DUAL ROLES OF TREES IN SOIL-BASED HERITAGE CONSERVATION

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IFLA 2025
Guiding landscapes
Nantes France

P278

SYMBIOSIS AND RISK
The Dual Impacts of Trees on the Soil-based Heritage Conservation

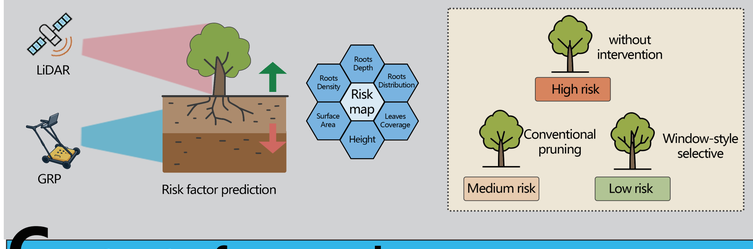
Abstract

Soil-based heritages are vital to world cultural heritage, reflecting ancient human activities and the dynamic coupling between historical sediment and contemporary landscape functions (Zhang et al., 2012). Along with climate change, global soil-based heritage sites are exposed to more significant risks (Machat, C., & Ziesemer, J., 2017). Regarding biological factors, vegetation exhibits an annual 25 % increase in underground biomass, creating conflicts between tree root systems and their displacement of soil structures (Grabosky & Gucunski, 2019), which has led to the degradation of the apparent morphology of the soil-based heritages. Nevertheless, trees also provide rainfall interception and soil stabilization (Xiao et al., 2024). The dual impact mechanism and the assessment methodology of trees form a critical foundation for heritage vegetation management, representing a current research gap.

In this study, a novel estimation model for root-system states is developed from a digital perspective using airborne LiDAR and ground-penetrating radar. Above-ground and below-ground components of vegetation on soil-based heritages are linked through pixel clustering, feature extraction, and deep-learning techniques.

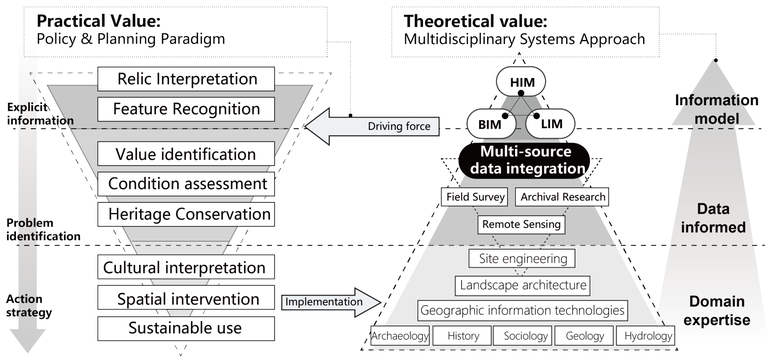
We found that: (i) Model outputs match field surveys; (ii) Spatial heterogeneity persists, with the southeast most disturbed by root pressure, underscoring urgent control; (iii) Selective thinning of dominant trees while retaining moderate canopy gaps best lowers risk.

This noval framework offers a new lens for soil-heritage protection, fills the dual-impact assessment gap, and supports fine-scale, multi-source management. Practically, this study informs policy for heritage management and provides planning suggestions aligning conservation with national strategies for Yangzhou ancient city ruins.



Background

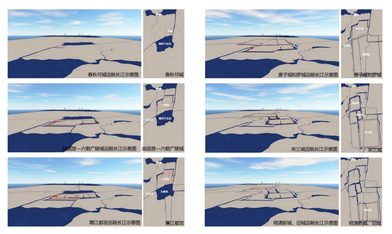
. Methodological Framework



. Location and Historical Evolution

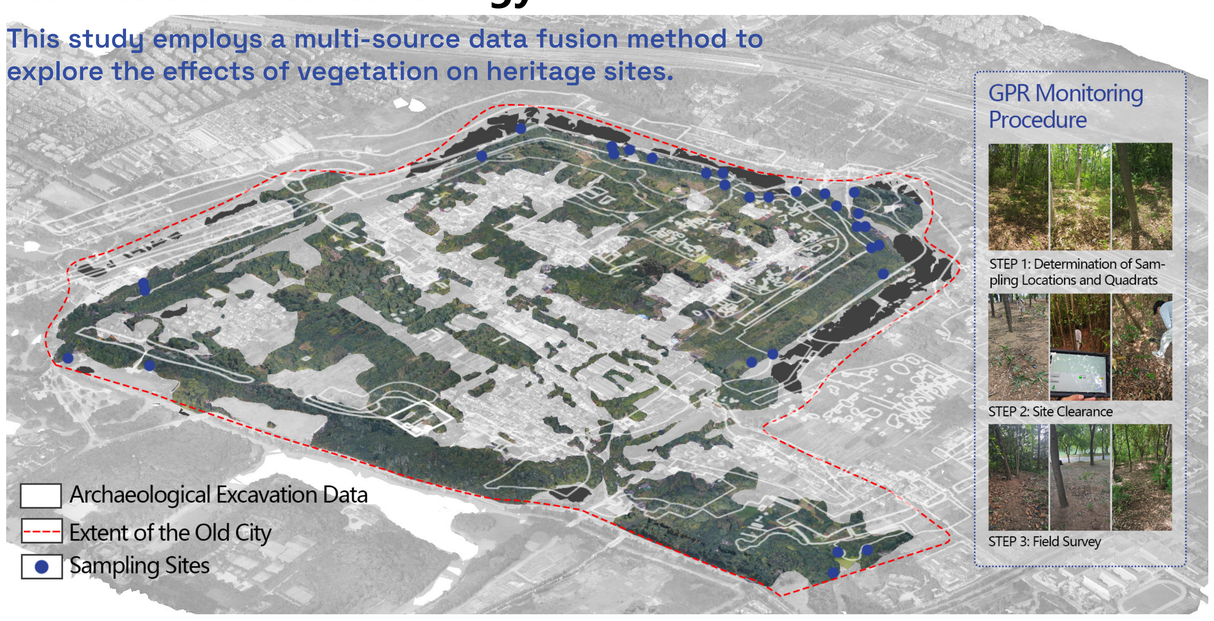


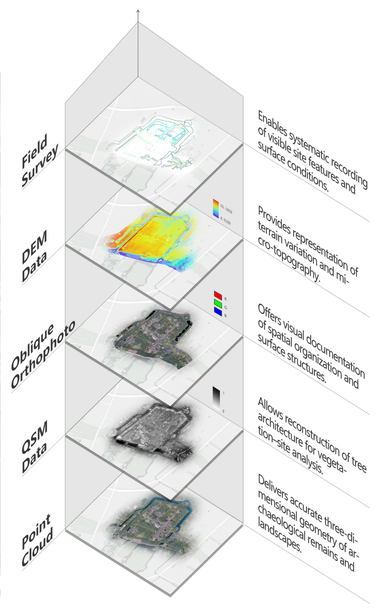
Shugang Hill, in western Yangzhou by the Beijing–Hangzhou Grand Canal, is a Yangtze River remnant with Tang–Song heritage.

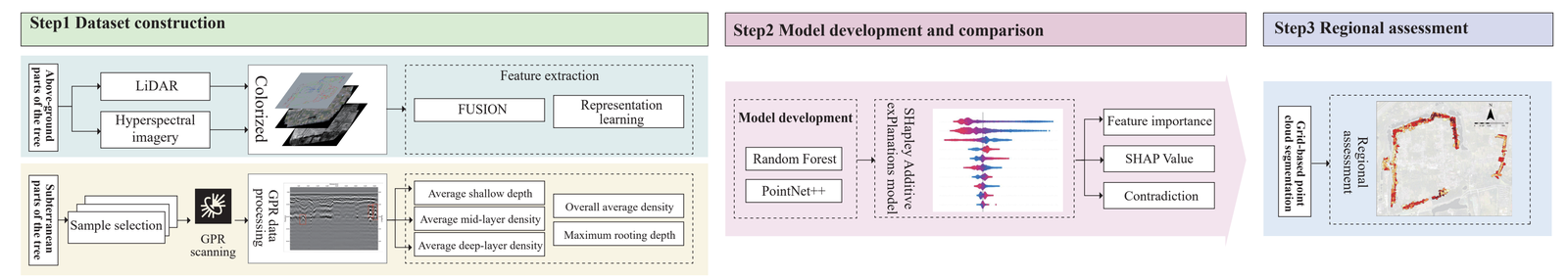


. Material and methodology

This study employs a multi-source data fusion method to explore the effects of vegetation on heritage sites.

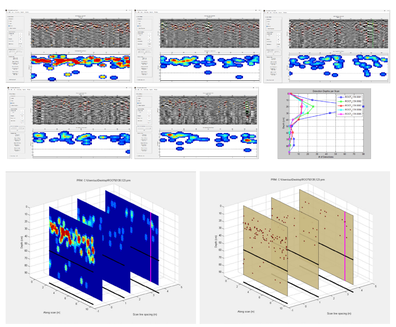


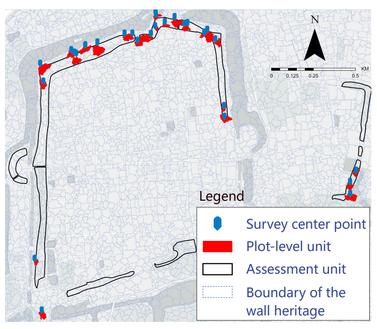




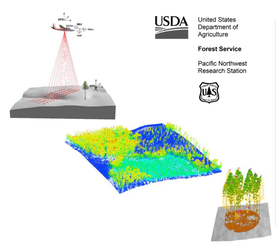
Content of research

• Plot-level root extraction

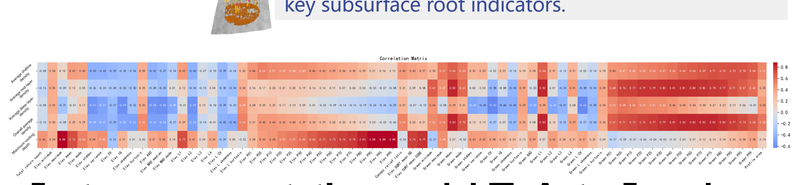




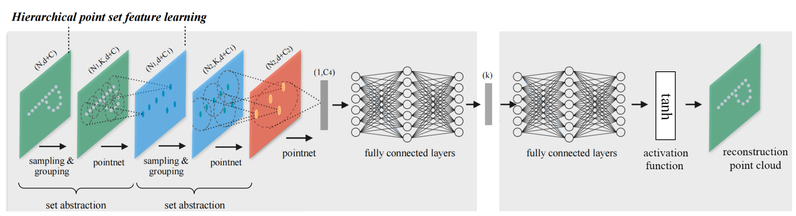
• : FUSION/LDV

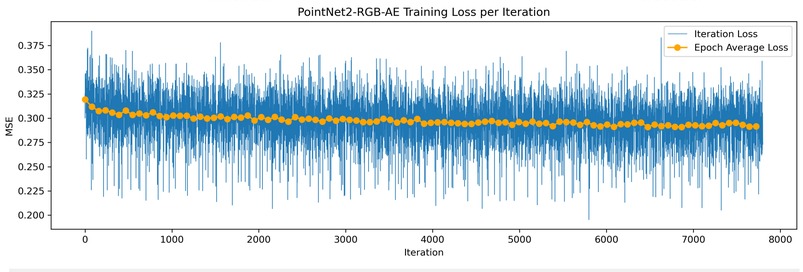


FUSION/LDV is a free LiDAR software from the USDA Forest Service. It extracts over 50 metrics (tree height, point density, etc.) from point clouds.
In this study, the software was used to extract features from plot-level point clouds and correlate them with key subsurface root indicators.



• Feature representation model Ⅱ: Auto-Encoder framework based on PointNet++ architecture



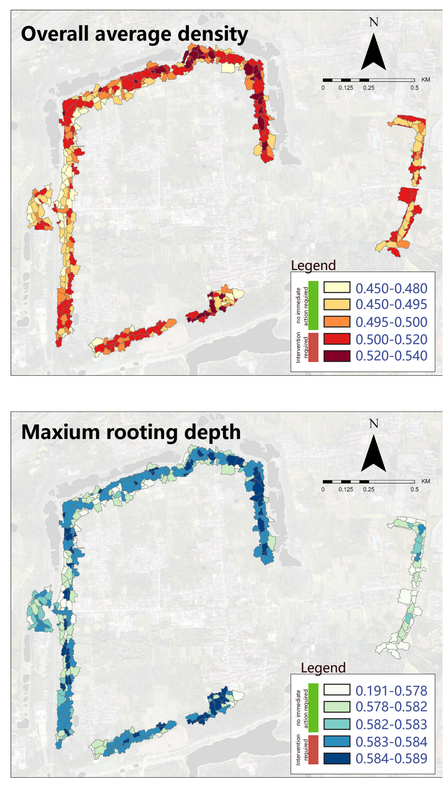


Thestudy tried AE for point-cloud features, but the model failed to converge and was therefore excluded from subsequent modeling.

• Performance of model

A random-forest model was built between the point-cloud metrics in Feature Representation Model I and five key root parameters, with a 3:7 train-test split. Results show that above-ground assessment of below-ground roots is feasible. Maximum rooting depth was predicted best (R^2 = 0.708); SHAP analysis revealed that height-related metrics had the greatest influence, followed by overall average density (R^2 = 0.601) and the green spectral index (a proxy for canopy density). Notably, the model delivers acceptable accuracy for shallow- and deep-layer density, but shows high uncertainty for mid-layer density.

• Prediction of root state



Discussion

The impact of plant roots on ancient city walls is gradual and cumulative. Initially minor, it can worsen over time, eventually causing severe or even destructive damage.When deciding which native trees to preserve or remove at the Shugang site, the key is assessing how their roots systematically affect the wall's structural integrity.
Root impact depends on six factors: depth, size, density, type, growth rate, and biochemical traits. This study only examined depth and density; the remaining factors need further research.



This study additionally explores root-treatment methods: White-rot fungi were fermented for spores, mixed into medium, injected into wall-root boreholes, and monitored for decay. fungal growth and root decay are then monitored regularly.

Context us

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