Regulating Ecosystems Services of Fragmented Urban Forests: *Microclimatic Cooling Footprints and Thermal Comfort Attenuation in Manila, Philippines*

Ian Clement M. Delgado

Thesis Adviser: Enrico L. Replan, PhD., RPF

Thesis Reader: Bernard Alan B. Racoma, Ph.D.

Institute of Environmental Science and Meteorology

College of Science, University of the Philippines - Diliman

Abstract

Rapid urbanization and accelerating climate change exacerbate the Urban Heat Island (UHI) effect in tropical megacities, creating severe thermal stress for urban populations. This study evaluates fragmented urban forests for microclimatic cooling and thermal comfort regulation across the City of Manila, Philippines. Using a multi-scale methodological framework, multispectral remote sensing data from Landsat 8/9 and MODIS Terra are processed via Google Earth Engine to derive land surface temperature (LST) profiles and spectral indices, including Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Built-up Index (NDBI). Spatiotemporal heat patterns and thermal vulnerability zones are delineated through Emerging Hot Spot Analysis (EHSA) and Local Outlier Analysis (LOA). Ground-truthing is conducted using a stratified sampling design across a historic core triad: Arroceros Forest Park, Rizal Park, and Intramuros, utilizing 20m × 20m nested plots, alongside 5m × 100m linear transects for roadside ribbons and representative micro-patches. Field measurements quantify key botanical and structural traits, including diameter at breast height (DBH), total tree height, crown dimensions, canopy cover, and Leaf Area Index (LAI), distinguishing native from non-native species to evaluate ecological adaptability and microclimatic cooling trade-offs. Furthermore, microclimatic sensor transects, 24-hour diurnal ENVI-met microclimate simulations, and RayMan Pro modeling quantify localized cooling footprints (ΔT) and human thermal comfort attenuation (Physiological Equivalent Temperature, PET). Statistical integration using Linear Mixed-Effects (LME) models, thermal comfort indices, and multiple regressions links physical tree traits and canopy geometry directly to ambient cooling efficacy. By synthesizing spatial metrics, empirical field data, and predictive greening scenario simulations, this research provides vital evidence-based insights to assist urban planners

and Local Government Units (LGUs) in transforming fragmented canopy patches into cohesive, heat-resilient green infrastructure networks within local land use and climate adaptation strategies.

Keywords*: urban forest; microclimatic cooling; thermal comfort attenuation; urban heat island; physiological equivalent temperature; leaf area index; land surface temperature*