A SEMI EMPIRICAL MODEL TO EVALUATE URBAN WIND ENVIRONMENT WITH TREES

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Abstract

High-density urban areas are often associated with limited outdoor natural ventilation. Given the growing call for more vegetation in the cities, it is important to study the **wind resistant of urban trees** in order to address outdoor natural ventilation problem in the landscape planning. Currently, Computational Fluid Dynamics (**CFD**) simulation and wind tunnel experiment can only model the simplified street canyon with roadside trees, **at the expense of intensive technical support and high computational cost**. Thus, the impact of research outputs on the landscape planning remains low.

In this study, we developed **a practical semi-empirical model** to provide scientific understandings for the landscape planning practice. This research **correlated the urban density and tree geometry indices with wind speed**, thereby enabling planners to calculate trees' effects on airflow using their in-house data. This **knowledge-based landscape planning** allows to introduce more trees into urban areas, while avoiding negative effects of trees on the outdoor wind environment at cities at the same time.

I. Development of Modelling Method

The development of the new modelling method is derived from the balance between momentum flux and the drag force of both buildings and trees on airflow.

Momentum flux = Drag force (building + trees)

Semi-empirical model:

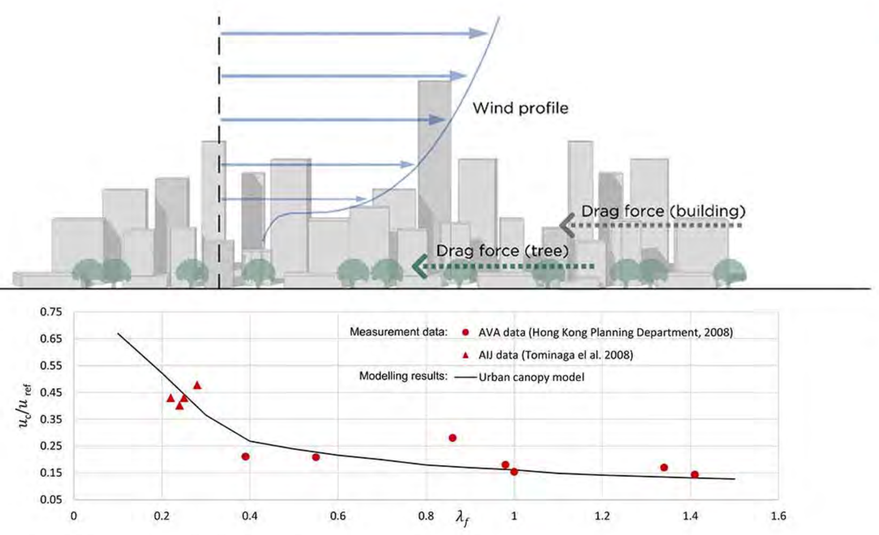
$$\frac{U_c}{u_*} = \left(\frac{2(1-\lambda_p)}{C_{D\_building}\lambda_{f\_building} + C_{D\_tree}\lambda_{f\_tree}}\right)^{0.5}$$

$u_* = 0.12 \cdot U_{ref}$, when $\lambda_{f\_building} \geq 0.4$

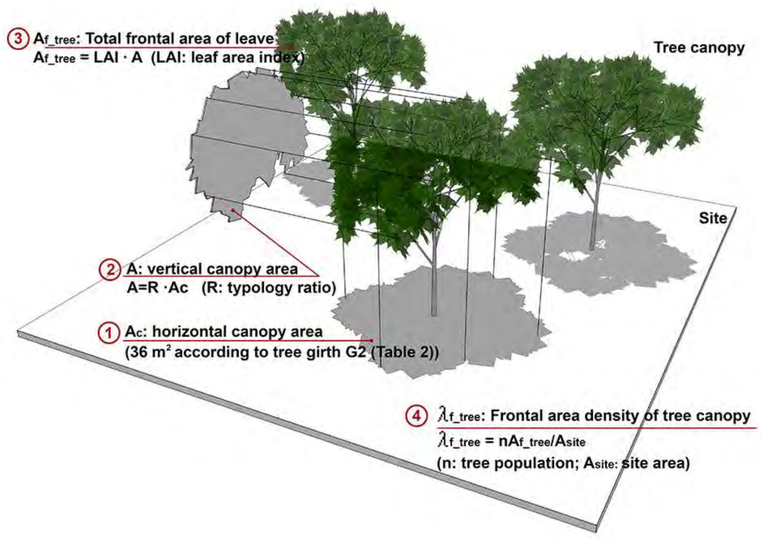
Modelling of friction velocity

$\lambda_{f\_tree} = \frac{n\,A_{f\_tree}}{A_{site}}$; $A_{f\_tree} = LAI \cdot A$; $A = R \cdot A_c$

Parametrization of FAD of trees



Modelling of friction velocity (u*)



Parametrization of FAD of trees (λ_{f_tree})

II. Parametric Study -- Effects of Urban Density, Tree Species and Population

A **parametric study** at Hong Kong was conducted using this new semi-empirical model to clarify the effects of trees on the urban wind environment. From this study, we found that:

1. As the **green coverage ratio** increases, the wind velocity decreases, i.e. planting more trees in urban areas could slow down air flow at the urban canopy layer.

2. Effects of trees on the urban wind environment greatly depend on **the density of the urban context**, as well as **the density and typology of plant canopy**:

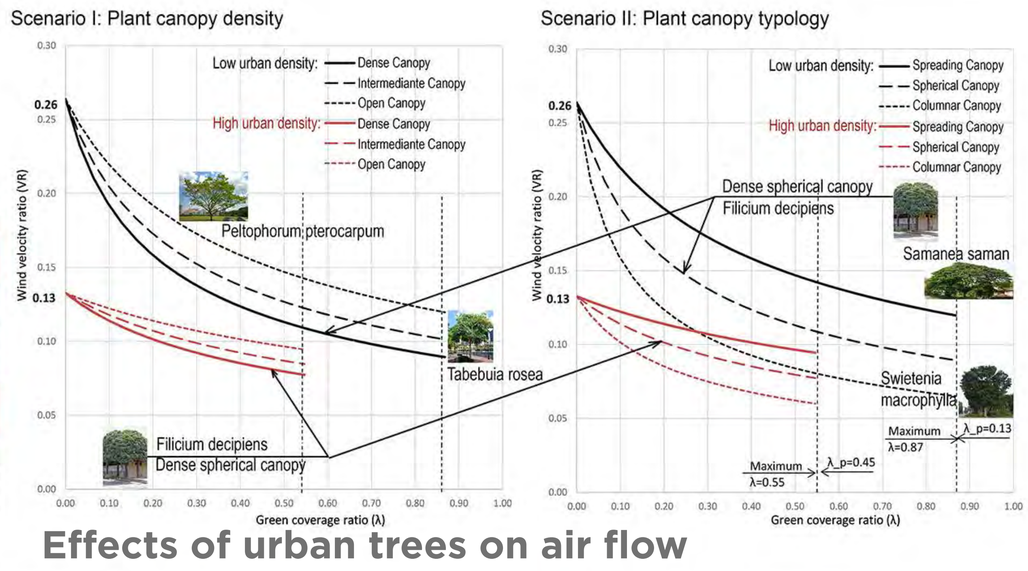
a: Wind velocity decreases more rapidly in low density urban areas compare to high density urban areas with the same tree species and densities.

b: Open and spreading canopy trees have smallest impact on the urban wind environment compare to dense and columnar canopy trees.

Two tree geometry parameters in two scenarios are highlighted, i.e. **Leaf area index (LAI) in Scenario I and tree typology ratio (R) in Scenario II.**

The input data (i.e. urban density and urban tree geometry indices) for the parametric study are summarized in table below.

Scenario I	Site	Urban Density		Urban tree geometry				
		$\lambda_{f(0\text{-}15m)}$	λ_p	A_c	R	LAI (Dense Canopy)	LAI (Intermediate Canopy)	LAI (Open Canopy)
High density case	Sheung Wan	0.45	0.45	36	1.0	4.0	3.0	2.0
Low density case	Sha Tin	0.18	0.13	36	1.0	4.0	3.0	2.0
Scenario II	**Site**	**Urban Density**		**Urban tree geometry**				
		$\lambda_{f(0\text{-}15m)}$	λ_p	A_c	LAI	R (Spreading Canopy)	R (Spherical Canopy)	R (Columnar Canopy)
High density case	Sheung Wan	0.45	0.45	36	4.0	0.5	1.0	2.0
Low density case	Sha Tin	0.18	0.13	36	4.0	0.5	1.0	2.0



Settings of parametric study

Effects of urban trees on air flow

Swietenia macrophylla

Filicium decipiens

Samanea saman (Rain tree)

Peltophorum pterocarpum

Suggestions of tree species

III. Implementation

A case study at Tsim Sha Tsui, one of the metropolitan areas with limited urban vegetation at Hong Kong to illustrate how to **apply the understandings in this study into landscape design practice.**

Map of impact of trees on urban wind environment (100 m x 100m)

A: High impact (Low density area)

Increasing green coverage ratio by planting grass or shrub, rather than trees. The tree species chosen for waterfront areas must be with porous and spreading canopy.

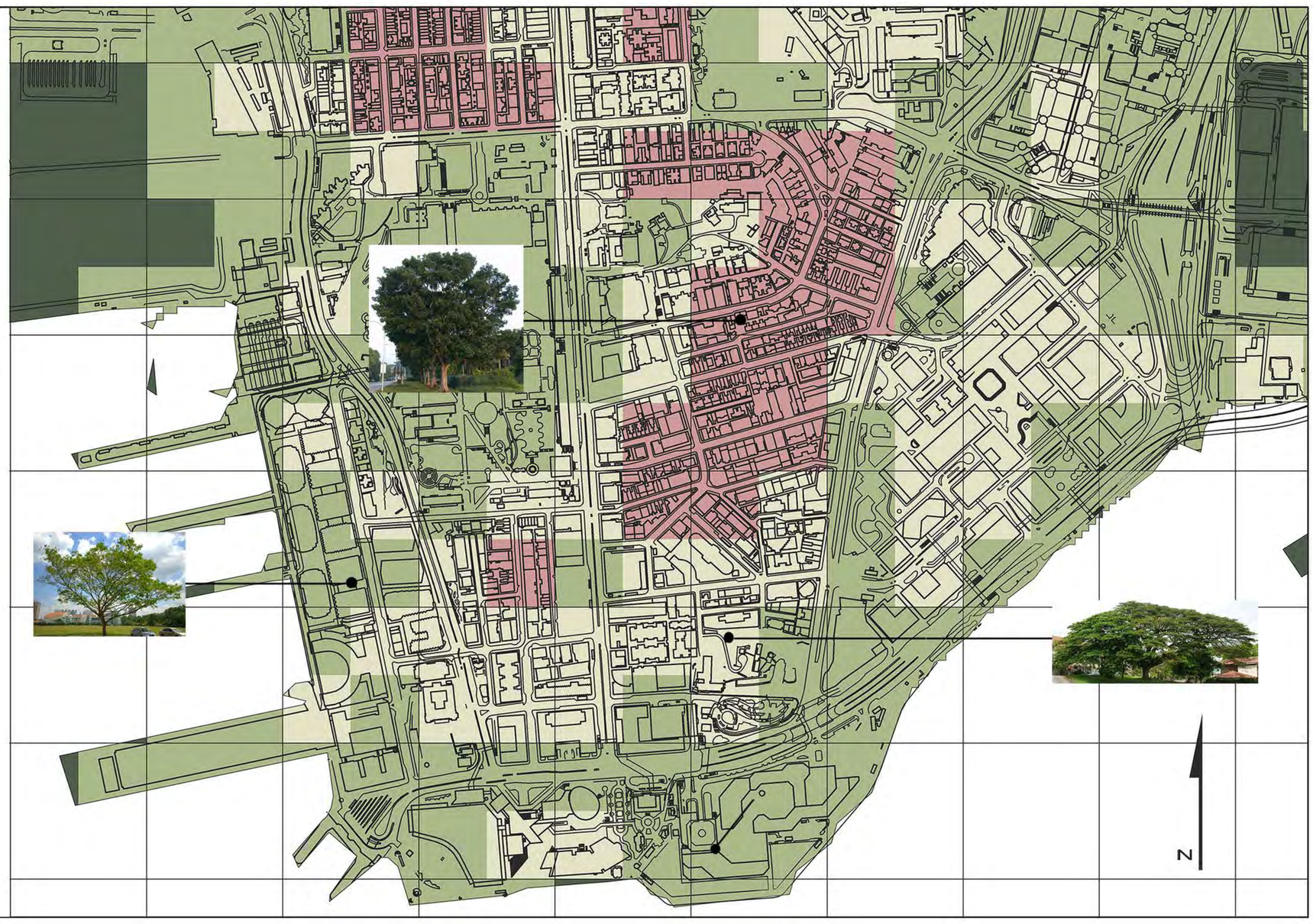
B: Intermediate impact (Medium density area)

Increasing green coverage ratio by choosing the trees with porous and spreading canopy

C: Low impact (High density area)

Increasing green coverage ratio by planting trees for more shading and evapotranspiration benefits, since wind speed is not sensitive to tree population and species at these areas.

No building



More details:

Yuan, C., Norford, LK., Ng, E., 2017, A Semi-Empirical Model for the Effect of Trees on the Urban Wind Environment, Landscape and Urban Planning, 168, 84-93.

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