Urban Heat and Health

in Johannesburg

A Multidimensional Analysis of Vulnerability, Explanatory Modelling, and Predictive Outcomes

concept_note (1).png

Craig Parker, MSc, MM-PDM, BS
School of Public Health
University of the Witwatersrand

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PhD Protocol Presentation

Why This Research Matters

Urban heat is increasingly threatening public health in Johannesburg

Human Impact

- **0.9%** mortality increase per 1°C above 18.7°C
- **2.1%** increase for elderly residents
- Record temperatures reaching **38°C**

Spatial Inequality

- Townships up to **6°C** hotter than wealthy areas
- Informal housing **15°C** higher indoor temperatures
- Minimal green infrastructure in vulnerable areas

Presentation Overview

- Background and Context
- Research Gap & Rationale
- Conceptual Framework
- Research Aims & Objectives
- Methodology
- Ethical Considerations
- Expected Outcomes
- Project Timeline

Research Journey:
Understanding → Explaining → Predicting → Acting

Background and Context

Climate Change and Heat-Health Impacts

Global warming exceeding **1.2°C** since pre-industrial era

Urban areas experiencing amplified effects

Johannesburg impacts:

- Record **38°C** (2016)
- Mortality increases **0.9%** per 1°C above 18.7°C
- Elderly: **2.1%** increase per 1°C

Urban temperatures up to 8°C warmer than surrounding rural areas

global_temp.png

Figure: Global temperature trends showing

Climate Projections for Johannesburg

By 2050 (High-Emissions Scenario)

$\approx$ **2°C** warming

Hot nights (>20°C) to **quadruple**

3-4 additional weeks of very hot days

By 2100: potential **6-7°C** increase

IPCC: Beyond +2°C, heat-related mortality in Africa will sharply rise

`max_temp.png`

Figure: Johannesburg maximum

Urban Context and Legacy of Apartheid Planning

- Johannesburg: 5.87 million people, 1753m elevation
- Legacy of apartheid spatial planning:
  - **Wealthy areas:** Abundant green spaces, tree canopy
  - **Townships:** Dense settlements, minimal vegetation, dark surfaces

Temperature Disparities

- Townships $\approx$ **6°C** hotter than surrounding areas
- Indoor temperatures in informal settlements up to **15°C** higher than ambient
- Extreme vulnerability for elderly and chroni-

heat_stress.png

Figure: Thermal imagery showing stark

Research Gap and Rationale

Research Gap and Rationale

Current Research Limitations

- Limited African urban heat studies
- Siloed disciplinary approaches
- Models developed in Global North with limited applicability
- African-specific urban challenges understudied

Johannesburg's Unique Challenges

- Historical spatial disparities
- Complex disease burden (HIV, TB, NCDs)
- Accelerating climate impacts
- Informal housing predominance

This research addresses critical knowledge gaps in African urban heat-health research by integrating spatial, physiological, and predictive approaches

Conceptual Framework

Heat Vulnerability Framework

Three Interconnected Dimensions:

Adaptive Capacity

Exposure Heat intensity and duration

- Dense urban areas: Up to **5°C** higher
- Nighttime retention in informal settlements

Sensitivity Population susceptibility

- Health status, chronic conditions
- Age extremes, pregnancy

Adaptive Capacity Resources for coping

- Access to cooling, healthcare, support
- Economic resources, social networks

HVI.png

Figure: Heat Vulnerability Index components showing the interplay

Research Aims & Objectives

Primary Aim

Understand spatially stratified heat-health interactions in Johannesburg and develop evidence-based approaches to mitigate heat-related health risks

Three Interconnected Objectives:

Understanding Heat-Health Interactions

Where are the vulnerable populations?

Who are the vulnerable?

How will risks evolve?

1. Vulnerability Mapping
(Descriptive)

2. Heat-Health Dynamics
(Explanatory)

3. Predictive Modeling
(Predictive)

Objective 1: Heat Vulnerability Mapping

Key Activities:

- Comprehensive spatial vulnerability assessment
- Integration of multiple data sources:
  - **Environmental:** Satellite imagery, temperature networks
  - **Socioeconomic:** Housing quality, infrastructure access
  - **Health:** Disease prevalence, healthcare access
- Advanced spatial statistical analysis

Expected Outcomes

- High-resolution vulnerability maps
- Identification of vulnerability hotspots
- Quantification of spatial vulnerability patterns

temp_distribution.png

Figure: Heat Vulnerability Index distribution

Objective 2: Heat-Health Dynamics Methodology

Clinical-Computational Approach:

Validated mechanistic pathway modeling

Multi-system physiological analysis

Temporal dynamics analysis

Distributed Lag Model

$$g[E(Y_t)] = \alpha + \sum_{l=0}^{L} f(x_{t-l}, l)$$

Machine Learning Approaches:

Random Forests for feature importance

XGBoost with SHAP values for explanation

LIME explanations for model interpretability

mechanisms-inflammatory.drawio (2

Figure: Inflammatory pathways affected by

Objective 3: Heat-Health Prediction Modeling

Key Activities:

- Development of predictive frameworks for heat-related outcomes
- Stratified predictions by:
  - Geographic location
  - Demographic characteristics
  - Housing conditions
- Identification of risk conditions at specific temperature thresholds
- Focus on vulnerable populations:
  - Elderly residents
  - People with pre-existing conditions
  - Those with limited adaptive capacity

Model Applications

- Early warning systems
- Healthcare resource allocation
- Heat action plan development
- Spatial targeting of interventions
- Climate adaptation policy

Multi-method Approach and Data Sources

Methodological Approach:

Advanced geospatial analysis

Statistical modeling

Machine learning techniques

Sample Size:

All 135 Johannesburg wards (complete coverage)

5,000-7,000 clinical records

¿80% power for detecting relevant effects

Key Data Sources:

Category	Sources
Health Data	Clinical trials & cohort studies (2000-2022)
Environmental Data	Landsat 8, Sentinel-2, ERA5, MODIS LST
Socioeconomic	Gauteng City-Region Observatory, QoL Surveys

Integrated multi-source approach enables robust and comprehensive analysis

Objective 1: Vulnerability Mapping Methodology

Analytical Approach:

Principal Component Analysis for Heat Vulnerability Index

Geographically Weighted PCA for spatial non-stationarity
$X_i = V_i \Lambda_i V_i^T + \varepsilon_i$

Spatial clustering (LISA)
$I_i = z_i \sum_j w_{ij} z_j$

Geographic de-identification to ensure privacy

seasonal_heat.png

Figure: Urban heat patterns showing

Objective 2: Heat-Health Dynamics Methodology

Clinical-Computational Approach:

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mechanisms-inflammatory.drawio (2

Figure: Inflammatory pathways affected by

Objective 3: Predictive Modeling Methodology

Modeling Framework:

Ensemble machine learning approaches

Time-series cross-validation

Stratified risk profiles

Key Equations

$$L(\phi) = \sum_{i=1}^{n} l(y_i, \hat{y}_i) + \sum_{k=1}^{K} \Omega(f_k)$$

$$\text{AUC-ROC} = \int_0^1 \text{TPR}(\text{FPR}^{-1}(t))dt$$

Temporal Analysis:

Scale	Health Outcomes
Immediate (0-24h)	Cardiovascular, renal function markers
Short-term (1-7d)	Inflammatory markers, metabolic changes
Medium-term (7-30d)	Chronic conditions, adaptation responses

Model Evaluation

Nested cross-validation

Ethical Considerations

Regulatory Compliance

- Wits HREC (ref 220606)
- US HHS regulations (45 CFR 46)
- South Africa's POPIA (2013)

Data Privacy

- Data minimization
- Secure restricted access
- Geographic jittering
- AES-256 encryption

Secondary Data Usage

- Verification of consent
- Contractual guarantees
- Institutional compliance

This research prioritizes ethical data usage, privacy protection, and responsible data stewardship while maximizing public health benefits

Expected Outcomes and Impact

Public Health Practice

- Targeted vulnerable population interventions
- Precise clinical risk stratification
- Proactive outreach protocols

Climate Adaptation Policy

- Transferable methods for African cities
- Comprehensive heat-health action plans
- Cross-sector collaboration models

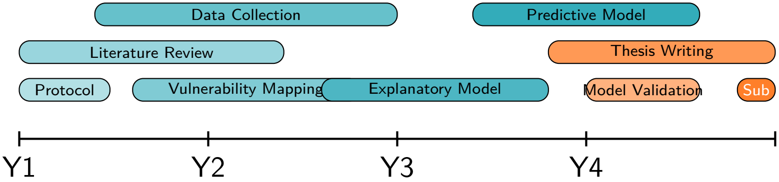
Urban Planning

- Evidence-based cooling strategies
- Green infrastructure priority areas
- Resilient building designs

Community Resilience

- Locally-accessible information
- Community-based monitoring
- Targeted intervention strategies

Project Timeline



Key Timeline Information

36-month research project with four phases

Critical milestones: Protocol (M3), Data collection (M9), Mapping (M18), Validation (M30), Submission (M36)

Supervision Framework

Multidisciplinary Supervisory Team

Supervisor	Affiliation	Expertise
Dr. Admire Chikandiwa	Wits University	Clinical epidemiology
Prof. Matthew Chersich	Trinity/Wits	Climate and health
Prof. Akbar Waljee	Michigan	Statistical modeling, ML
Dr. Christopher Jack	UCT	Urban climate risk

Meeting Structure

Biweekly primary supervision

Monthly team meetings

Support Resources

Wits Research Computing

Climate System Analysis Group

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- Climate System Analysis Group (UCT)
- Wits Health Consortium
- South African Weather Service

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Thank You

Questions & Discussion

craig.parker@witsphr.org