resilience Measurement Methods and Indices (Heng Cai1 , Nina S.N. Lam1, Yi Qiang2, Lei Zou1, Rachel M Correll1, Volodymyr Mihunov1).
Disaster resilience has become an important societal goal which captures the attention of academics and decision makers from various disciplines and sectors. Developing tools or metrics for measuring and monitoring progress of resilience is a critical component that requires extensive research to achieve better understanding. However, different fields have different emphases and the knowledge gained from the various studies are scattered and fragmented. To provide an integration of the literature and reflect on the current state of resilience measurement, we conducted a synthesis analysis through a systematic review of 174 scholarly articles on disaster resilience measurement from 2005 to 2017. Using a review table designed for this study and content analysis, we extracted key information from each article on resilience definition, type of measurement method, resilience indicators used, and proposed adaptation strategies. Results indicate that 39.7% of the articles used qualitative methods for resilience measurement and 39.1% of the articles used quantitative methods. However, only 10.3% of all the 174 articles 2 conducted empirical validation of their proposed resilience indices. The three most frequently suggested adaptation strategies were empowering local governments and leaders, raising community awareness, and enhancing community infrastructure and communication. These findings suggest that future research need to incorporate validation and inferential ability into resilience measurement. Extending from static resilience measurement to dynamic system modeling and bridging the disconnection between resilience scientific research and practical actions are also pressing needs.

Assessment of the canopy urban heat island of a coastal arid tropical city: The case of Muscat, Oman (Yassine Charabi, Abdelhamid Bakhit).
The spatio-temporal variability of the canopy-level urban heat island (UHI) of Muscat is examined on the basis of meteorological observations and mobile measurements during a span of 1 year. The results indicate that the peak UHI magnitude occurs from 6to7 hours after sunset and it is well developed in the summer season. The warm core of the UHI is located in the Highland zone of Muscat, along a narrow valley characterized by low ventilation, high business activities, multi storied buildings and heavy road traffic. Topographically, this valley is surrounded by mountains formed of dark-colored rocks such Ophiolites that can absorb short wave radiation and contribute, herewith, to the emergence of this warm urban core. In addition, this mountainous terrain tends to isolate this location from the cooling effect of the land–sea breeze circulation during the day time. In this warm valley the hottest temperature is encountered in the compact districts of old Muscat. In comparison, the urban thermal pattern in Lowland zone of Muscat is fragmented and the urban rural thermal difference is reduced because of the lower urban density of the residential quarters. In addition, the flat alluvial terrain on which these residential quarters are located is consistently exposed to the land breeze circulation. Also, the study illuminates and emphasizes the importance giving due consideration to the nature of the rural baseline when assessing the urban effect on an area's climate. For Muscat City, irrespective of the rural baseline used, a significant difference in the value of the urban heat island is registered.

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SYSTEM ARCHITECTURE

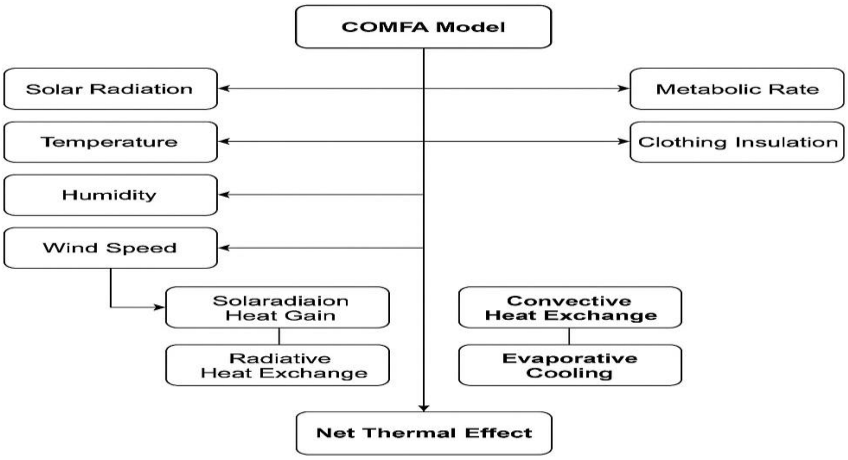

Figure 1 Model Architecture

A. Algorithms

In this research, we utilized a simplified version of the comfort formula (comfa) model to calculate outdoor thermal comfort (otc) for individuals walking. Comfa is a logical, energy-conserving model that determines the overall heat gain or loss experienced by the human body due to its interactions with the environment. It takes into account various factors related to energy exchange, such as metabolic heat production, radiative heat transfer, convective cooling, evaporative cooling, and solar heat absorption. Our implementation modifies the comfa model to accommodate real-time data obtained from environmental sensors. The following elements were utilized to calculate the net thermal load (qnet), which signifies the otc value :

Qnet = M + Qs + Qr + Qc + Qe

Where:

- M: Metabolic heat (set as a constant for walking pedestrians)
- Qs: Absorbed solar radiation (estimated as a function of measured solar irradiance)
- Qr: Radiative heat exchange (modelled using the Stefan-Boltzmann law based on air temperature)
- Qc: Convective heat exchange (based on wind speed and air temperature differential)
- Qe: Evaporative heat loss (estimated from humidity and metabolic activity)

The calculations for these measurements rely on sensor inputs such as temperature, humidity, solar radiation, wind speed, pressure, altitude, and air quality. Although pressure and air quality were measured during the study, they were not incorporated into the energy budget calculation but could potentially be adjusted in future model enhancements. Every data record from the sensors was fed into a Python-based function that utilized this model, resulting in a qnet value that was interpreted as the otc. When qnet values are high, it means there is more thermal stress, while lower or negative values suggest comfortable or cool conditions.

Formulas:

$Qnet = M + Qs + Qr + Qc + Qe$

Where:

Qnet: Net thermal load on the body (W/m²)

M: Metabolic heat production (W/m²)

Qs: Solar radiation absorbed by the body (W/m²)

Qr: Net radiative heat exchange (W/m²)

Qc: Convective heat exchange (W/m²)

Qe: Evaporative heat loss due to humidity (W/m²)

Each term is computed as follows;

M = constant metabolic rate (e.g., 58 W/m² for walking)

Qs = 0.7 × Sr

Sr = Measured solar radiation (W/m²)

(Assuming 70% absorption by the body surface)

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$Qr = \varepsilon\sigma(Ta^4 - Tskin^4)$
ε = Skin emissivity (≈ 0.95)
σ = Stefan-Boltzmann constant (5.67×10^{-8} W/m²K⁴)
Ta = Air temperature in Kelvin
Tskin = Standard skin temperature (≈ 303.15 K)
$Qc = \rho \times cp \times V \times (Ta - Tskin) / (1 + Rc)$
ρ = Air density (1.225 kg/m³)
cp = Specific heat of air (1005 J/kg·K)
V = Wind speed (m/s)
Rc = Clothing thermal resistance (clo × 0.155 m²·K/W)
$Qe = -0.42 \times (RH / 100) \times (M + Qs)$
RH = Relative Humidity (%)

Below is the step by step implementation....
Step 1: Connect environmental sensors to Arduino and ESP8266.
Step 2: Write Arduino code to read and send sensor data via Wi-Fi.
Step 3: Transmit real-time data to ThingSpeak or cloud storage.
Step 4: Export or fetch data into a Python environment.
Step 5: Preprocess data (clean, convert, normalize).
Step 6: Implement the simplified COMFA model in Python.
Step 7: Calculate OTC for each data row using the model.
Step 8: Classify OTC into comfort levels (e.g., Hot, Comfortable).
Step 9: Visualize OTC trends with graphs or dashboards

B. *Deployment Model*

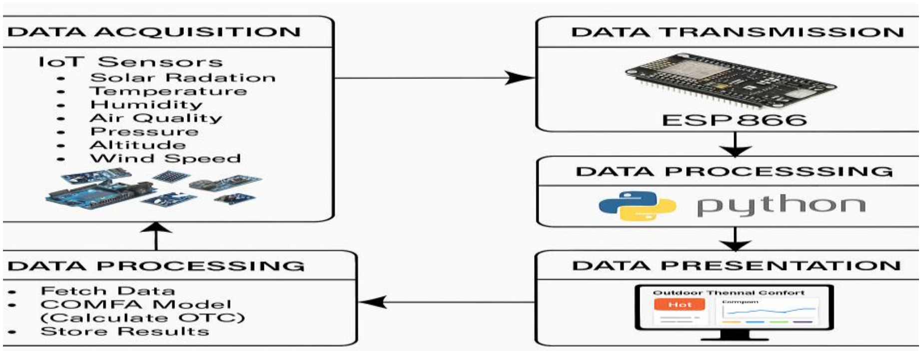

Figure 2 Model Overview

RESULTS

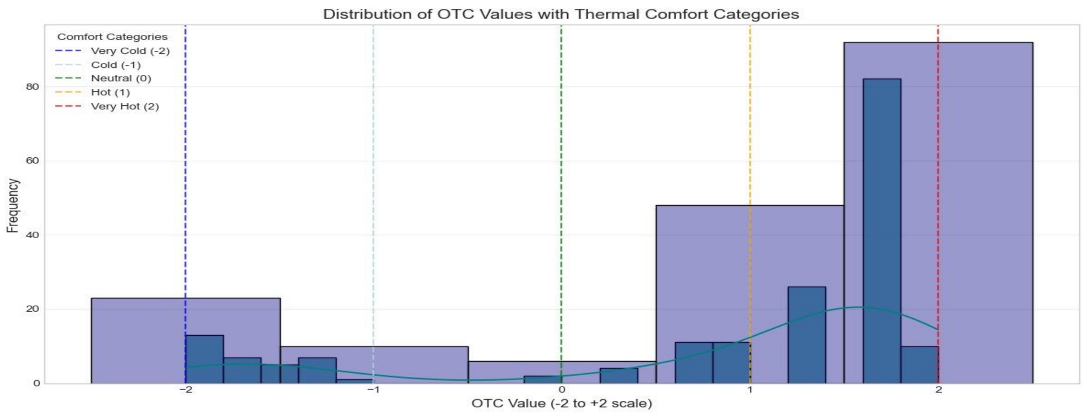

Figure 3 Distribution of OTC values in the dataset

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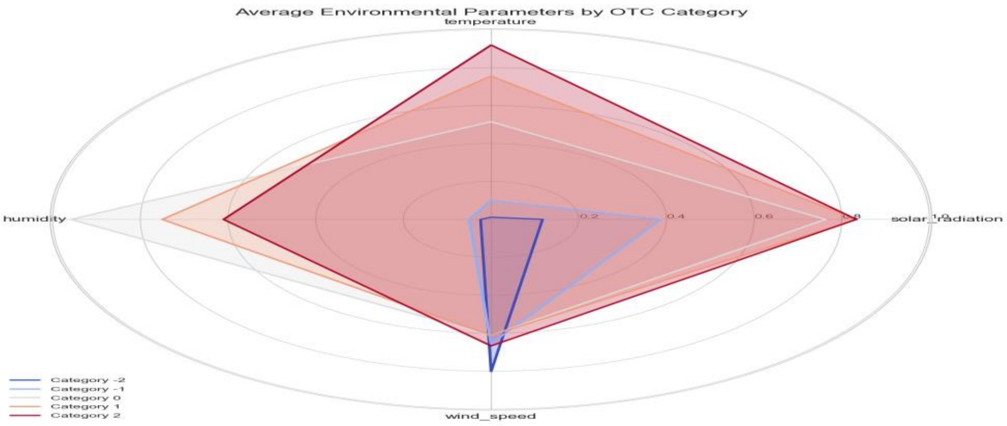

Figure 4 Radar chart for values across OTC

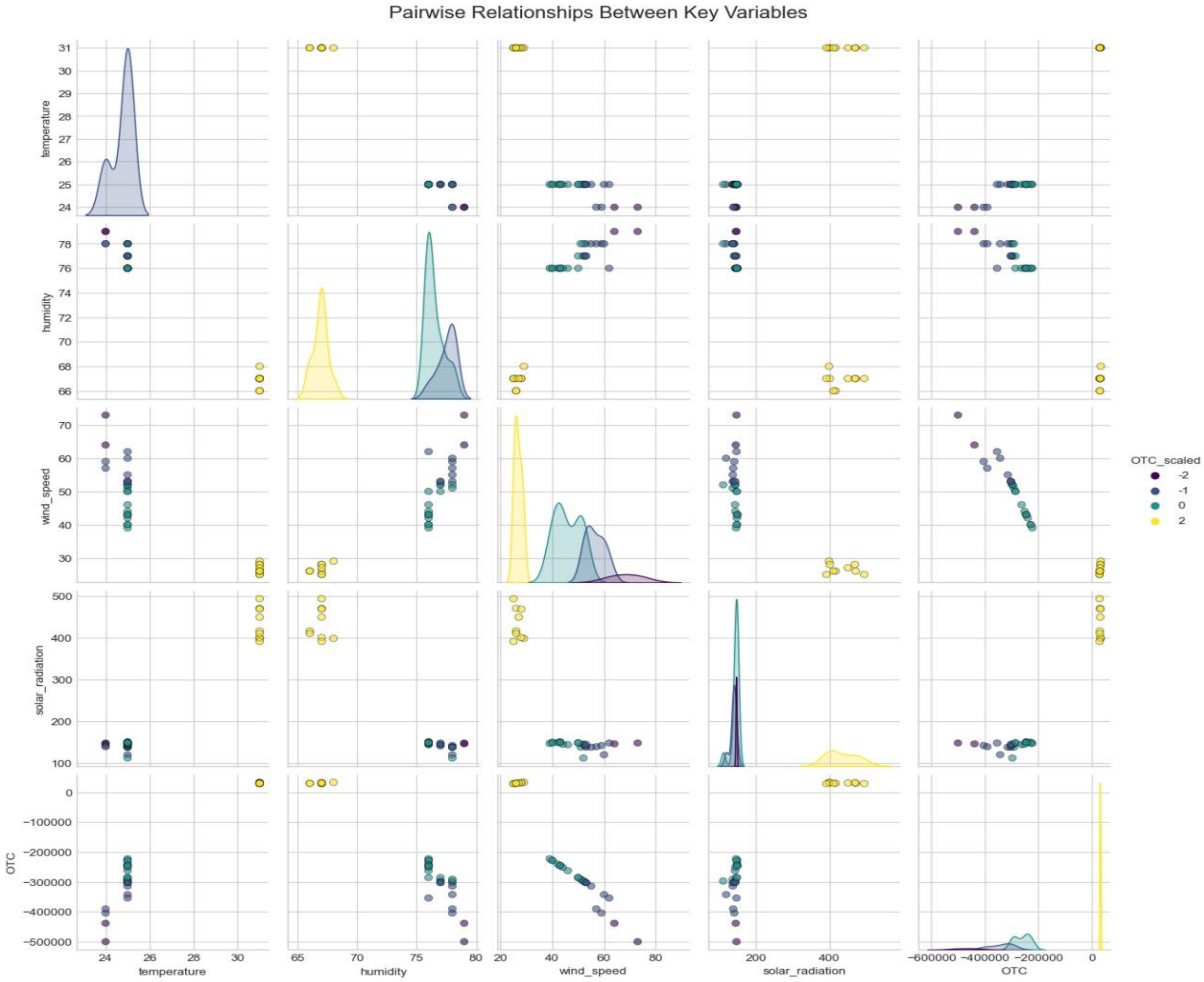

Figure 5 Distribution of OTC values with thermal comfort interpretation

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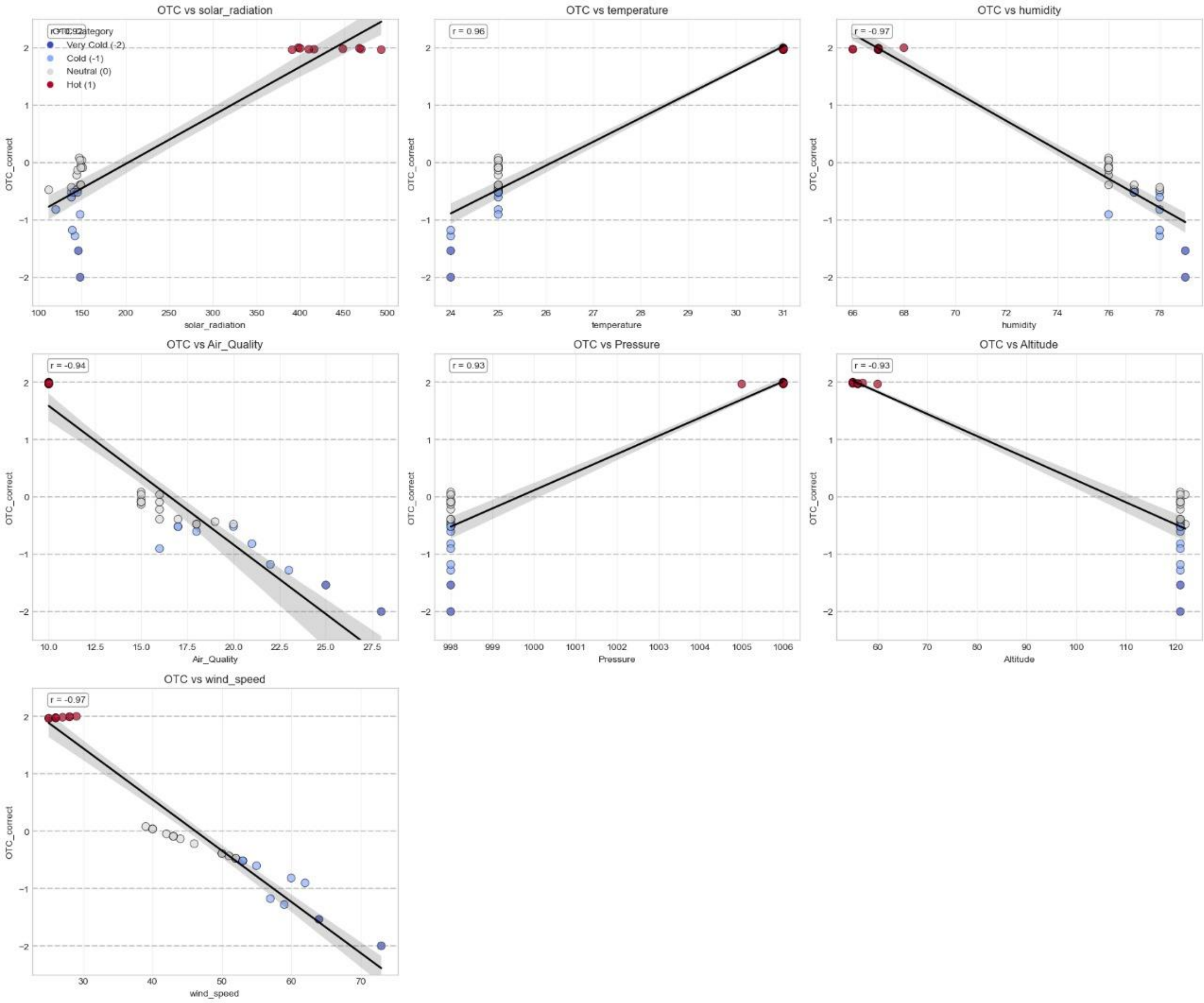

Figure 6 Scatter plots of environmental attributes vs. OTC

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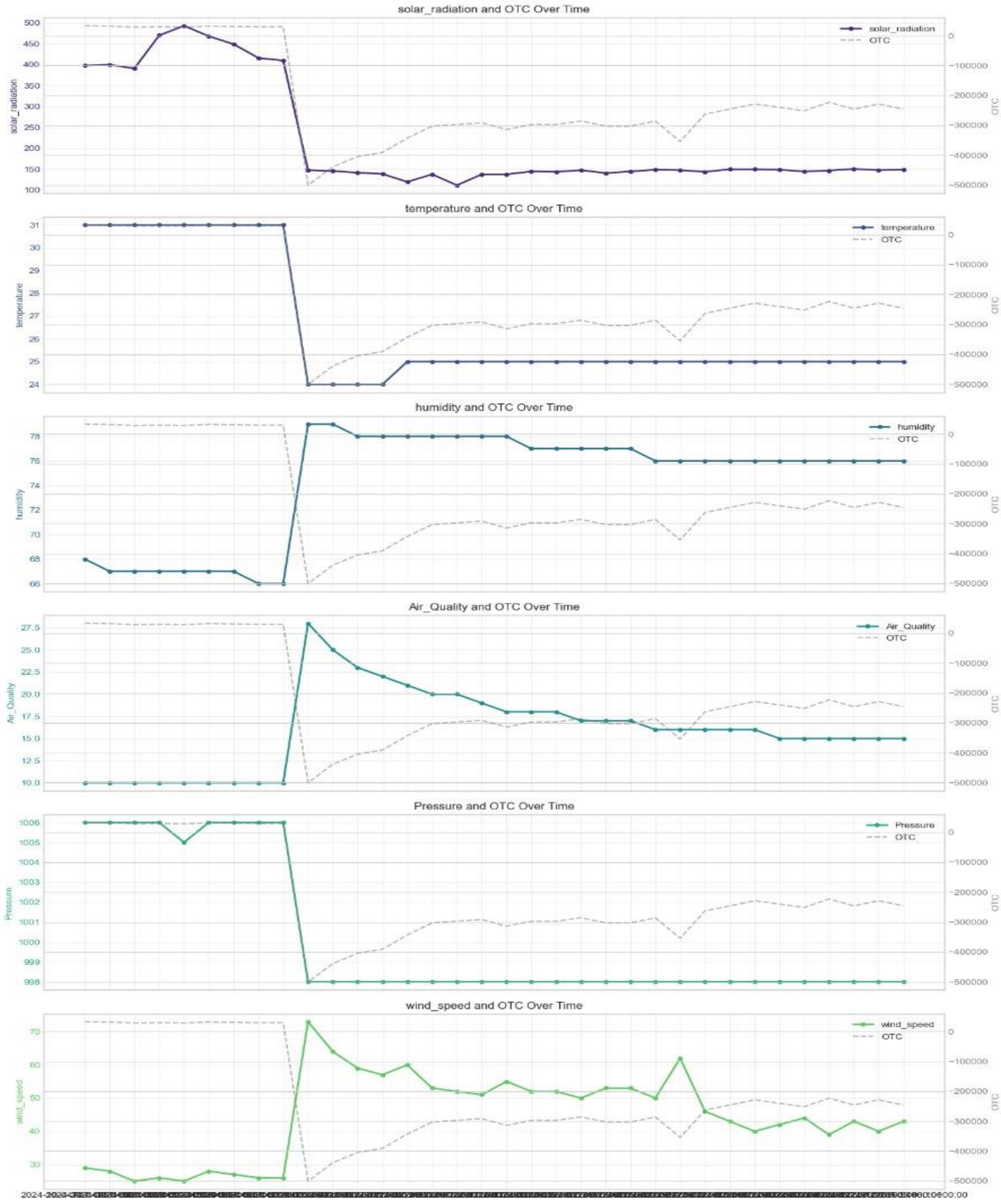

Figure 7 Time series of environmental attributes vs. OTC

CONCLUSION

The cooling effects of inexperienced infrastructure (GI) have been very well researched due to the improved interest in reducing city warmness islands (UHIs). Not with standing its significance, little studies has been

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completed on how GI enhances pedestrians' road-stage out of doors thermal consolation (OTC), by using investigating how city greenery and water our bodies mitigate out of doors Thermal comfort-derived urban warmth Islands (OTC-UHIs), this take a look at fills this expertise gap in step with the findings of our take a look at, GI appreciably reduces OTC-UHIs all through hot, muggy summers due to the excessive warmness capacity of pavement and buildings, quite evolved urban regions have smaller day-to-night time versions in land surface temperature, ensuing in a tropical middle of the night phenomenon. better vegetation cowl increases the cooling outcomes of GI, which reduces the intensity, frequency, and duration of OTCUHI. The vegetation cowl ratio and sky view elements have a vast effect on cooling, and the connection between OTC-UHIs and concrete morphology changes at some point of the day. furthermore, parks have a longer cooling effect distance than rivers, especially at night time, according to a power curve relationship for GI's cooling effect distance. Our results reveal that through addressing the weather-induced UHIs, the green use of GI can greatly increase pedestrians' avenue stage OTC.

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