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2nd African Forum On Urban Forests

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Transforming Urban Air Quality: Green Infrastructure Strategies for Hawassa City, Ethiopia

Addressing Air Pollution through Nature-Based Solutions

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Outline of the presentation

Introduction & background

Research gap statment and objectives

Methodology

Results and discussions

Conclusion and recommendations

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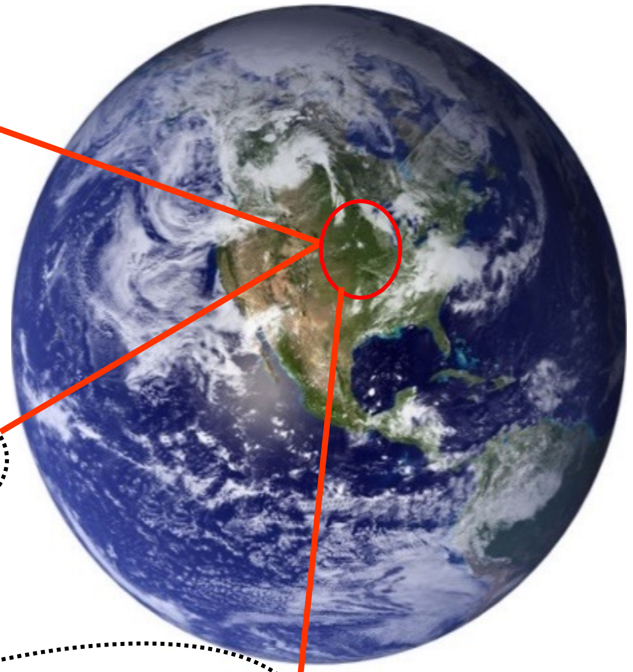
Introduction

Urbanization & air pollution: A growing crisis

- Rapid urbanization: global population shift towards cities
- Despite their small cover proportion, cities are major contributors to global air pollution.
- **Air pollution hotspots** (Ouyang et al., 2022):
  - ✓ globally causes **~4.5 million** premature deaths annually
  - ✓ This disproportionately affecting the Global South

Cities → **3%** of the Earth's land surface

Current urban population **57%** →**68%** in 2050



99% cities in the Global South → pollution concentration exceeds WHO guidelines (WHO, 2022)

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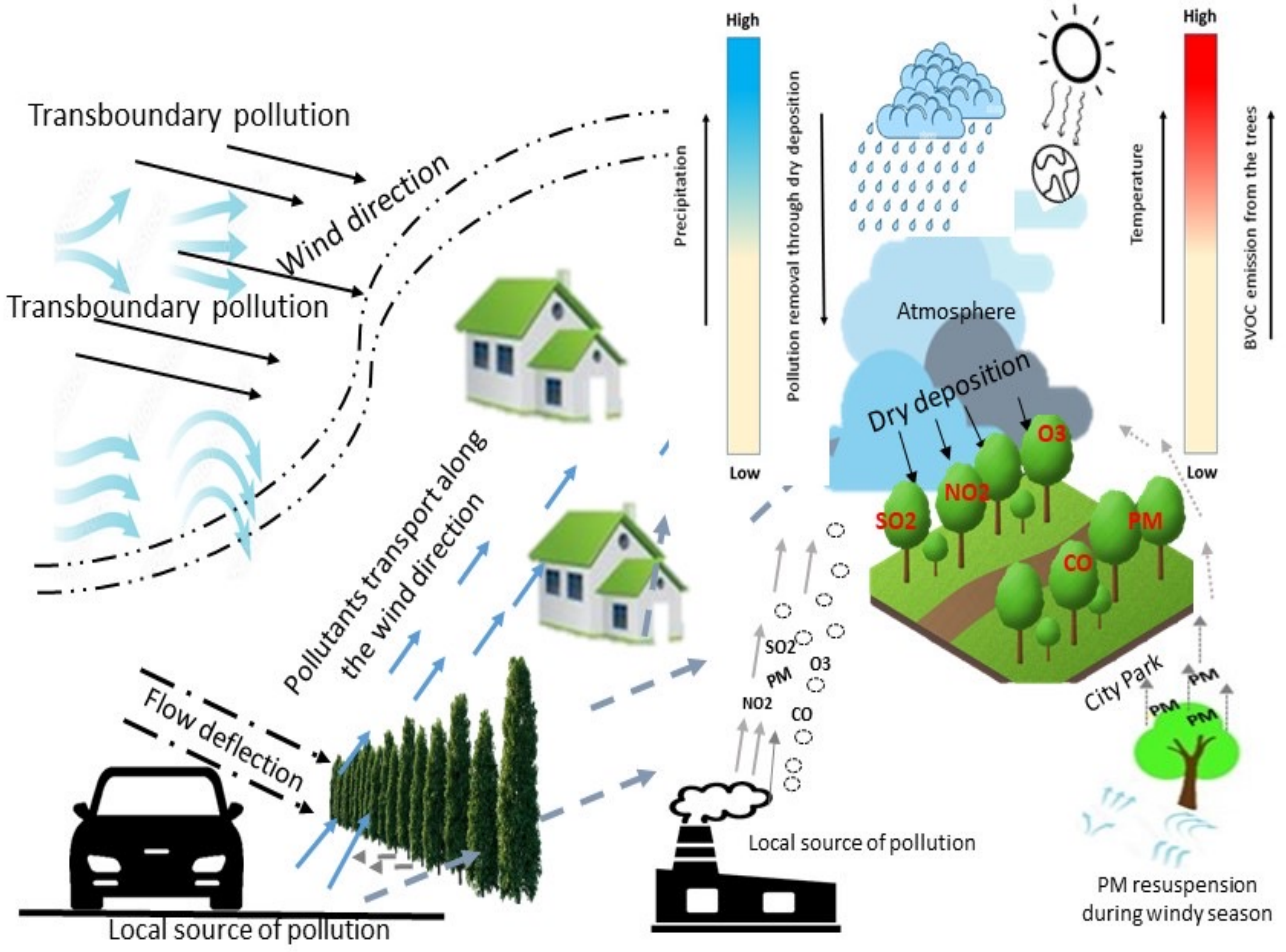
Introduction

Urban Green Infrastructure: A Natural Solution to Air Pollution!

- **Urban trees as air purifiers:**
  - ✓ Absorb gaseous pollutants through leaf stomata
  - ✓ Trap airborne particles on plant surfaces

- **With strategic GI planning:**
  - ✓ **maximize air quality benefits**
  - ✓ **minimize BVOC-related impacts**



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Problem statement - consequences of failing to integrate UGI in the urban centers of Ethiopia

Growing air pollution risks

- ✓ Cities with no or fragmented UGI integration → increasing pollution
- ✓ Rapid urbanization → land scarcity & uneven ES distributions
- ✓ Unbalanced green vs. grey infrastructure worsens the challenge

Limited evidence and understanding

- ✓ Lack of data on GI effectiveness in air quality improvement
- ✓ Urban trees planting without considering BVOC emissions
- ✓ Insufficient evidence for informed GI planning & management

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Research objectives:

- ○ Quantify the air pollution removal capacity of UGIs in Hawassa City & their monetary value.
- ○ Evaluate BVOCs emission from urban tree species in the City.
- ○ Map the spatial distribution of pollution interception and BVOC emissions across the City.

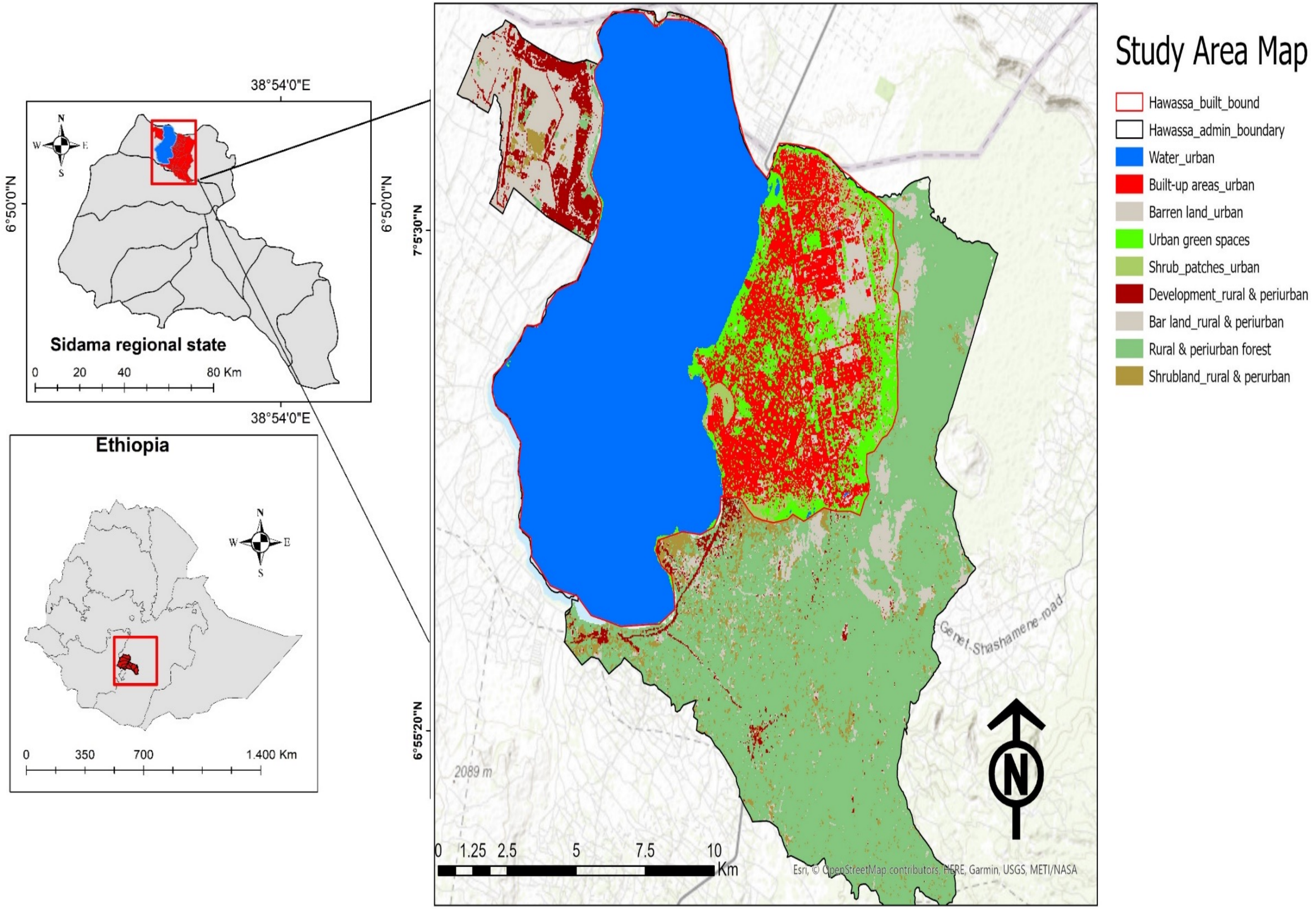
Research questions:

- ✓ What factors accelerate pollutant deposition on tree canopies?
- ✓ How can UGI be optimized for maximum pollution removal and minimal BVOC emissions?
- ✓ What spatial trade-offs exist in UGI for air quality improvement?

Study area

Hawassa city, Southern Ethiopia

- Medium sized ~ 387K pop., 4% growth/yr)
- Tropical climate with bimodal rainfall pattern:
  - ✓ Avg. rainfall: ~1,013 mm
  - ✓ Temp.: 6–34°C (Avg. 23.75°C)
  - ✓ Wind speed: Peaks mid-June–Aug, lowest Sept–June
- UGI elements ~ lack strategic planning



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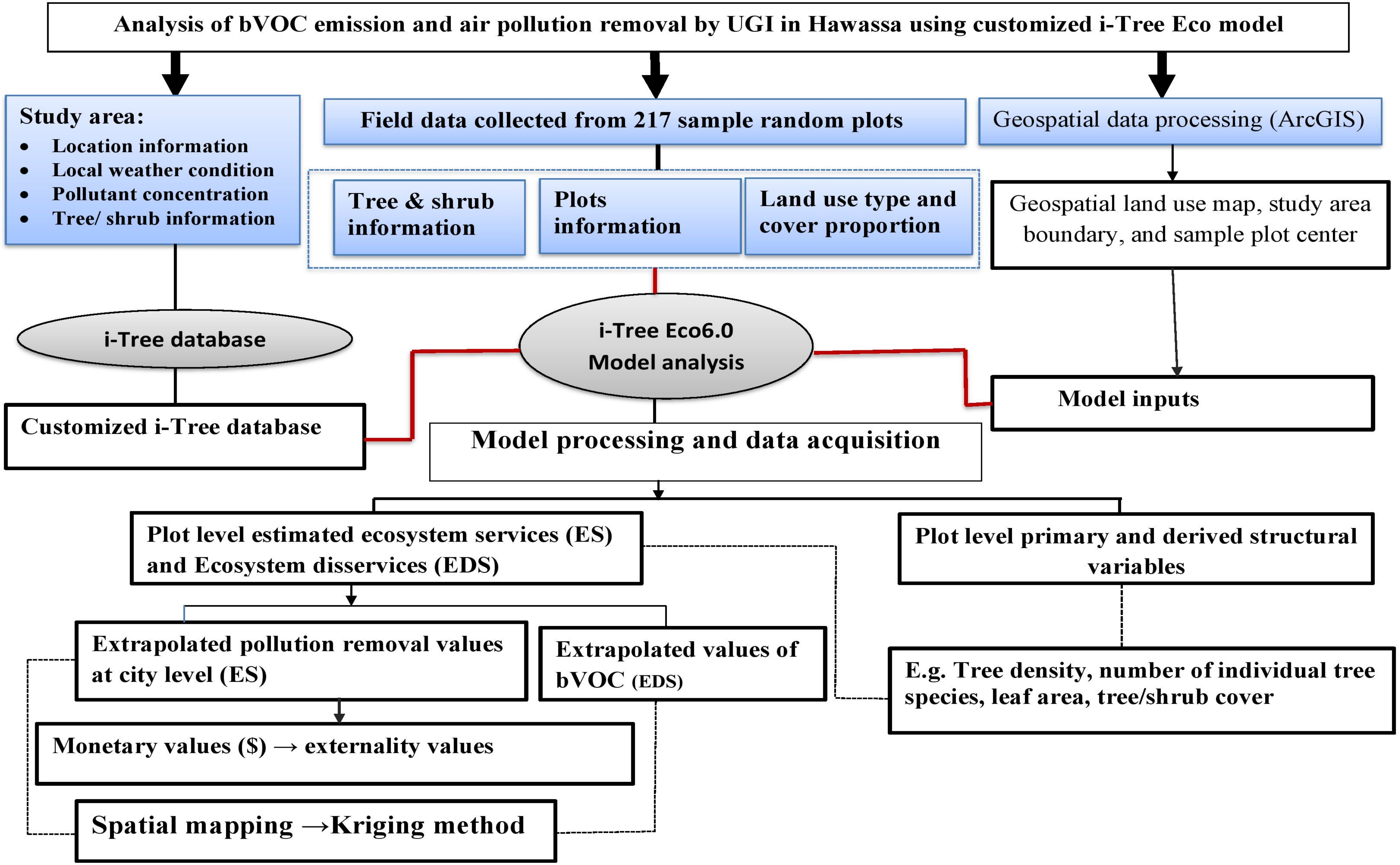
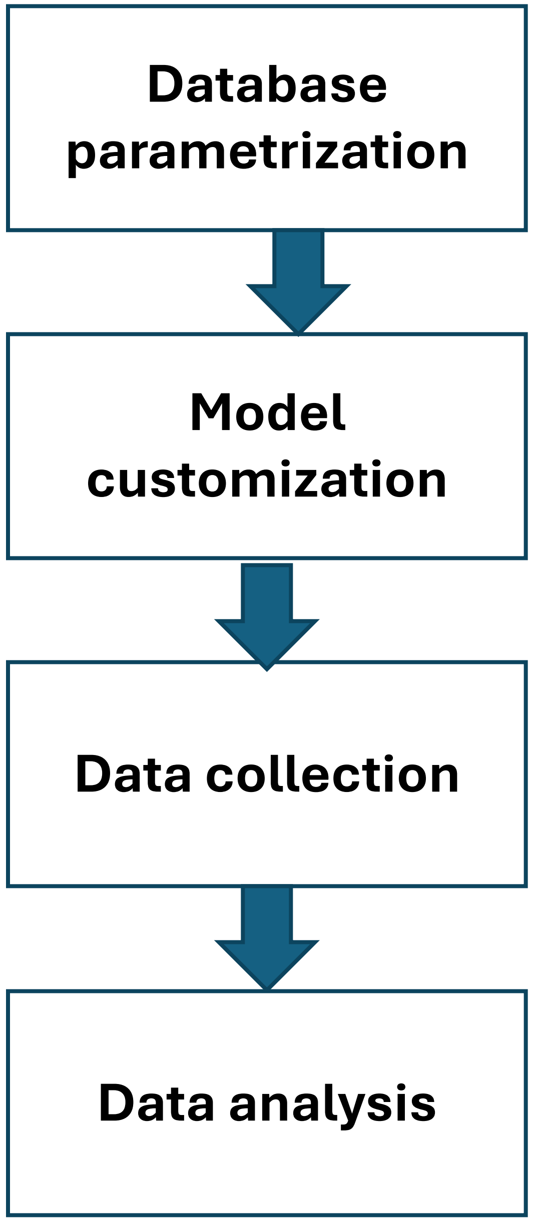
Methodology

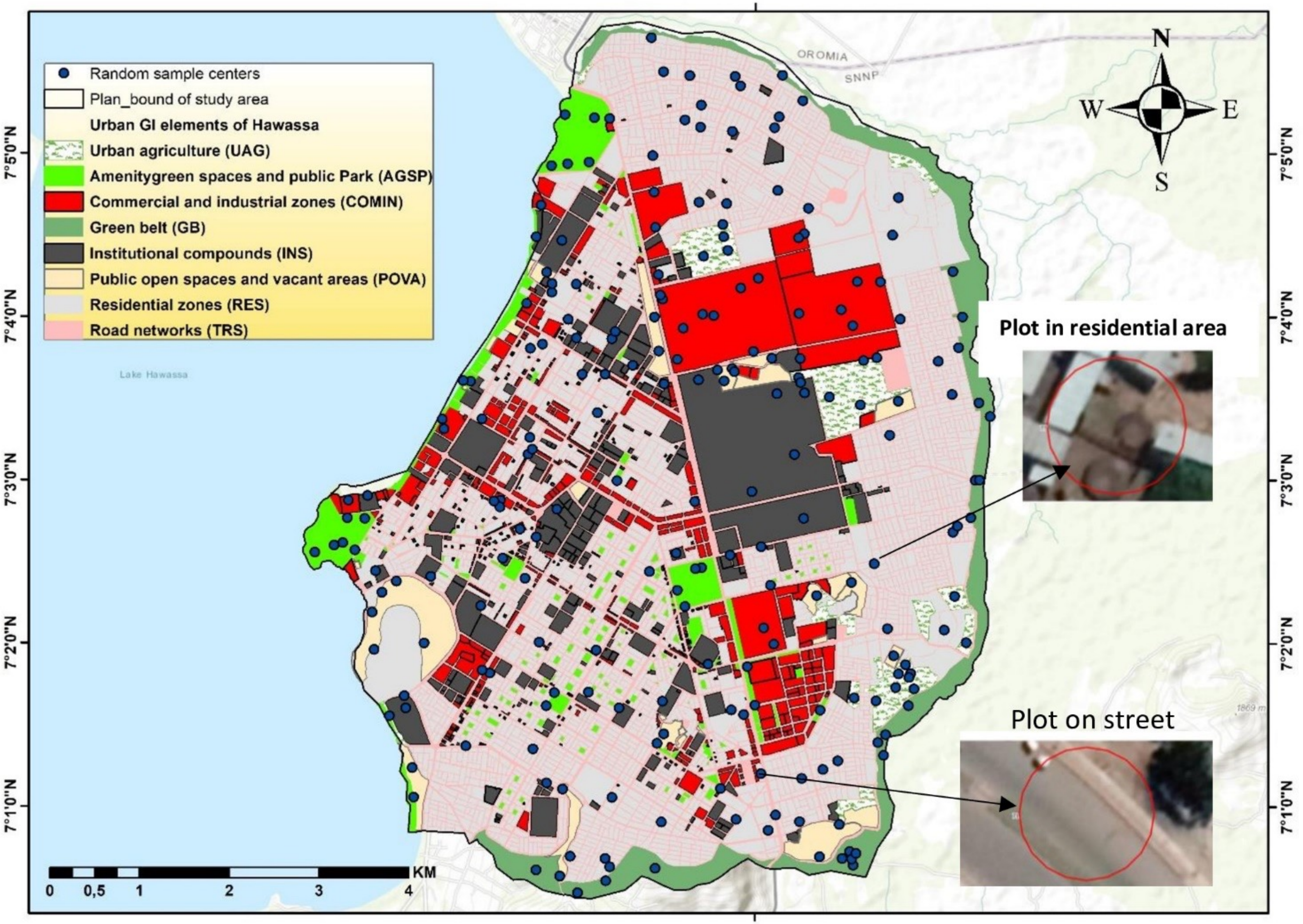
Methodology overview: model customization





Methods: Data collection

Stratified random sampling



Field Measurements

- ✓ Plot information
- ✓ Ground cover data
- ✓ Tree/shrub inventory

Methodology - Air pollution and bVOC analysis and valuation

Dry Deposition Model

$$F = V_d \ x \ C$$

- F = pollutant flux (removal rate in μg m^{-2} h^{-1})
- C= Pollutant concentration (μg m^{-3})
- V_d = dry deposition velocity of pollutants (cm s^{-1})

$$\mathrm{Vd} = \frac{1}{Ra+Rb+Rc}$$

- Aerodynamic (R_a),
- Quasi-laminar boundary layer (R_b),
- Canopy resistance (R_c),

Monetary value:

- **Default externality values** due to lack of local data

BVOC emission analysis

$$E = BE \ x \ B \ x \ \gamma$$

- E = BVOC Emission rate
- B = leaf dry biomass (g)
- BE = genus-specific emission factor (μgC/g)
- γ = Environmental correction factor (temperature, light)

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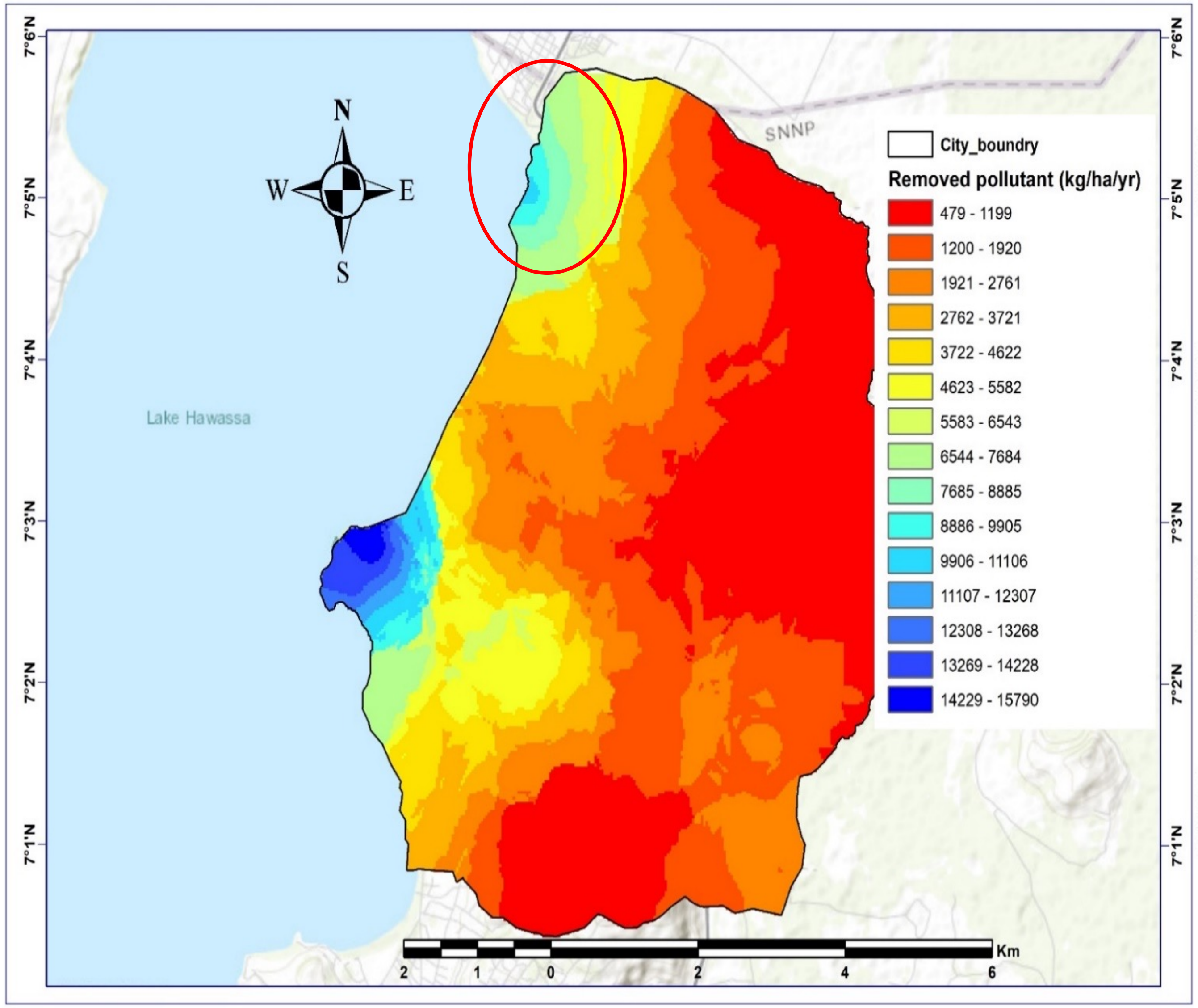
Result and discussions

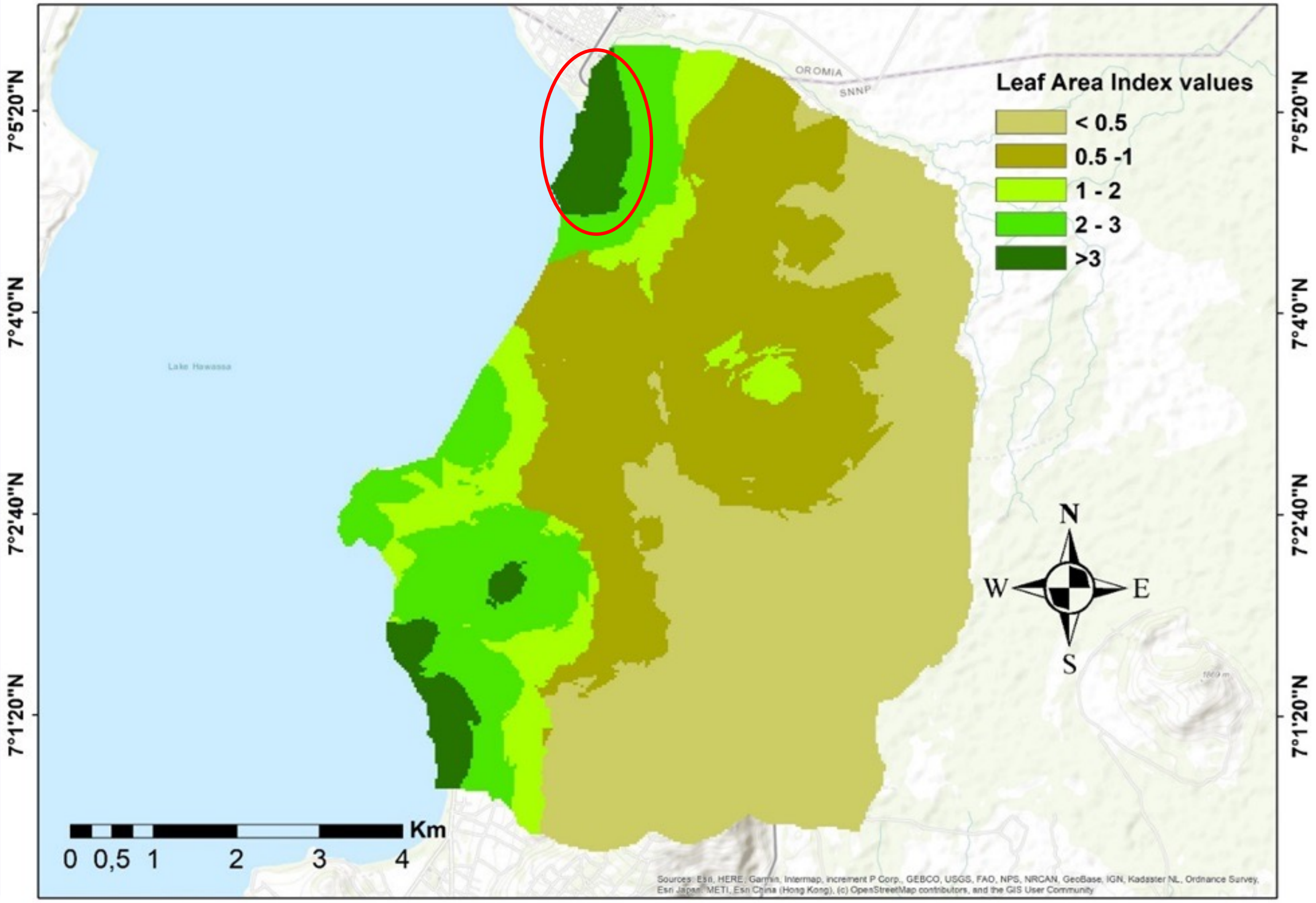
Air pollution removal spatial variation

- Total air pollutant removal: **274.2 t yr-1** **(21.3 g m^2 yr^{-1} tcc)**
- Highest removal: INS, RES, AGSP



Important factors:

- Pollutant concentration
- Areas with higher broadleaved tree cover
- Pollution removal efficiency linked to LAI and TCC



Result and discussions

Seasonal variations

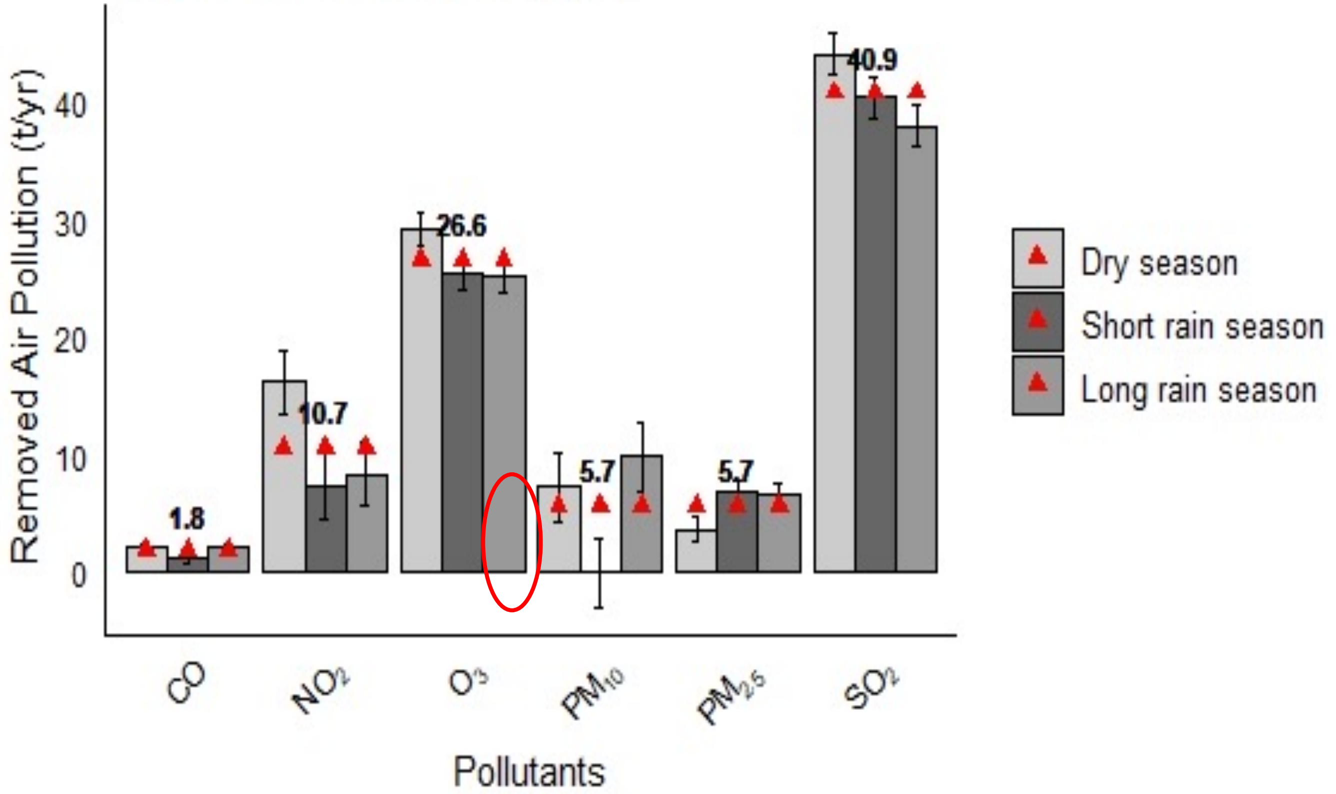
- Highest removal: driest season (Nov., Dec.)
- Lowest removal: long rainy season (Aug.)

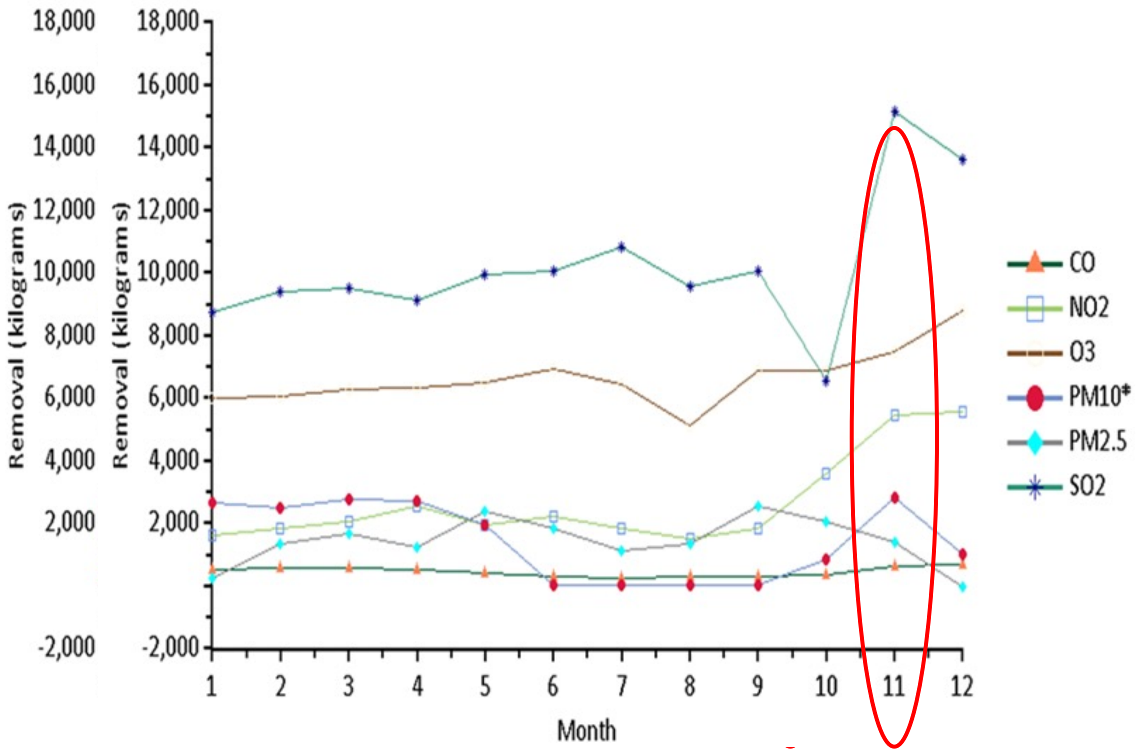
PM2.5 exception:

✓ negative value as it released back during the driest and windiest month

Factors: climate-dependent

- Wet vs. dry: ↓ removal → rainy season → reduced dry deposition
- Temperature & Wind: ↑Temp. and ↓wind speed – high removal





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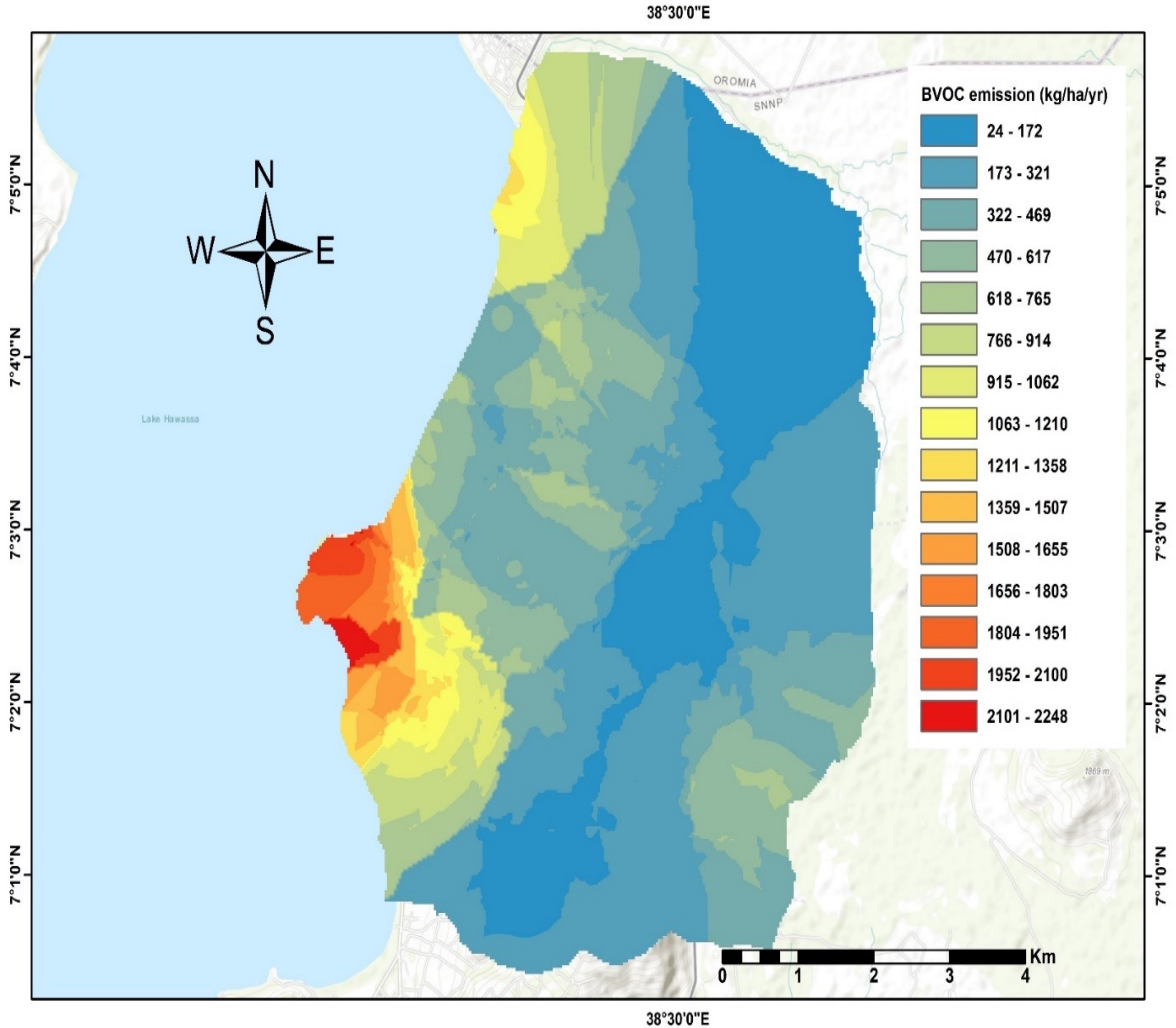
Results and discussions: BVOC Emissions

Urban trees contribute to increased air pollution by emitting BVOCs

- ✓ BVOC Emissions: **35.8 t yr.$^{-1}$**
- ✓ Dominant BVOCs: Monoterpenes and Isoprene
- ✓ **BVOCs** + **NOx** (high temp) → **O_3** & **CO** **(secondary pollutants)**

Key emitters:

- ✓ ***Eucalyptus genus and Ficus sur***
- ✓ These species contributed 51% of the total emissions



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Conclusions & recommendations

- Hawassa's GIs removed **274.2 t** of pollutants annually **(mainly SO_2, O_3, NO_2),** improving air quality
  - ✓ Efficiency directly linked with LAI and TCC
  - ✓ higher in parks and institutional areas, lower in transportation/commercial zones.
- **Seasonal/climatic influence: e**fficiency drops in the rainy season due to high precipitation.
- **Tree species:**
  - ✓ large, broad-leaved trees with higher leaf area are the most effective in air pollution removal
  - ✓ *Eucalyptus and Ficus genus* emit more BVOCs, affecting air quality

- National policies with a strong commitment to urban green space development
- Expand tree cover and prioritize low-BVOC-emitting species for air quality improvement
- Further research on the economic trade-offs between the intangible UGI benefits and land sales revenue.

Thank you

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