THE UNIVERSITY OF HONG KONG
SCHOOL OF BIOLOGICAL SCIENCES

Postgraduate Student Public Seminar

"POST-FIRE FOREST RECOVERY IN THE TROPICS: PATTERNS, DRIVERS, AND IMPLICATIONS UNDER GLOBAL CHANGE"

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on Wednesday 2 September, 2026 at 3:30 pm
Room 6N-11, Kadoorie Biological Sciences Building

Abstract

Tropical forests play a critical role in the global carbon cycle, yet fire activity across these regions has risen sharply in recent decades, driven by climate change and land-use change. Accurately quantifying post-fire recovery trajectories and understanding the factors that govern them are essential for predicting the fate of tropical forests and informing conservation strategies. However, significant gaps persist in our understanding of whether post-fire tropical ecosystems can achieve full recovery, and how environmental conditions, fire regimes, and anthropogenic pressures shape recovery outcomes across scales. This thesis addresses these gaps by improving the monitoring of multi-decadal post-fire forest recovery and investigating the drivers of its spatiotemporal dynamics, from local protected areas to the tropics.

This thesis first developed an XGBoost-based machine learning model integrating spectral, textural, structural, and environmental variables to distinguish naturally recovering burned areas from those permanently converted to other land uses. The model achieves high classification accuracy (86.53%), enabling the separation essential for any reliable assessment of post-fire recovery. After this separation, natural recovery areas exhibited significant structural regeneration over two decades, with understory recovery outpacing upper-canopy recovery nearly twofold, while permanently converted areas showed no detectable structural recovery.

The methodology is then scaled to the entire Amazonian protected area (PA) network, spanning 437 PAs and nearly 17,000 fire events over two decades. A "structural recovery debt" metric is introduced to quantify the lasting structural shortfall of burned forests relative to unburned controls. Results reveal that by 2020, only 9% of burned forests had regained canopy structures comparable to unburned stands. Anthropogenic pressures impeded recovery in approximately 30% of burned areas, with the strongest impacts concentrated in the southeastern Amazon. Recovery followed a non-linear trajectory: rapid structural gains in the first post-fire decade gave way to progressively slower recovery thereafter. In areas buffered from direct human interference, fire severity and time since fire dominated recovery outcomes, while topography played a secondary role.

Lastly, the thesis compares the recovery of 1,724 large-scale fire events across pantropical regions between two periods (2003–2009 and 2010–2016) to evaluate whether intensifying drought has altered post-fire recovery dynamics. Post-fire hydroclimatic stress intensified substantially after 2010, with fires facing more frequent, severe, and longer-lasting droughts during the recovery window. Vegetation recovery time lengthened significantly, and this delay persisted even under equivalent drought levels, indicating a weakening of the intrinsic recovery capacity of tropical forests. Post-fire hydroclimatic variables collectively accounted for over 85% of the explained variance in recovery time, far exceeding the contributions of fire attributes and background environmental factors.

Overall, these studies advance a more complete understanding of tropical forest recovery after fire, spanning spatial scales from local protected areas to the entire tropics, capturing temporal dynamics from immediate post-fire years to multi-decadal trajectories, and disentangling the roles of climate, fire, and human activity. The methodological framework and insights developed here can inform operational post-disturbance monitoring systems and support evidence-based conservation planning for tropical forests under a changing climate.

--- ALL ARE WELCOME ---