VALIDATING ENVI-MET FOR RELATIVE HUMIDITY (RH) IN HIGH-DENSITY TEMPORARY ENCROACHMENT SPACES IN THE STREETS OF TROPICAL INDIAN MEGACITIES

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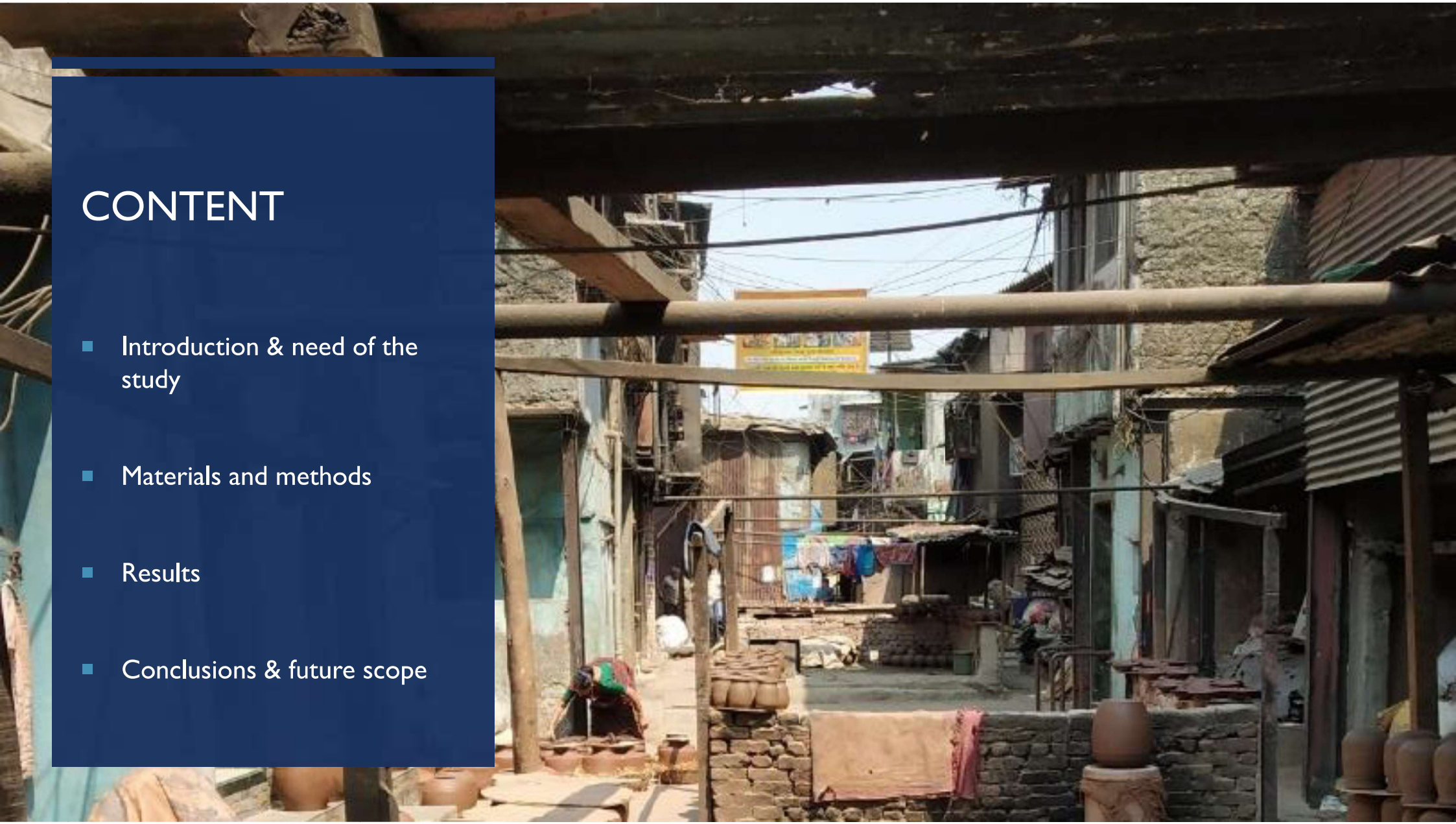

CONTENT

- Introduction & need of the study
- Materials and methods
- Results
- Conclusions & future scope

NEED OF THE STUDY

- Although human thermal exposure in cities has been studied across the globe, microclimatic and **biometeorological conditions in mixed-used spaces, informal economic activity settings, and informal settlements** have received little attention with **negligible studies** conducted *(Khalil et al., 2018), (Baruti and Johansson, 2018).*

- We present an analysis of **outdoor thermal comfort** and **microclimate** for **informal micro-entrepreneurial communities** in **Kolkata and Mumbai**.

- Both cities belong to the ***Aw* Köppen Climate Classification**, tropical hot and dry or Savannah climate. Due to excessive humidity, **uncomfortable thermal conditions persist year-round** in both cities.

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RESEARCH STATEMENT AND METHODOLOGY

RESEARCH OBJECTIVE

- *What is the influence of different micro enterprises or small businesses on outdoor microclimate in neighbourhoods in hot-humid context of Indian megacities ?*

  - To analyze how accurate the 3D CFD software ENVI-met 4.4 models microclimate associated with thermal comfort for an informal economic activity neighborhood in Indian megacity

    - Validation of Relative Humidity (RH) → **This presentation**

    - Validation of Air Temperature (Ta) and Mean Radiant Temperature (Tmrt)

  - To analyze the impact of space transformations related to micro-enterprises on outdoor microclimate by modelling and comparing sites with and without encroachment

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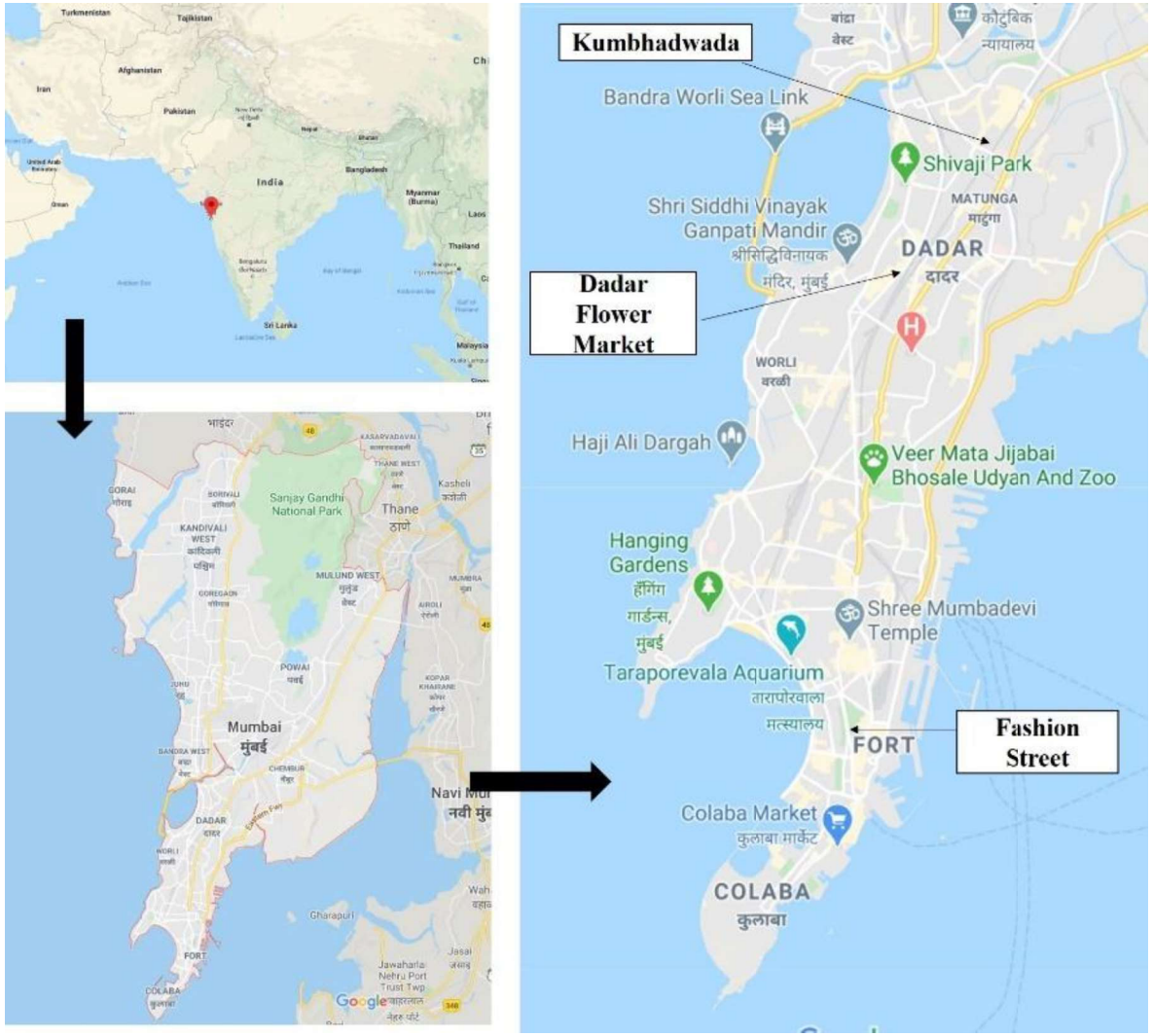
SURVEY CITY: MUMBAI



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CHARACTERISTICS: MUMBAI

- Mumbai (18°58′N and 72°49′E)
- Largest metropolis in India with a core population of 12.5 million according to the 2011 Census of India
- Most important city in the country due to its location, industry, and economy
- **Warm humid climate classified under the Köppen climate category *Aw* signifying tropical wet and dry climate** *(Kottek et al., 2006)*
- Due to the proximity of the Arabian Sea, the city receives **significant monsoon wind and precipitation during summertime.**
- The city has an annual mean temperature of 27.2°C
- **Summers are hot and humid with an average temperature between 30°C-35°C**
- **Summertime high sometimes reaches 40°C during April and May with a humidity over 75%.** Winters are mild and moderate.

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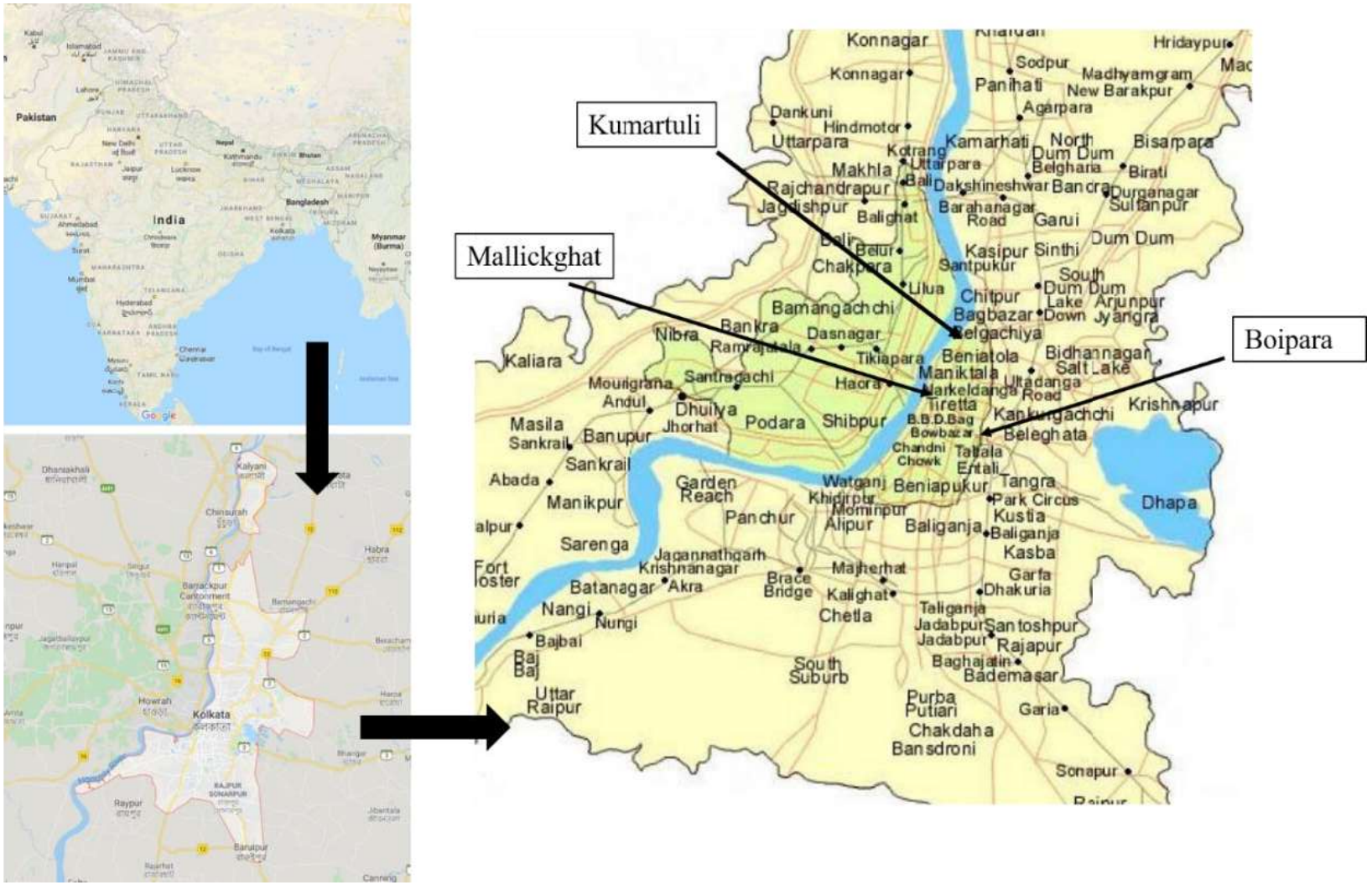
SURVEY CITY: KOLKATA



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SURVEY CITY: KOLKATA

- Kolkata (22°34′N, 88°22′E)
- Third-largest metropolis in India with a core population of 4.5 million according to the 2011 Census of India.
- Most important city in Eastern India due to its location, industry, and economy.
- As the city is close to the **Tropic of Cancer and the Hooghly River, Kolkata has a warm humid climate classified as *Aw* (tropical wet and dry) in the Köppen climate classification** *(Kottek et al., 2006), (Chatterjee et al., 2019)*.
- Due to the proximity of the Bay of Bengal, the city receives **significant monsoon winds and precipitation mostly during summertime.**
- Kolkata has an annual mean air temperature (T_a) of 26.8°C. Summers are hot and humid with an average T_a of 30-35°C.
- **Summertime maximum T_a reaches 40°C during the month of May, relative humidity (RH)> 70%.**
- April to June are considered summer with May and June being the hottest months.
- November to February are considered winter, which is mild and moderate with an average T_a of 25-30°C and an average RH of 60%. Wintertime minimum T_a seldom reaches 10-14 °C in January

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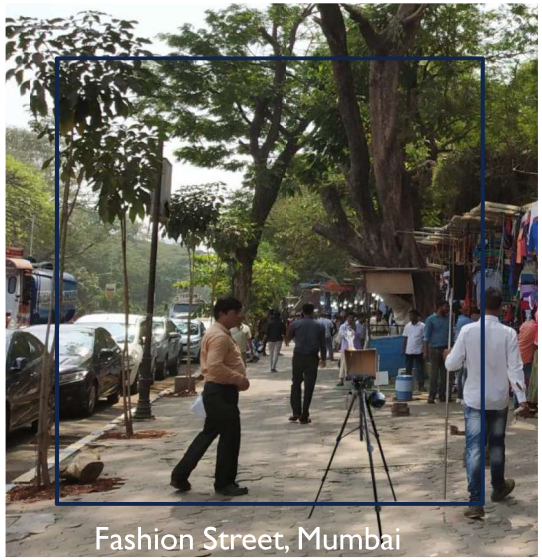
SURVEY: NEIGHBOURHOOD VISUALS


Fashion Street, Mumbai


Boipara, Kolkata


Mallickghat Flower Market, Kolkata


Kumartuli, Kolkata


Dadar Flower Market, Mumbai


Kumbhadwada, Mumbai

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SIMULATION METHODOLOGY: ENVI-MET

- Simulations were performed for **all the neighborhoods for summer and winter** and two cases, **one existing encroachment case and another without encroachment hypothetical case**.

- Thus, for each neighborhood, **a total of 4 simulations** were carried out.

- All the simulations were typically performed for a **12-hour duration from 5 AM to 5 PM**.

- We **discarded the first four simulated hours** from the final analysis as they were used as **spin up time** *(Taleghani et al., 2015), (Sharmin, Steemers and Matzarakis, 2017).*

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SIMULATION METHODOLOGY: ENVI-MET

All the Kumbhadwada models were simulated on a system (notebook laptop) with **Intel Core i5- 8250 CPU and 24 GB RAM**. Each simulation took around 12 days to be completed.

All the other simulations were performed in a system (workstation) with **Intel Xeon Silver 4210 CPU and 32 GB RAM**.

Each simulation in Fashion Street, Boipara and Kumartuli took around 8 days to be completed.

Each simulation in Dadar and Mallickghat took approximately 3 days to be completed.

Validation was carried out with the data collected from field measurements after *(Banerjee et al.,2020), (Banerjee et al., 2021)*

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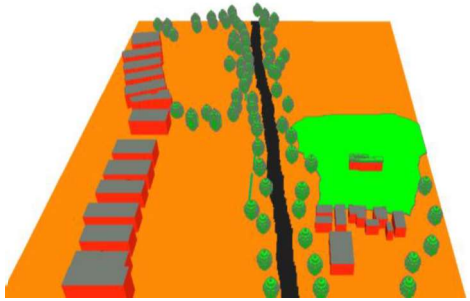
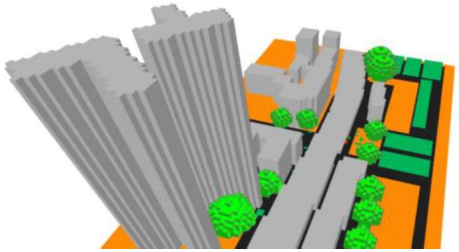
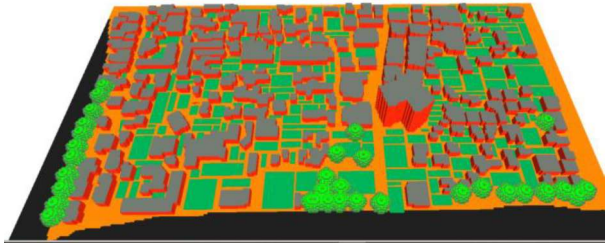
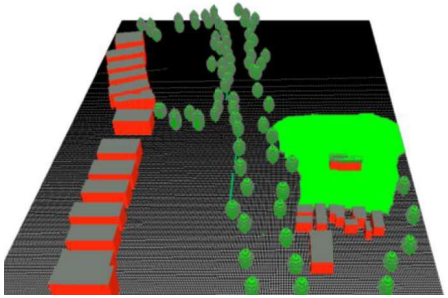
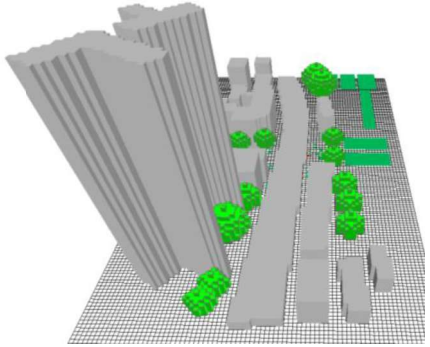
SIMULATION METHODOLOGY: AREA INPUT 3D FOR MUMBAI

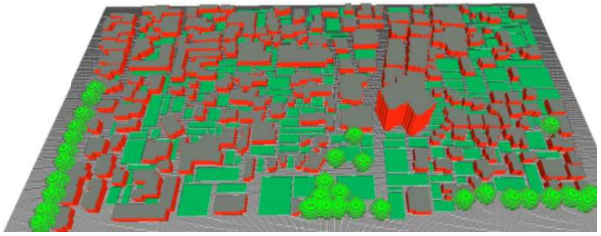












3D Area Input File for Fashion Street, Mumbai

3D Area Input File for Dadar Flower Market, Mumbai

3D Area Input File for Kumbhadwada, Mumbai

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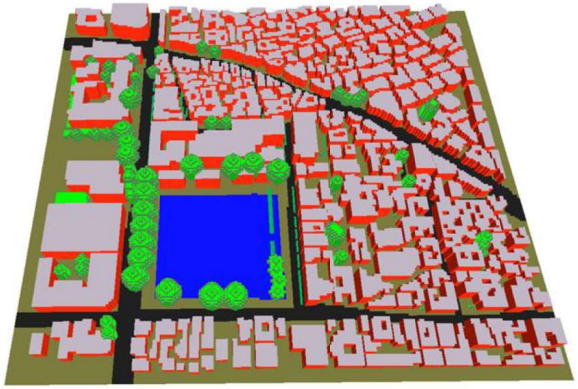
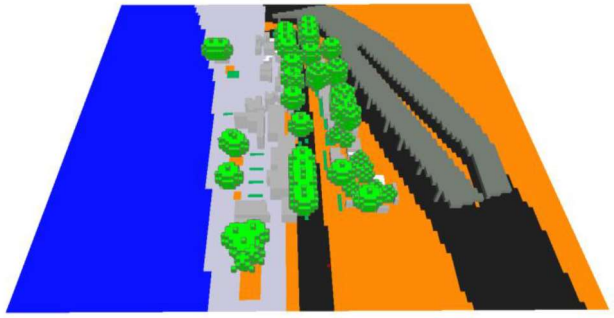
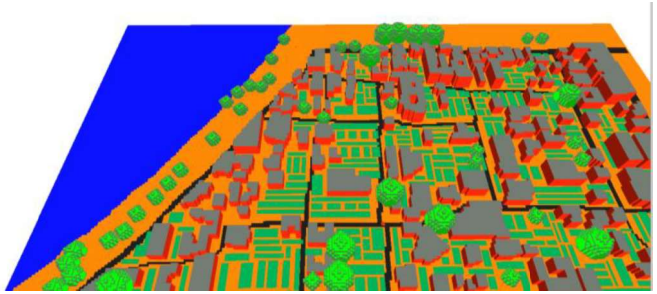
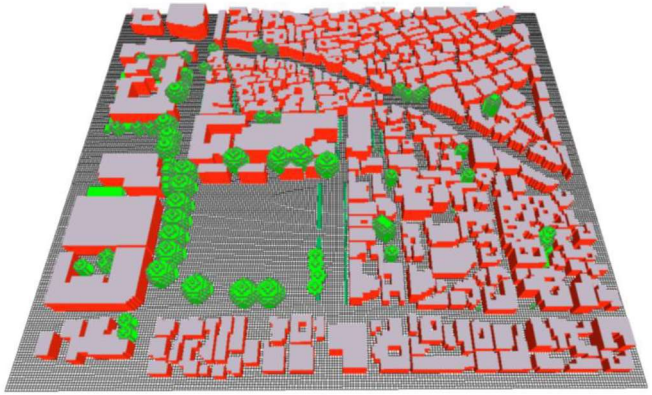
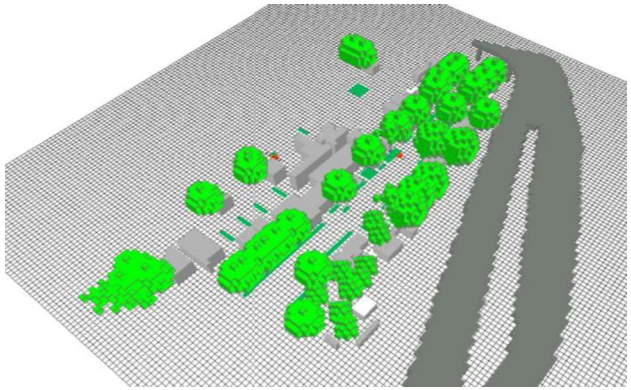
SIMULATION METHODOLOGY: AREA INPUT 3D FOR KOLKATA

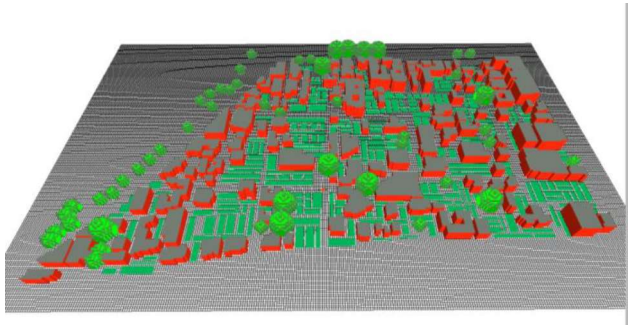












3D Area Input File for Boipara, Kolkata

3D Area Input File for Mallickghat, Kolkata

3D Area Input File for Kumartuli

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RESULTS

MUMBAI

ANALYSIS: VALIDATION RESULTS IN MUMBAI

	Fashion Street				Dadar Flower Market						Kumbhadwada					
	Shallow Canyon Total				Shallow			Deep			Shallow			Deep		
	R^2	d	MBE	RMSE	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE
RH	0.96	0.98	-15.04	15.16	0.98	0.99	4.75	0.96	0.99	-4.41	0.93	0.99	-2.32	0.74	0.99	-3.01

	Fashion Street						Dadar Flower Market						Kumbhadwada					
	Winter			Summer			Winter			Summer			Winter			Summer		
	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE
RH	14.96	0.97	-14.76	15.34	0.98	-15.33	10.89	0.98	0.75	1.40	0.99	0.06	15.12	0.97	-14.68	6.96	0.99	6.55

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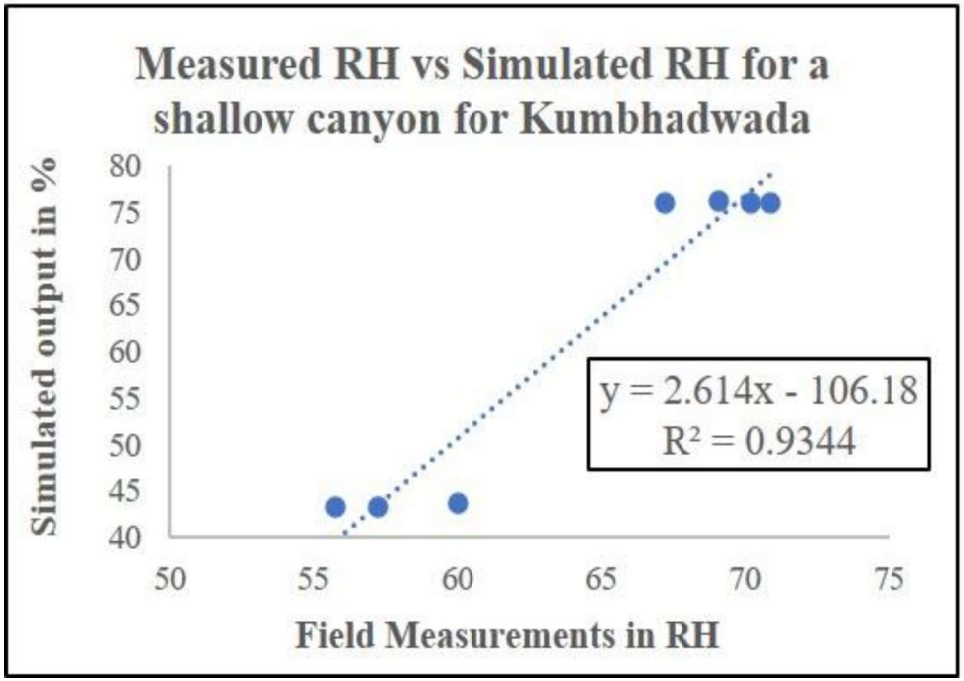
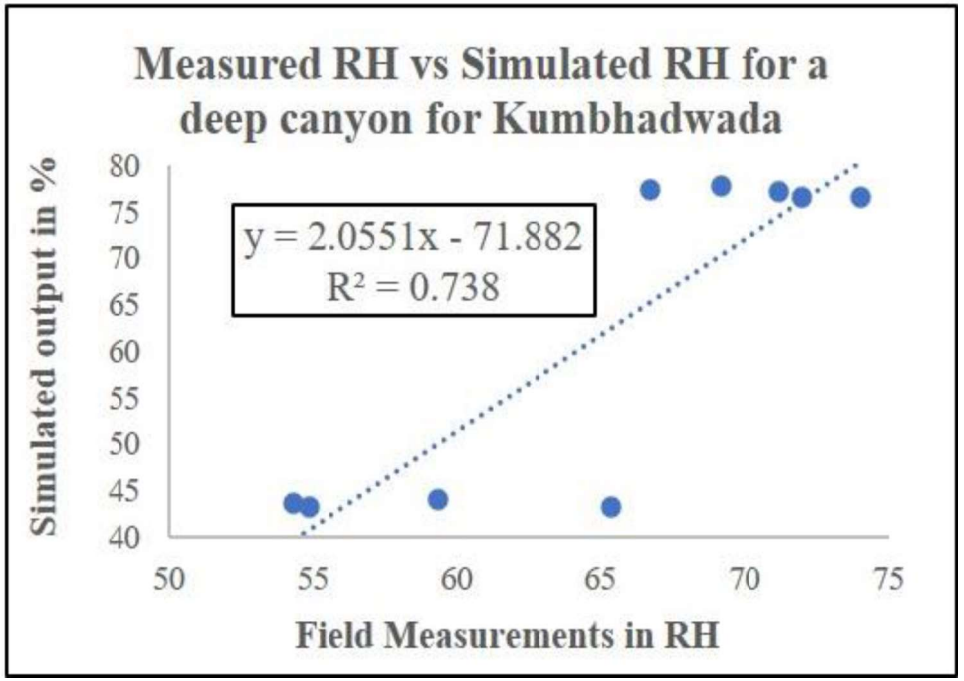
VALIDATION OF RELATIVE HUMIDITY IN MUMBAI





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KOLKATA

ANALYSIS: VALIDATION RESULTS IN KOLKATA

	Boipara						Mallickghat						Kumartuli					
	Shallow			Deep			Shallow			Deep			Shallow			Deep		
	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE	R^2	d	MBE
RH	0.68	0.98	15.51	0.08	0.98	16.21	0.77	0.99	4.94	0.59	0.98	11.97	0.99	0.99	9.64	0.84	0.99	10.43

	Boipara						Mallickghat						Kumartuli			
	Winter			Summer			Winter			Summer			Winter	Summer		
	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE	RMSE	d	MBE	RMSE/d/MBE	RMSE	d	MBE
RH	16.46	0.98	16.07	16.46	0.98	15.59	3.77	0.99	0.48	15.72	0.98	15.31		10.92	0.99	9.98

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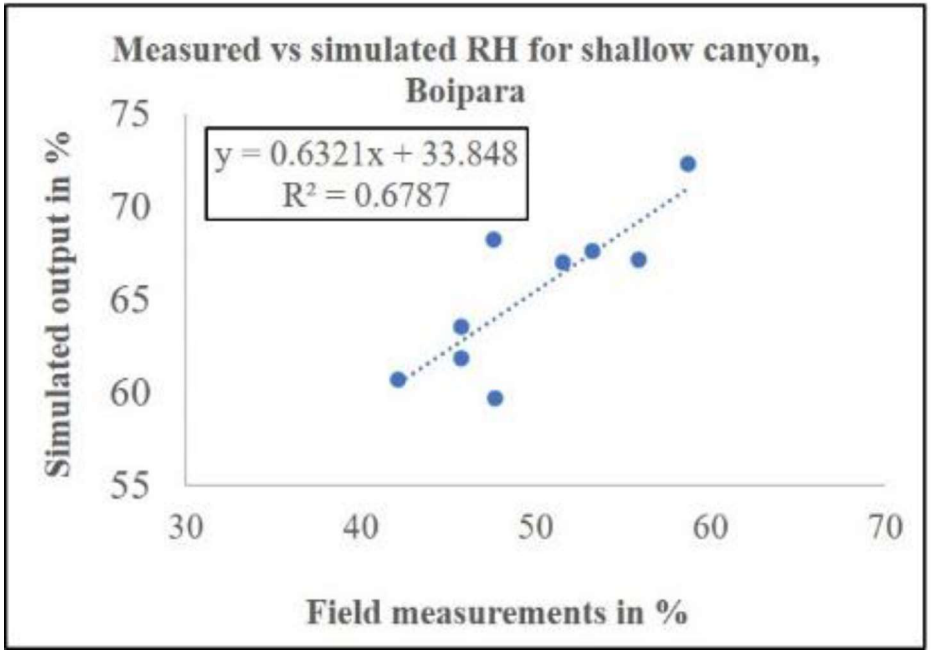
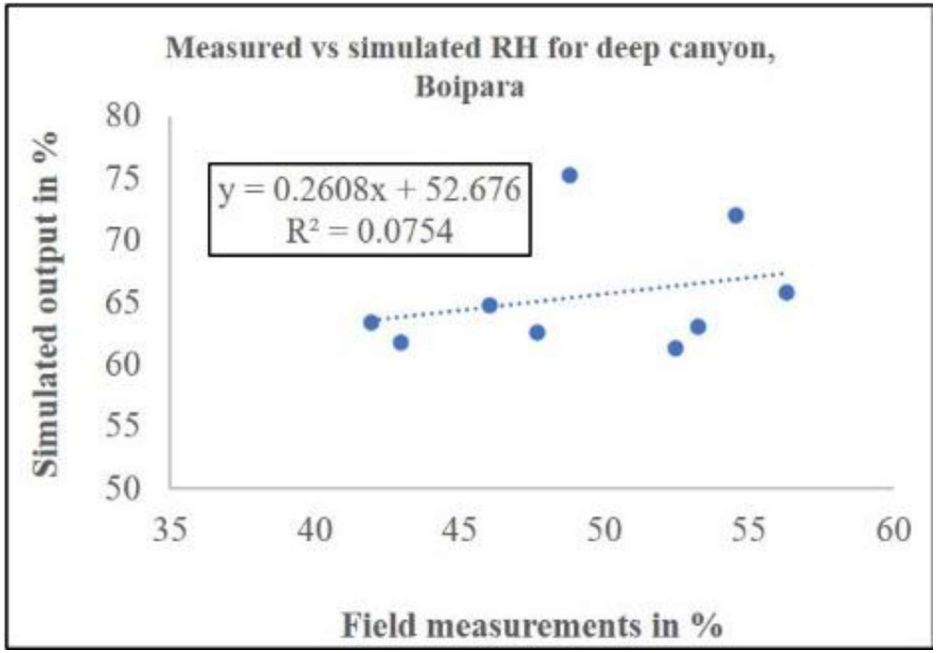
ANALYSIS: VALIDATION RESULTS IN KOLKATA





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COMMON ANALYSIS

- Negligible studies have validated RH so far.
- ENVI-met thoroughly overestimates RH
- This agrees with Huttner who reported an overestimation of RH by ENVI-met during the day hours (Huttner, 2012).
- This deviation can be attributed to the fact that the assumption of the boundary conditions such as a neutrally stratified atmosphere is not always valid in cities with strong radiative input such as Kolkata and Mumbai (Huttner, 2012).
- RH can predict the RH within shallow canyon better.
- Similar kind of difference between deep and shallow canyon RH pattern for both the neighborhoods could be attributed to the fact that within a deep canyon, anthropogenic heat related discrepancies can completely change the pattern of ambient RH.

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SUMMARIZING THE RESEARCH

- This is the first ENVI-met study conducted in Indian mixed-use neighborhoods characterized by complex geometric elements such as presence of elevated vehicular freeway or flyover, large rivers, and temporary encroachments.
- Previous studies have mostly catered to understanding impact of orientation, LCZ based microclimatic assessment and various mitigation measures predominantly for residential neighborhoods.
- We performed a robust validation with respect to Ta, Tmrt as well as RH.
- To our knowledge, this is the first study to validate ability of ENVI-met to predict RH in an Indian context.

Future Scope

- A first step towards analyzing the efficiency of ENVI-met for modeling high density complex urban neighborhoods with heterogenous morphological characteristics in Indian context.
- Grid size and time-step wise sensitivity analysis to assess the model performance.
- Sensitivity of four turbulence models can be checked, hourly forcing of wind speed can be input and validated to test model performance.
- ENVI-met has been widely used to compare heat mitigation strategies. Efficiency of various thermal comfort improvement policy guidelines and frameworks can be evaluated in order to minimize heat hazards.

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Thank You

SUPPLEMENTARY 1: RESEARCH LIMITATIONS

- The study is confined to understand **outdoor microclimate and thermal comfort**.
- **No indoor spaces or temporarily indoor/transition spaces** were studied in this context.
- Outdoor thermal comfort perception surveys were conducted in **open alleys, courtyards, verandas, and semi-outdoor spaces**.
- **No anthropogenic or infrastructure related heat modelling** is taken into consideration.
- **Only summer and winter data have been modelled**.