# Impacts of Typhoon Mangkhut on Trees

Hong Kong Observatory
Research Forum
Impacts of Super Typhoon Mangkhut
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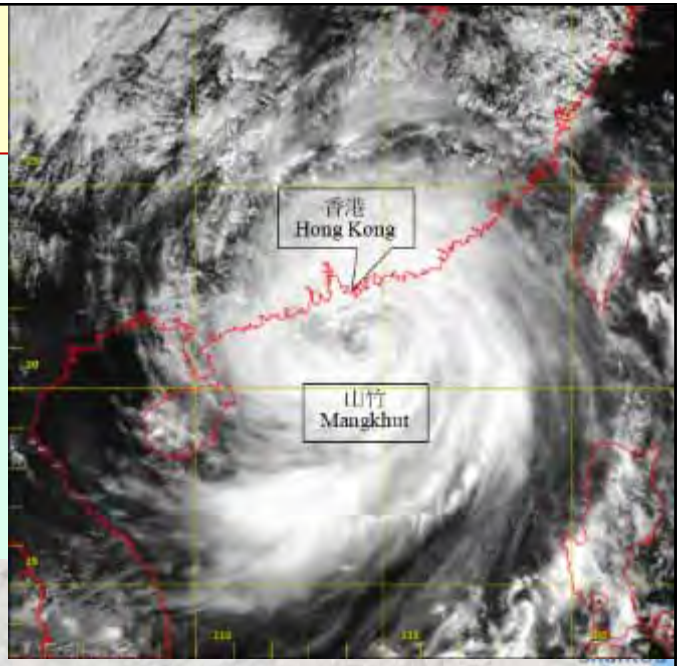
# Presentation outline

1. Introduction
2. Tree failure due to substandard planting materials
3. Tree failure due to inadequate soil volume
4. Tree failure due to poor soil quality
5. Tree failure due to soil-root damages
6. Innovative urban soil solutions

# Typhoon Mangkhut

**Typhoon Mangkhut strike:**

- 16 September 2018
- No. 10 Hurricane Signal for 10 hours
- Sustained maximum wind speed at 250 km/h
- The most powerful since records began in 1946.



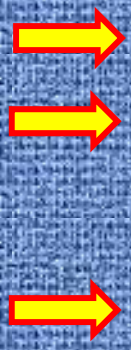

**Fortuitous events:**

- Weakened after sweeping through the Philippines
- Reduced from super to severe typhoon shortly before reaching Hong Kong
- Did not strike directly, closest at 100 km SSW of HK
- Did not stay longer
- Did not strike during astronomical spring tide

# Wind speed and tree damage: Traditional wind scales (variable and subjective)

Saffir-Simpson Hurricane Scale

Fujita-Pearson Tornado Scale

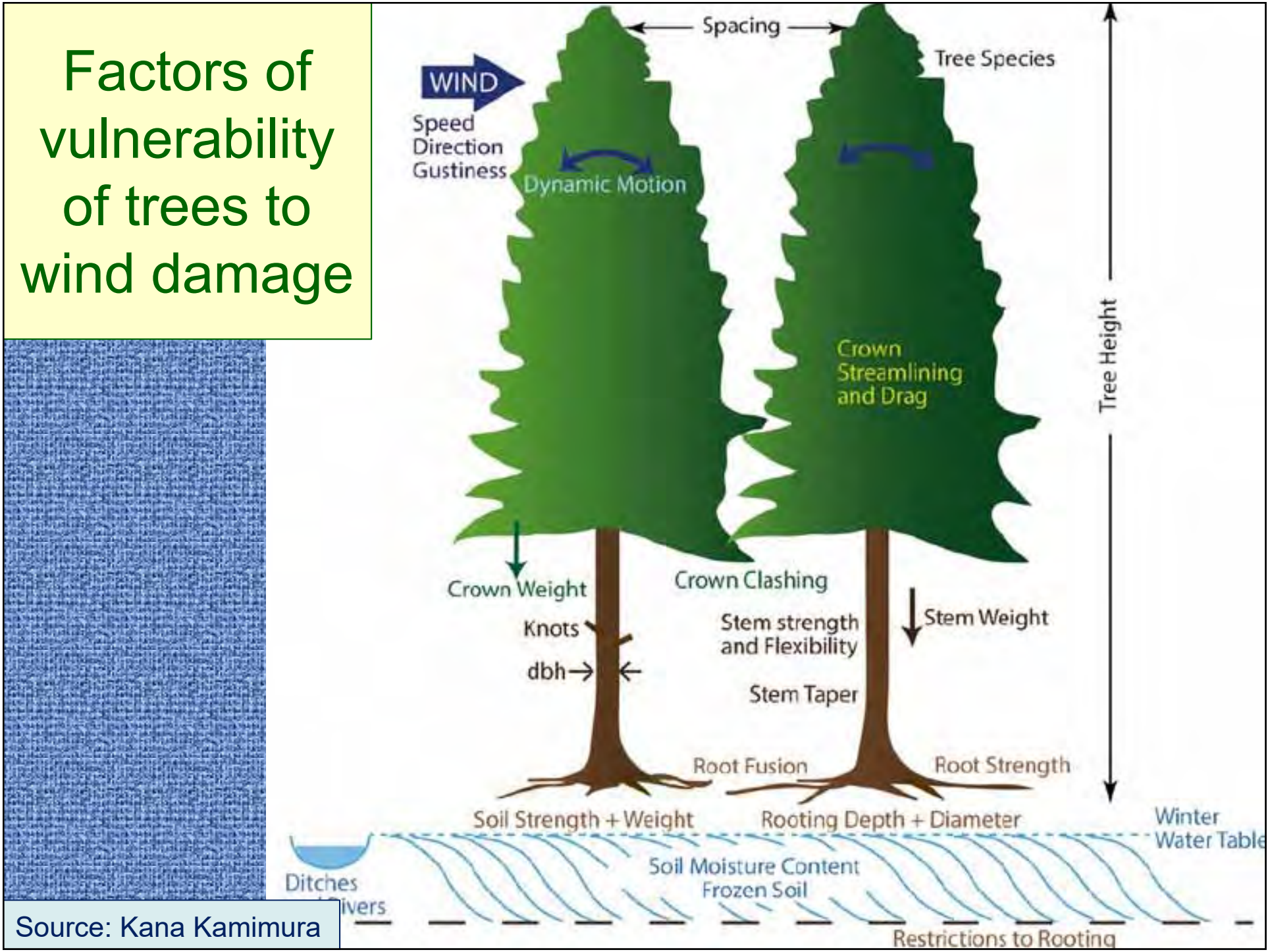


## Beaufort Scale of Wind Force

| Beaufort Force | Description | When You See or Feel This Effect | Wind (mph) | Wind (km/h) |
|---|---|---|---|---|
| 0 | Calm | Smoke goes straight up | less than 1 | less than 2 |
| 1 | Light air | Wind direction is shown by smoke drift but not by wind vane | 1-3 | 2-5 |
| 2 | Light breeze | Wind is felt on the face; leaves rustle; wind vanes move | 4-7 | 6-11 |
| 3 | Gentle breeze | Leaves and small twigs move steadily; wind extends small flags straight out | 8-12 | 12-19 |
| 4 | Moderate breeze | Wind raises dust and loose paper; small branches move | 13-18 | 20-29 |
| 5 | Fresh breeze | Small trees sway; waves form on lakes | 19-24 | 30-39 |
| 6 | Strong breeze | Large branches move; wires whistle; umbrellas are difficult to use | 25-31 | 40-50 |
| 7 | Moderate gale | Whole trees are in motion; walking against the wind is difficult | 32-38 | 51-61 |
| 8 | Fresh gale | Twigs break from trees; walking against the wind is very difficult | 39-46 | 62-74 |
| 9 | Strong gale | Buildings suffer minimal damage; roof shingles are removed | 47-54 | 75-87 |
| 10 | Whole gale | Trees are uprooted | 55-63 | 88-101 |
| 11 | Violent storm | Widespread damage | 64-72 | 102-116 |
| 12 | Hurricane | Widespread destruction | 73+ | 117+ |

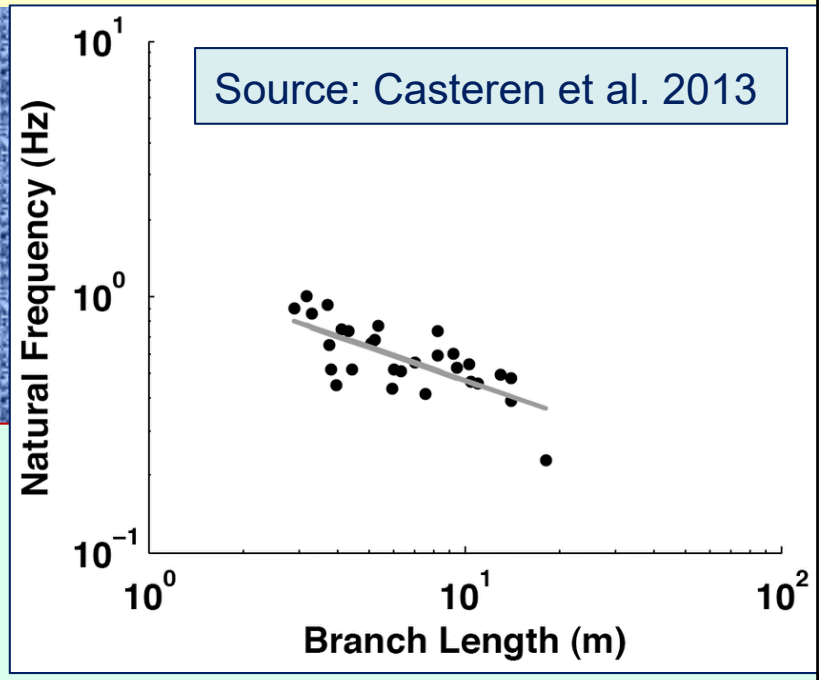
Source: Engineer Diary

# Factors of vulnerability of trees to wind damage




Source: Kana Kamimura

# Tree natural frequency ($f_N$) and resonance



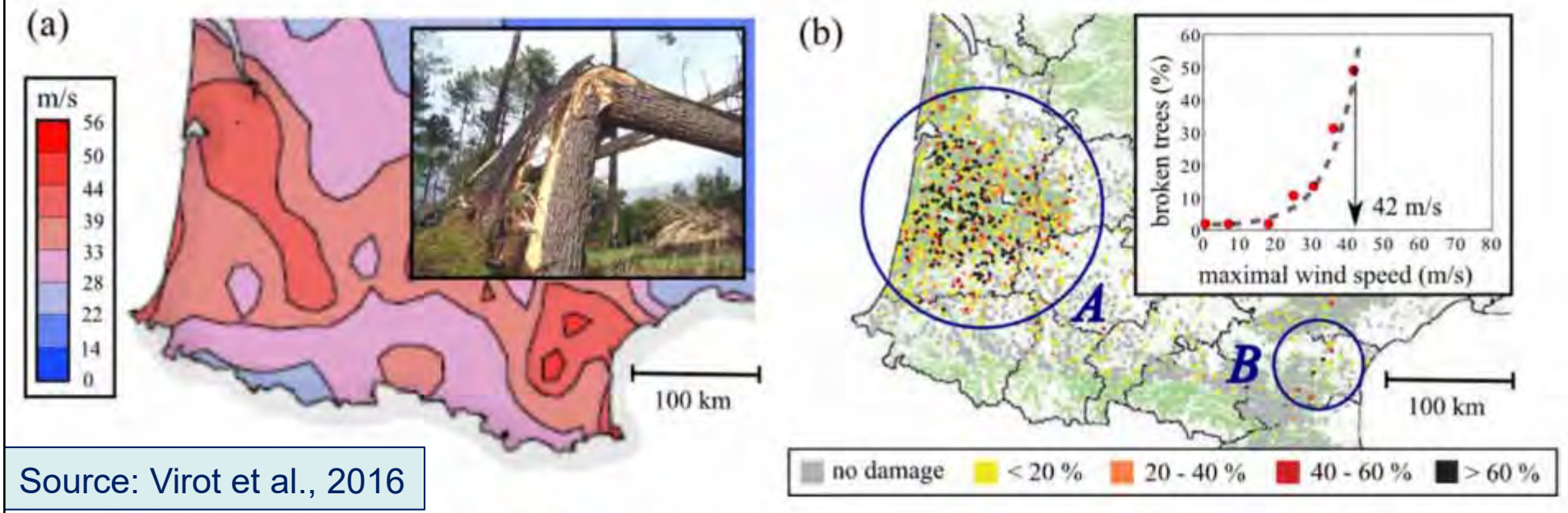

- Every object has a natural frequency
  - Every tree part has a $f_N$
- If wind pulses arrive at a frequency near $f_N$
  - More efficient transfer of energy from wind to tree
  - Inducing tree sway at higher amplitude
- May create *resonance*
  - Wind force amplifies tree sway as oscillatory motion
  - Enhanced absorption of wind energy by the tree
  - Quickly and considerably increases the magnitude of displacement
  - Exerted force can reach a threshold called the *critical bending moment* above which the tree may fail

# Critical wind speed (CWS)

CWS > 42 m/s or 151 km/h: Massive tree failure, conifers (soft wood) and broadleaf (hard wood)

Weakly related to biomechanical traits: Stem diameter, tree height, wood elastic property, species

At < 20 m/s or 72 km/h: Little or no damage




Source: Virot et al., 2016

FIG. 2. Storm Klaus (South-West of France, January 24th, 2009). (a) Maximal wind speed recorded during the storm Klaus. (Data: Météo France [19]; calculated from an average over 1 s). (Inset) A trunk breakage in a pine forest [in the area A of Fig. 2(b)], attributed to storm Klaus. (Photograph: Saint Julien en Born City Hall). (b) Percentage of broken trees attributed to the storm Klaus. (Data: Inventaire Forestier National [26]). Area A is a forest of pines, whereas area B is mainly a forest of oaks. The highest wind speeds were recorded in these areas, leading to extreme damage regardless of tree species. (Inset) Correlation between wind speed and tree damage. There is no statement of damage below 20 m/s, whereas a majority of trees gets broken for wind speeds exceeding 42 m/s.

# Main modes of tree failure

Root lodging (uprooting, windthrow, toppling)

Stem lodging (snapping, buckling, breakage)

Source: USDA

C Y Jim: Typhoo

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Young tree inherited circling roots from poor nursery practice
Source: C.Y. Jim 2019


Small root ball with little root growth into site soil since planting
Source: C.Y. Jim 2019

Roots of young tree unable to extend into site soil to establish anchorage

Source: C.Y. Jim 2019

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Large tree trapped in “standard” tree pit
第七屆全港運動會
The 7th Hong Kong Games
九龍城
Source: C.Y. Jim 2019

Large tree with root growth shaped and restricted by tiny pit

Source: C.Y. Jim 2019

Large tree with few roots extending beyond small circular pit

Source: C.Y. Jim 2019


Large tree with stout roots failing to break out of the tiny pit into the site soil
Source: C.Y. Jim 2019


Large tree with roots tightly packed in tiny planter
Source: C.Y. Jim 2019

Large tree with dense and entangled roots boxed in the tiny circular planter

Source: C.Y. Jim 2019


Large tree with roots jailed in tiny and shallow planter
Source: C.Y. Jim 2019


Large tree with roots squeezed into the very narrow planter
Source: C.Y. Jim 2019


Large tree with dense root system locked in the shallow planter
Source: C.Y. Jim 2019


Large tree imprisoned in a tiny pit at a large and paved site
Source: C.Y. Jim 2019

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Very shallow root growth due to poorly drained soil
Source: C.Y. Jim 2019


Shallow, coarse-texture and gravelly soil
Source: C.Y. Jim 2019


Heavily compacted and very poor soil in the planter
Source: C.Y. Jim 2019


Planter filled with soil composed of coarse and loose sand and gravles with little organic matter
2018-9-17 11:53
Source: C.Y. Jim 2019

Planting site filled with loose, sandy amd stony soil with poor structure and meagre organic matter

Source: C.Y. Jim 2019

Very poor soil composed of largely compacted construction rubbles

Source: C.Y. Jim 2019


Tree pit covered by a surface layer of concrete
Source: C.Y. Jim 2019

Tree pit fill with a layer of concrete near the surface

Source: C.Y. Jim 2019

Tree planted in soil of merely a few cm in depth


Source: C.Y. Jim 2019

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Large tree with roots repeatedly damaged and cut by adjacent trenching and road works


Source: C.Y. Jim 2019


Source: C.Y. Jim 2019

Roots entangled with and constrained by the tree grille

Source: C.Y. Jim 2019


Large tree girdled by the metal ring of the tiny tree pit
Source: C.Y. Jim 2019


Slope stabilization work resulting in soil compaction and shotcrete sealing
Source: C.Y. Jim 2019


Slope stabilization work harming existing roots and limiting new root growth
Source: C.Y. Jim 2019

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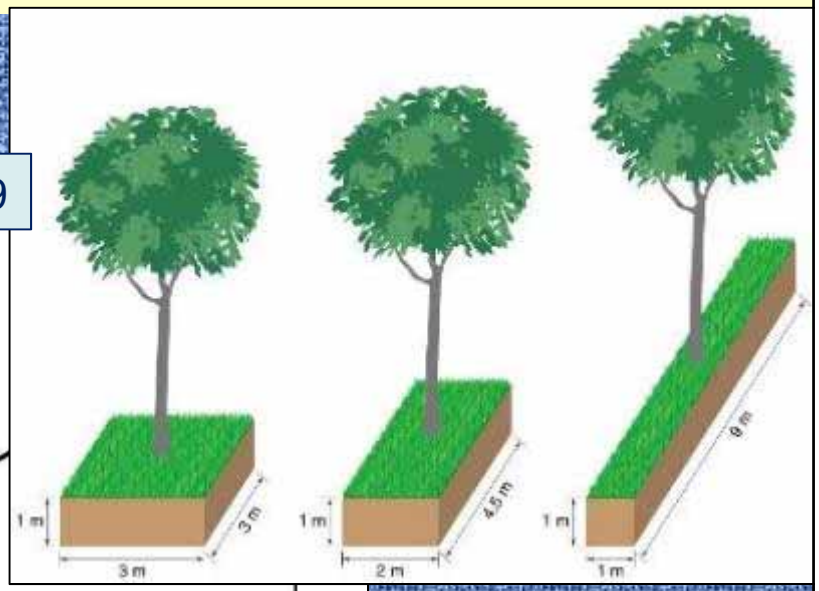
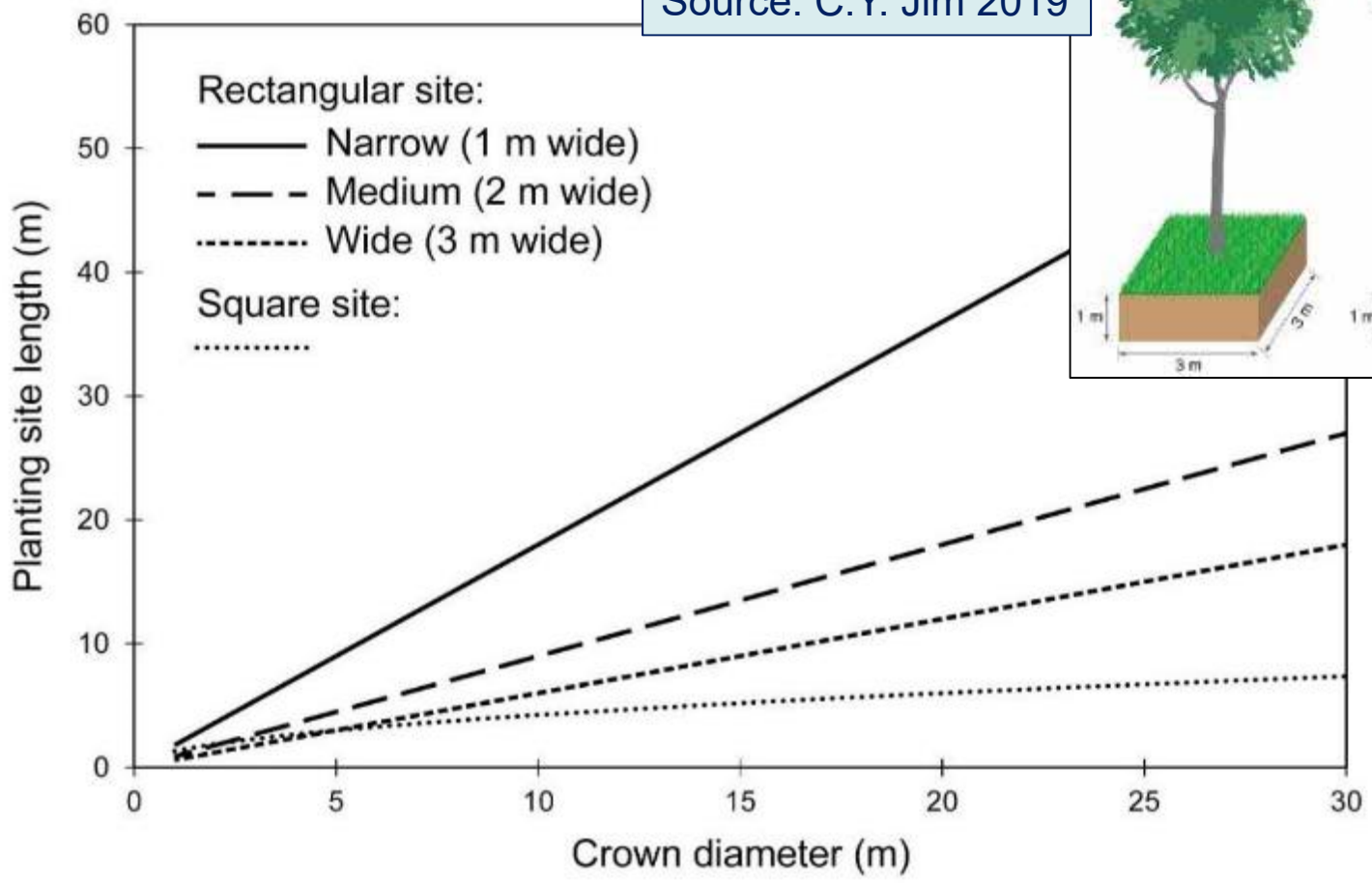
# Soil area provision (SAP) reckoned by crown diameter

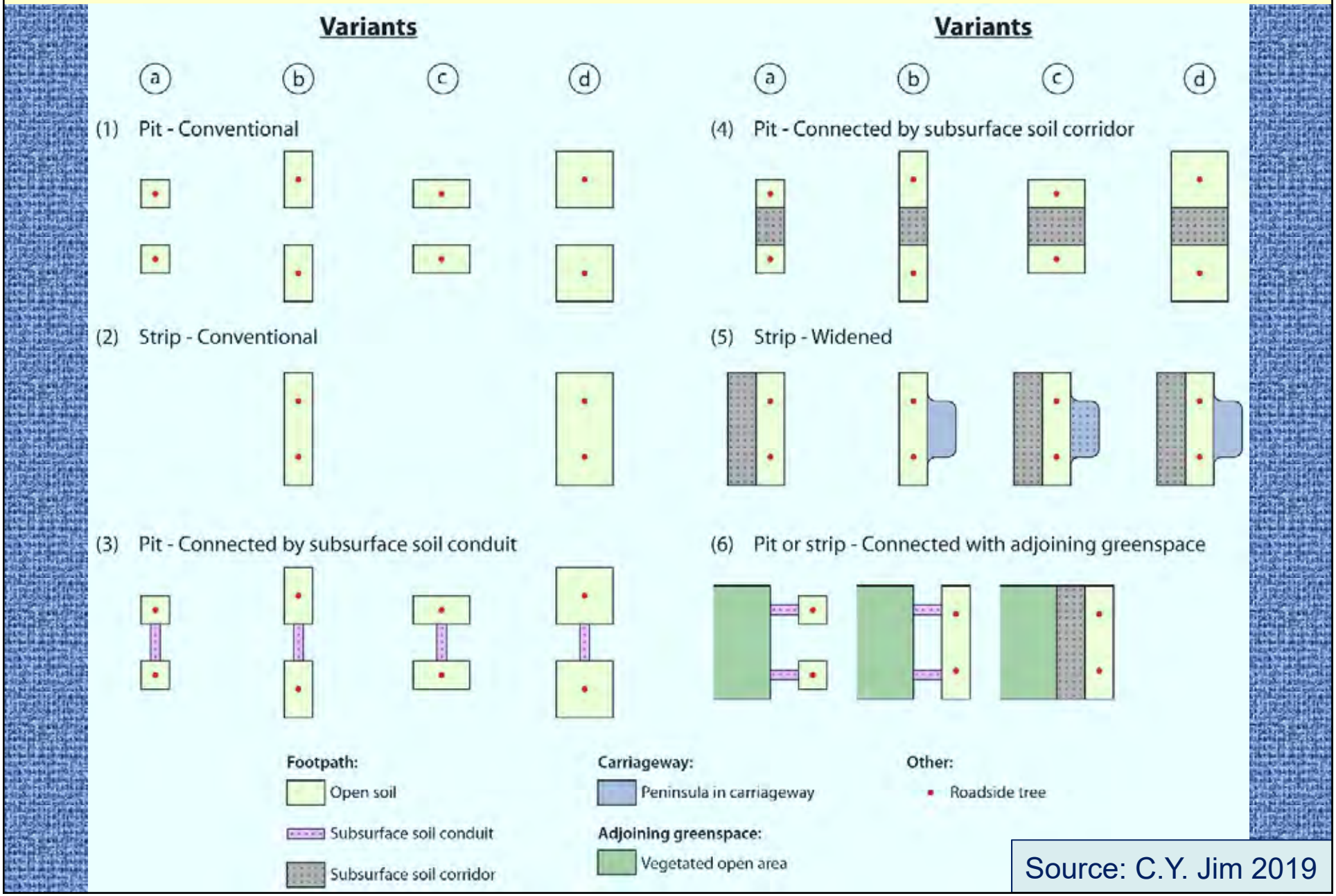
Source: C.Y. Jim 2019



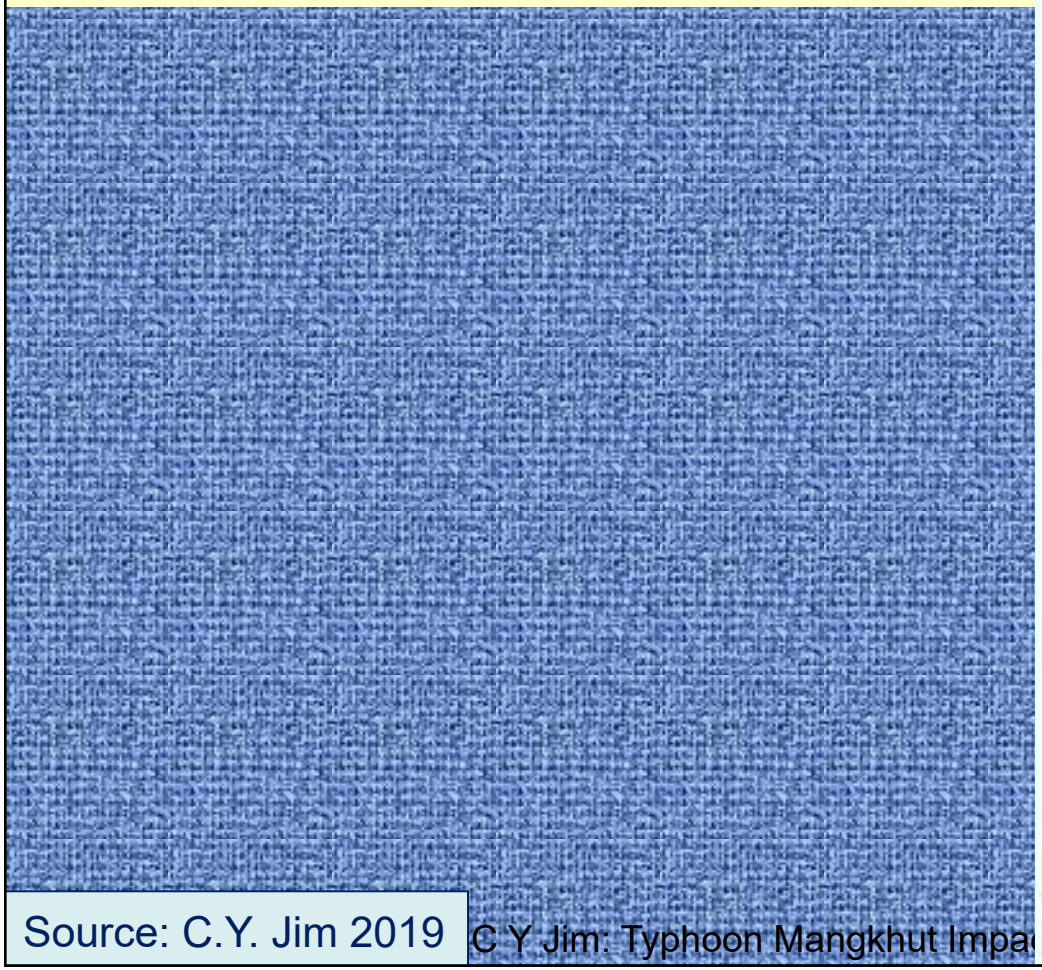

1 m crown diameter requires 1.8 $m^3$ soil volume
or 1.8 $m^2$ of soil area with 1 m soil depth

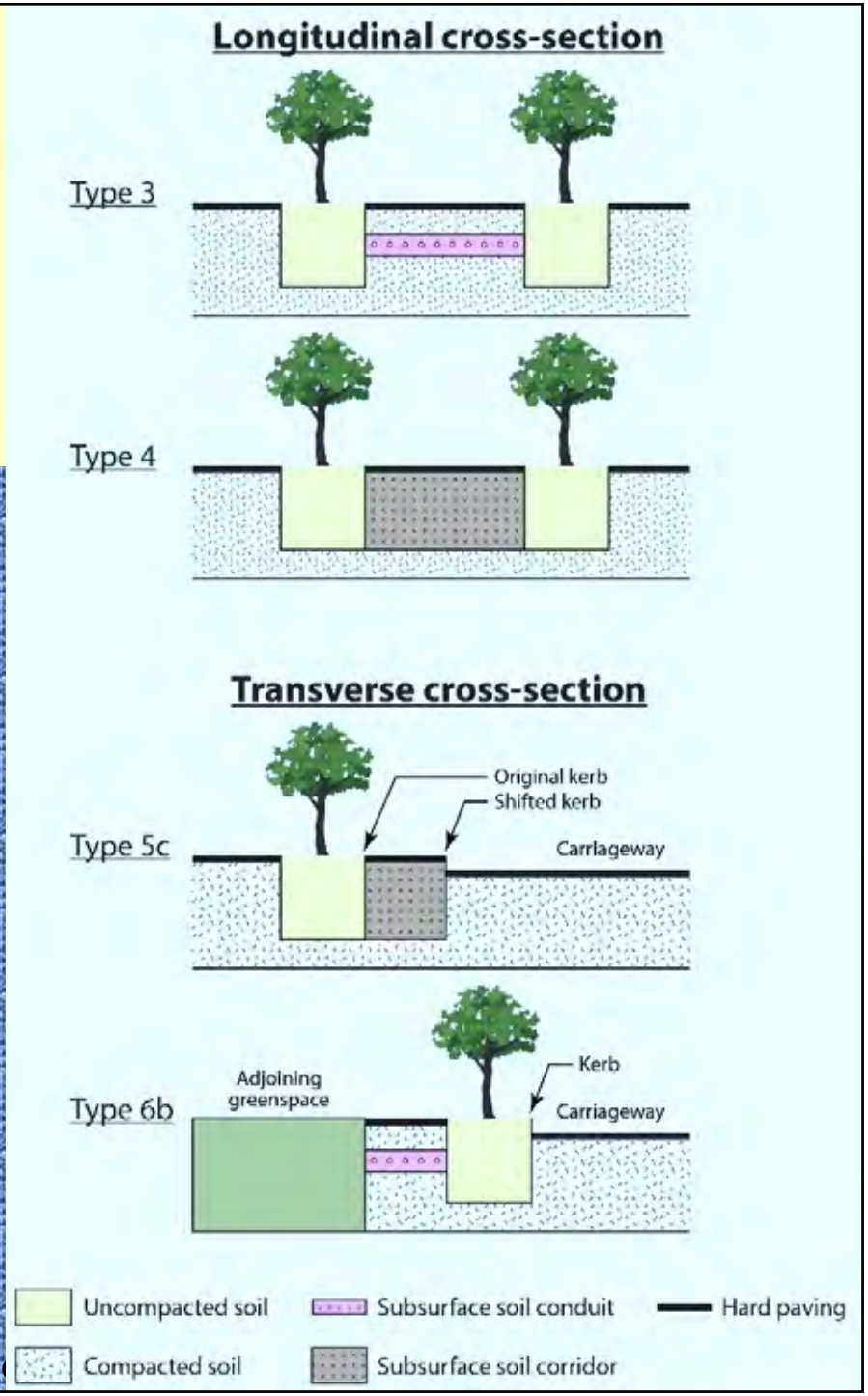
# Strategies for roadside soil volume extension




Source: C.Y. Jim 2019

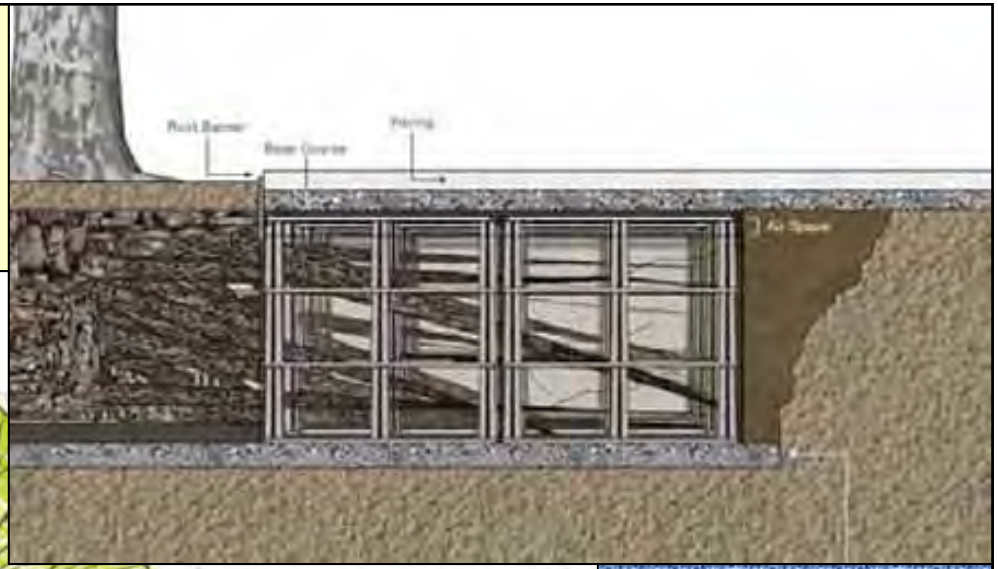
# Strategies for roadside soil volume extension: Soil connectors






Source: C.Y. Jim 2019

# Suspended paving: Soil and root spread



Structural Cells: DeepRoot Partners L.P
San Francisco, CA

Canopy storm water retention

Canopy evapo-transpiration

**SOIL CONDITIONS**
Diverse, healthy soil biology
High cation (nutrient) exchange capacity
High water holding capacity
Organic replacement
Low Compaction

Water harvest through deck with maximum infiltration and soil porosity

Limited run off

Adequate soil respiration
O2 CO2

Ground water wicking from cell bottom

Good drainage

Designed to meet ASSHTO H-20 Loading.
Air space under deck restores natural soil functions

Space for flare and large roots

**LARGE CANOPY**
**Long life cycle**

**LARGE HORIZONTAL ROOT SYSTEM**

Surface absorbing

See page 4

Thank You
Comments and Questions are Welcome