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Spatial variations in forest succession rates revealed from multi-temporal habitat maps using Landsat imagery in subtropical Hong Kong

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Secondary succession is one of the major processes in forest habitat restoration across degraded landscapes globally, especially in tropical regions. Hong Kong, situated on the northern fringes of the Asian tropics, has undergone near-complete clearing of its original forests due to human activities in history, and most of its current vegetation was formed by regenerations in recent decades. Understanding the dynamics of vegetation changes over time involves various biotic, abiotic, and anthropogenic factors related to different ecological processes. Remote sensing imagery, with the ability to discern habitat patterns across spatial and temporal scales, provides an effective tool for addressing this requirement. In particular, the Landsat satellite mission has provided continuous earth observation data since 1972 and has been widely used in time-series analyses of habitat transformations.

This study leveraged all available Landsat imagery to examine the coverage of six habitat classes in the forest-regenerating landscape of Hong Kong from 1973 to 2022. A multi-temporal classification workflow was developed, which combined cross-calibration of Landsat sensors, random forest classification, decision-level fusion after classification, and temporal smoothing. An overall accuracy of 90.1% was achieved when assessed using various office- and field-collected data, with accuracy exceeding 86% and 88% when individual classes and mapping periods were considered respectively. Based on the multi-temporal habitat maps produced from the classification workflow, survival analysis was used to examine the time required for successional changes, and correlation analysis was used to associate the transition time with various natural and anthropogenic factors.

The results indicate that (i) a single classification model could be developed using all images acquired by multiple Landsat sensors across years, including the earliest Landsat 1–5 MSS data, which is crucial in extending the temporal baseline and adding a decade of habitat information. (ii) Incorporating more images in the classification model enhanced overall accuracy, with the highest accuracy achieved when all available images were included. Classification performances for earlier years and transitional classes showed higher vulnerability to the reduced proportion of input images. (iii) The natural landscape in Hong Kong gradually transformed from being grassland-dominated in the 1970s to woodland-dominated in the 2010s. Grasslands took a median time of 21 years to become shrublands and another 29 years to become woodlands, but the first quartiles

of 7 and 10 years respectively indicate a high spatial variability. Hill fire was the most important factor positively correlated with the transition time (restricting forest succession), while increasing proximity to seed sources and protected area designation produced the highest negative correlations (accelerating the process).

This study demonstrates the value of connecting the Landsat time series with human impacts and management practices to produce spatially explicit ecological insights. The experience of forest regeneration in Hong Kong, formed by both conservation interventions and natural succession, will benefit the increasing interest in forest protection and restoration in the wider tropical region.