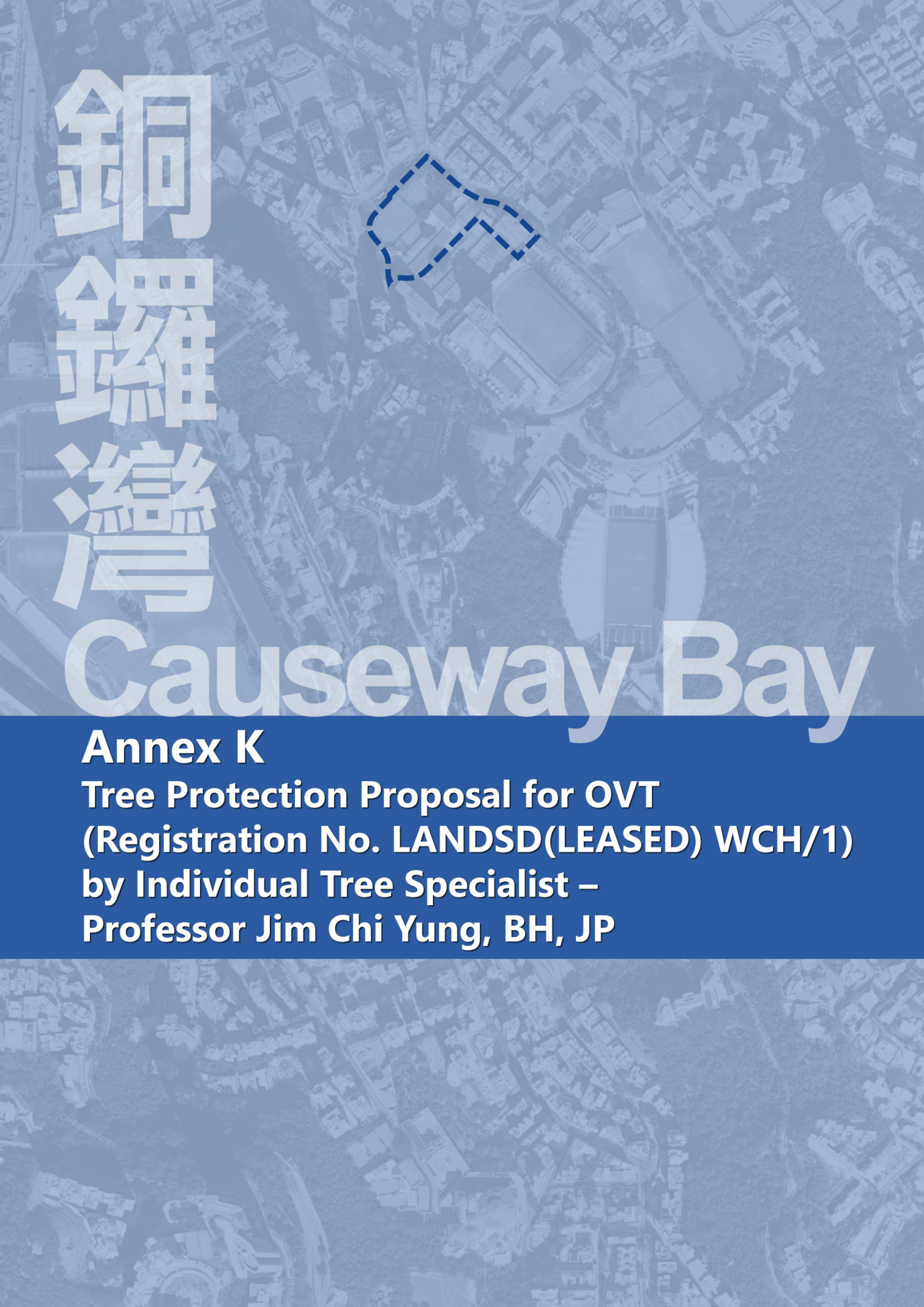


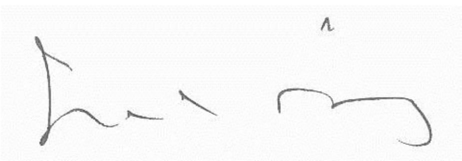
銅鑼灣 Causeway Bay

Annex K

Tree Protection Proposal for OVT (Registration No. LANDSD(LEASED) WCH/1) by Individual Tree Specialist – Professor Jim Chi Yung, BH, JP

A new lease of life for OVT WCH/1 in the commercial development on IL No. 8945, Causeway Bay, Hong Kong

Report text
Accompanied by a PowerPoint presentation with 36 slides



Prepared by Professor C.Y. Jim
Independent Tree Expert
27 August 2025

A new lease of life for OVT WCH/1 in the commercial development on IL No. 8945, Causeway Bay, Hong Kong

1. Introduction

The site at IL No. 8945 ("Project") for a commercial development includes a tree protection clause in the land lease. A large Old and Valuable Tree (OVT) at the front of Leighton Road is required to be protected. A Pink Hatched Green Area (PHGA) has been demarcated on a map in the lease document, which coincides with a Tree Protection Zone (TPZ) defined by the tree's dripline but minus the part hanging above the Leighton Road outside the site boundary.

The land lease stipulates protection of the TPZ, which is a roughly semi-circular area of about 555 m^2 inside the Project site. The Client wishes to include a southern part of the TPZ area in a Banyan Plaza, which will provide a rare town square in the busy commercial district of Causeway Bay. Its implementation requires a level change in a portion of the TPZ. Accordingly, an alternative tree protection-cum-rehabilitation scheme ("Scheme") that diverged from existing thinking was developed to find a win-win solution.

The Scheme is based on the present OVT's declining growth and inordinately poor site conditions, and a dim prognosis of its performance in the next few decades. The most restrictive tree growth factor is the severe shortage of open soil area, lack of good quality soil, and the extensive proportion of the TPZ dominated by highly compacted soil sealed by impermeable paving. The Scheme attempts to resolve these apparently intractable tree-growth impediments by improving the soil area, volume, and quality to trigger a new lease of life to the declining tree. It offers a co-use of a portion of the TPZ land, with the surface for Plaza and the underlying space for soft landscape in the form of high-quality and uncompacted soil to optimise tree root growth.

With reference to implementing the Scheme, the Independent Tree Expert (ITE) is expected to help the Client regarding:

(1) Leading the project's landscape team to prepare the manual for the post-construction maintenance of the OVT, which includes a maintenance schedule.
(2) Helping the Client to scrutinise the credentials and experience of a Qualified Professional who will shoulder the duties of monitoring and supervising the works associated with the OVT for effective implementation of the Scheme on site in accordance with the design and method statements.
(3) Advising the Qualified Professional in preparing the quarterly reports on the OVT, which should include photo records for the site works affecting the OVT, to be submitted to the Lands Department.

2. Tree performance and prognosis

2.1. OVT growth and tree form

The OVT, labelled WCH/1 in the government's OVT Register, is a large Indian Rubber Tree (*Ficus elastica*) that has dwelt at the roadside site at Leighton Road for about eight decades. Instead of developing a normal rounded crown in vertical projection, it has formed an unnatural oval shape with the major axis aligned with the road (Slide 1). The crown measures 44 m by 26.4 m, covering 912 m^2.

Old photographs of Leighton Road were mined from Google Maps to assess the tree's growth in recent decades. The oldest available photograph was recorded in May 2009, which was compared with the latest one dated February 2024 (Slide 2). The images indicate that the tree's growth has reached a ceiling and has hardly expanded in 15 years. The stagnated development could be attributed to the extremely confined and harsh growth conditions. The struggling tree may have exhausted the limited soil potential of the constrained site, resulting in stagnated growth.

Examination of recent photographs signifies tree decline. A large proportion of the Google Street View frontal photographs are of poor quality, which cannot be used for visual tree assessment. Two images with better quality were extracted to compare recent tree performance between May 2019 and February 2024 (Slide 3). They show that the OVT has demonstrated symptoms of decline, indicated by a reduction in foliage density. The tree is suffering from the brown root rot disease. The moth attack in June 2024 has caused complete defoliation, which has mobilized its food reserve stored in large stems and roots to develop a new crop of leaves.

The food reserve of a large tree has a limited capacity, especially for an emaciated tree. Even for a relatively healthy tree, recovering from three major defoliation events is the upper limit. The OVT may not have the capability to tackle another episode of a major pest or disease attack. In other words, the next drastic attack may considerably weaken the tree and push it further down the decline spiral to lapse into the irreversible state. If the reserve is too meagre or the natural enemy assault is too severe, it may kill the tree. In sum, the present quite fresh green leaves on the OVT should not be interpreted as a sign of good health. It should only be construed as the fresh green colour of new leaves. Something must be done to prevent further drastic pest infestation to avoid this latent threat. The tree management and treatment must include measures to rehabilitate its health to strengthen its ability to resist or pest pathogenic incursions and restock its food reserve. This rehabilitation exercise must be implemented at an early opportunity before the tree declines to an irreversible stage.

The tree's crown development is pronouncedly asymmetrical in the north-south direction along the minor axis of oval shape. Excluding the 3.5 m width of supports provided by the Existing tree strip, the crown spread was measured from a vertical aerial photograph (Slide 4). The north crown labelled the Road side is shorter at 8.8 m or 38.4% of the weight. The south crown labelled the Plaza side is notably longer at 14.1 m or 61.6% of the weight. This gross imbalance in crown weight distribution imposes a stress on the tree's supporting system, composed of a main trunk plus many root stands that serve as secondary trunks. With a long cantilever length, the south crown is prone to fork failure and branch breakage. This part of the tree will hang above the proposed Plaza, which will attract heavy patronage, especially on weekends and holidays. It is pertinent to do something in advance to abate this potential hazard. Additional support is required on the south side to prop the extended south crown. This is especially indispensable given that the tree is suffering from the debilitating brown root rot disease.

2.2. Existing soil conditions and root growth limitations

The OVT's growing site demonstrates the grave soil constraints faced by many urban trees in Hong Kong. The only open soil area supporting tree growth is a narrow Existing tree strip at merely 3.5 m wide (Slide 3). Moreover, the soil is lifted above the adjoining road surface at +6.0 mPD, with the linear soil body supported by a low masonry retaining wall. To its north is the completely paved road with no possibility of root extension.

To its south is a completely paved sports ground at an elevated level of about +9.6 mPD. The soil underneath the hard and impermeable paving is heavily compacted with limited porosity, water and nutrients, hence it is unsuitable for root growth. A few roots may have ventured sporadically into this soil through the occasional crevices in the soil body. Otherwise, most of OVT's roots are growing at a high density in the Existing soil strip. As the soil in this confined strip has a sloping surface, the material is likely to have been somewhat compacted to a medium level with reduced porosity. It is amenable to root growth, but cannot be regarded as a good soil.

The sizeable Indian Rubber Tree has vividly displayed the banyan character of the species. It develops two kinds of roots, namely the normal subterranean roots and soft aerial roots that can become woody root stands. This OVT sent many aerial roots downward to reach the soil in the Existing tree strip. Thereafter, they lignified into root stands, which tend to be inosculated (fusion of adjoining woody tissue) with adjacent root stands to form a compact supporting complex (Slide 5). The supplementary woody columns have allowed the tree to extend eastward and westward along the narrow Existing tree strip to prop branches to form an unusually broad oval tree crown covering 44 m.

The root stands are so densely developed that they form an impenetrable mass, maximizing the use of the limited open soil area (Slides 5 and 6). They are literally making use of every inch of the tree strip to develop root stands. A very narrow metal receptacle installed about two decades ago has been filled with root stands (Slide 7). These visual clues send clear body language to tree assessors that the tree has exhausted the capacity of the limited soil width for root stand growth and is crying out for help to provide additional soil area. The present soil constraint has evidently stressed the tree and imposed a lid on its further growth (cf. Section 2.1, second paragraph). In response, some measures should be applied to free the tree from the stifling soil bondage.

2.3. Urgent need to offer a new lease of life to the stifled OVT

OVTs in other places are often given special treatments to help their growth. For precious old but declining trees, specially designed measures have been developed to rehabilitate them. Amongst various techniques, soil improvement and replacement have been adopted to revive trees in distress (Slide 8). Such high-order arboricultural practices have been recorded in different parts of China (e.g., Slide 9) and other countries (e.g., Slide 10). In some enlightened urban tree management cases, the poor soil of an entire street can be replaced by good soil to foster tree performance in a holistic and long-term manner (e.g., Slide 11).

Such soil treatments are applied in response to the degraded soil conditions that have chronically weakened the victim trees. The soil quality can be upgraded by various means, such as removing the impermeable paving, loosening the soil, adding organic amendments or fertilizers, inserting pipes filled with porous soil, and opening trenches filled with good soil. The package of restorative approaches should be tailor-made to the specific soil limitations. If the *in-situ* soil condition is too poor to be rectified, the entire soil volume under the tree crown can be replaced with a well-prepared fabricated soil mix (FSM).

The subject OVT has been severely constrained by the soil limitation for about eight decades. The poor tree has exhausted the limited site potential and displayed stagnated growth. The recent attacks by the brown root rot disease and moth have triggered tree decline. The enfeebled tree will be less able to resist or tolerate future attack by natural enemies. It may become more susceptible to invasion by wood-decay fungi to weaken its structure and increasing the risk of branch breakage. The asymmetrical crown and uneven weight distribution present a risk of branch failure for the users of the Plaza, which is expected to be heavily patronised. If tree protection follows the passive approach by keeping the *status quo*, the tree may continue to decline.

To our understanding, the key objective of preserving an OVT is to ensure that the meritorious tree will remain strong, stable and safe for some years to come. It is expected to continue to contribute to ecological, environmental, landscape and socioeconomic functions to embellish the site and its environs. Some innovative and proactive measures can be applied to help the tree regain its health and continue to perform for many years to come.

3. Proposed OVT protection-cum-rehabilitation scheme

3.1. Site demarcation into three soil-rooting zones

The soil improvement methods are based firmly on recent tree and soil science research. They include the application of recent soil science research findings to urban tree management (Slide 12); the need to expand and connect soil bodies to improve urban tree growth (Slide 13); the application of urban soil science to landscape architecture practice (Slide 14): and enlisting the deep research results on heritage trees to improve their long-term health and safety (Slide 15).

Adhering to the fundamental principle of OVT conservation, a tailor-made protection-cum-rehabilitation scheme ("Scheme") was developed to fit the purpose of the project. Special measures were custom-designed catering to the OVT's specific site and tree conditions and projected use of the site. Starting with the current state of a semi-circular area sealed by impermeable hard paving and underlain by poor-quality compacted soil, the Scheme proposes a tripartite division of the site into three soil-rooting zones (Slide 16). Each zone will receive different treatments to maximise its capability to improve the OVT's growth in the long run. The pertinent objective is to transform a routine OVT protection scheme to an innovative OVT protection-cum-rehabilitation joint scheme, expanding the vista of tree protection to cover the realm of rehabilitation. The growth of the champion tree should be accompanied by champion-quality soil. The soil must be rootable rather than just any residual poor-quality material.

By expanding the rootable soil area by over four times compared with the present state and also improving the soil quality, our Scheme aims squarely at providing a new lease of life to the declining tree. Adding Zones 2 and 3 will considerably increase the OVT's rootable soil area (Slide 16) by connecting the soil in contiguous zones (Slide 17). Therefore, the development project offers a rare opportunity, once in a century, to revive the old tree. A condensed outline of the three zones is given below. Details are explained in the following subsections. Cross sections of the rootable-soil zones are depicted in Slides 18 and 19.

(1) *Zone 1 Existing tree strip*: The 3.5 m wide and 170 m^2 soil area with massive subterranean roots and root stands will be left undisturbed.
(2) *Zone 2 New tree strip*: This is a new planting area that measures 5.7 m wide and 270 m^2 soil area will be transformed from the previous paved sports ground to open soil with soil enhancement treatments and root preservation.
(3) *Zone 3 New soil crescent*: This segment has a maximum width of 9.8 m and a 285 m^2 soil area. We propose to replace the compacted low-quality site soil with a high-quality uncompacted fabricated soil mix. Due to overlapping with the proposed Plaza, it is designed for the co-use of the precious land resource to create a win-win scenario. The modern soil cell technique will be adopted to build a suspended pavement and hold the rootable soil below it.

3.2. Designing a rooting highway traversing the three soil-rooting zones

The Scheme is not just providing good soil for root development in the soil-rooting zones. It aims at applying the principle of soil contiguity and continuity to foster tree root growth in confined urban sites (Slide 17). In this enlightened urban forestry practice, a tree planting site with a limited soil volume can be connected to an adjacent or nearby site and borrow the soil for root development.

The crux of the proposed design is to connect the soil in the three soil-rooting zones so that they provide an uninterrupted *rooting highway* for the OVT's roots to grow from the Existing tree strip into the New tree strip, and then into the New soil crescent (Slides 18 and 19). This soil continuity brings a substantially enlarged rootable soil catchment. Using the Existing tree strip as the basis, the open soil area will be increased from 19% to 49%, and the total rootable soil area from 19% to 80% (Slide 16). This approach denotes the most optimal way to meet the soil needs of the large old tree.

The substantial rootable soil refurbishment is tantamount to returning the entire tree protection zone (TPZ) inside the development site to the OVT's root development. It should be noted that on the Road side, this soil refurbishment is not possible. This continuous soil body traversing the three zones is envisaged to provide a lot more water, nutrients and strengthen its root anchorage to raise tree stability and safety. The soil improvement and replacement will ensure that the roots will grow liberally in the zones. The tree will have the chance to rejuvenate.

It is necessary to build a new balustrade to stop visitors from moving into the New and Existing tree strips because of the hazard of people falling down to the Leighton Road level (Slides 18 and 19). The balustrades are anchored and stabilized by a series of balustrade footings. The size, shape and thickness of the reinforced concrete footings are designed according to relevant building regulations. They will be installed along the southern edge of the New tree strip. Each balustrade footing will support a post. The posts will support a beam that runs above the new ground surface. The new balustrade will then be built on the beam. The balustrade footing design has been adjusted to minimise the blockage of root passage from the New tree strip into the New soil crescent. The finely adjusted design only blocks 6.4% of the circa 44 m length of the interface (Slide 18). Between the balustrade footings, the rooting highway will not encounter any obstruction (Slide 19).

3.3. Minimising excavation influence on roots

The New tree strip shall be divided into a 3.5-m-wide north belt and a 2.2-m-wide south belt (Slides 18 and 19). They shall receive different soil treatments, after which both belts will receive the same improvements. The original soil and embodied roots in the northern belt will be kept intact. A small amount of fabricated soil mix will be added to replace the space vacated by the paving removal (area A marked on Slide 18). The southern belt will be excavated to install the balustrade footings. On the four sides of each balustrade footing, the site soil will be excavated to form safe and stable 30-degree slopes. To reduce impacts on preserved roots and soil, the reinforced concrete balustrade footings and associated posts and beams shall be considered for prefabrication in a factory and transported to the site for installation. The dimensions of the balustrade footings will be reviewed in detail design stage, and the technical design submission will be submitted to related government departments in due course.

The excavation will affect the few roots in the New tree strip and the New soil crescent. Measures are proposed to preserve and minimise disturbing the roots there. The excavation exercise will be conducted in four phases, to be separated by a three-week recuperation period to allow the tree to adapt to the root disturbance (Slide 20). It will proceed in sequence as AA, BB, and CC pairs on the two sides of the strip. Finally, segment D will be excavated. The excavation segments shall correspond to the balustrade footings. The sequence is based on the assumption that fewer roots are found on the two sides and more in the central portion. The roots at the interface of the two zones will be carefully cut using a clean arborist secateur or saw.

In the course of excavation in the southern belt of the New tree strip, special precautions are proposed to preserve roots with >10 mm diameter (Slide 21). The target roots encountered during excavation will be carefully lowered onto the 30-degree slope surface. They will be covered by four layers of hessian and kept moist at all times. No human traffic, building materials or construction machines or tools shall be allowed to contact these preserved roots covered by hessian. A prominent cordon shall be established around the preserved roots to exclude disturbances. As soon as the completion of the balustrade footing, the hessian shall be removed, and the fabricated soil mix shall be refilled to the finished sloping surface and irrigated to nurture these salvaged roots.

On the Road side, the subterranean roots and masses of root stands in the Existing tree strip will not be disturbed (Slide 25). As the principal source of anchorage and support, they will continue to hold the OVT. On the Plaza side, the 5.7 m wide New tree strip will preserve the small number of existing roots growing in the compacted soil. The Scheme will bring a broadened rectangular rootable soil of 9.2 m width (3.5 m Existing tree strip plus 5.7 m New tree strip) and about 44 m length, offering circa 405 m^2 of open (unsealed) soil for root development. This area is equivalent to about 70% of the OVT's crown area on the Plaza side. In other words, this expanded rootable soil body can hold about 70% of the OVT's root system, because of the absence of rootable soil on the Road side. Moreover, this rootable soil volume is proximal to the tree trunk, and therefore accommodates most of the structural roots and the thickest roots that contribute to anchorage. The roots that will be removed in the New soil crescent are situated farther away from the trunk and therefore contain few structural roots. If present, they are likely to be thinner and much less important for tree anchorage. Therefore, it is envisaged that the OVT will remain stable despite the soil treatments.

With the removal of the impermeable paving and improvement of soil properties in the New tree strip, a significant amount of new subterranean roots and new root stands will develop in due course to further strengthen the tree's anchorage. The provision of good quality and uncompacted soil in the New soil crescent adds a considerable soil volume to rehabilitate the OVT. In the long run, the tree's health and stability are expected to be enhanced. The OVT is suffering from Brown Root Rot disease, which may aggravate to compromise the mechanical strength of the preserved roots in the Existing and New tree strips. The OVT's condition will be continually monitored to evaluate whether cabling is necessary at a later stage.

3.4. Soil enhancement treatments in the New tree strip

The New tree strip shall receive two special soil treatments to enhance its ability to support root growth. They include installing vertical mulching holes and lateral root paths. The former enhances the drainage and aeration of the compacted soil formerly sitting below the concrete paving. The added high-quality soil also raises the water and nutrient capacities of the soil. The latter provides root-friendly paths to foster and guide root growth through the new tree strip into the New soil crescent. They can significantly increase the rootable soil volume of the site and, in turn, improve the performance of the OVT.

The designated positions and orientations of these two soil improvement features are depicted in Slide 22. Eighteen vertical mulching holes will be opened at the proposed locations. The holes are 10 cm diameter, 70 cm deep and inclined at 20 degrees towards the New soil crescent. The lateral root paths are 15 cm wide, 70 cm deep in the form of vertical trenches oriented perpendicular to the long axis of the tree strip. An example of vertical mulching is shown in Slide 23, and an example of rooting trenches in Slide 24.

3.5. Innovative nurturing of sturdy root stands in the New tree strip

The New tree strip will provide excellent opportunities for the OVT to thrive. The notably enlarged open soil area and soil improvements will permit a significantly expanded root system to absorb a lot more water and nutrients to support its vigorous growth and develop new root stands to prop its enlarged crown.

The new root stands that will grow in the New tree strip will provide essential reinforcement to the large tree’s support system. It will shorten the branch cantilever on the Plaza side from 14.1 m to 9.8 m (compare Slide 25 with Slide 4). The notional weights of the north and south crowns will become 47.3% versus 52.7%, providing a far more balanced crown. This is a critical tree stabilization measure that will reduce the hazard of branch failure to the plaza users. The new root stands will also augment the ability of the tree to prop up its rather heavy and sprawling crown. The root stands, upon reaching the open soil, will send out many normal subterranean roots to significantly increase the tree’s soil catchment area. A lot more water and nutrients will be captured by the enhanced root system, raising photosynthetic capacity and food production and replenishing the depleted food storage.

The root stand development in the New tree strip can be moulded by skilful adjustment of aerial root growth locations and directions. The new aerial roots are soft and pliable. They are proposed to be guided to form two or three-dimensional complex root stands with a higher mechanical strength and load-bearing capacity (Slide 26). By applying the science of the banyan growth habit, instead of the routine single pole configuration, they can be steered to form an A-frame and tripod to support large branches and a flying buttress or compound buttress to support the main trunk or thickened secondary trunks. These lignified and inosculated root stands will provide sturdier and more assured supplementary support to the OVT.

3.6. Soil replacement at the New soil crescent

The New soil crescent (demarcated in Slides 16 and 18) is designed for soil replacement. A new fabricated soil mix will replace the existing low-quality and heavily compacted site soil. In this way, the current paved area with few roots growing in the compacted soil will be converted into an area with uncompacted and excellent soil to foster root growth.

The land area of the New soil crescent will be shared by dual uses, namely the Plaza and the soil to support root growth. Three methods are available to support suspended paving and allow rootable soil to be placed below it (Slide 27). This Scheme adopts the modern soil cell technique. The load of the paving and pedestrians will be transmitted via the soil cell framework to the bottom subgrade layer. Some examples of soil cell materials and configurations are shown in Slides 28 and 29, including cases where a high load-bearing capacity is required for road use.

A schematic section of the soil cell design is depicted in Slide 30. A strong open capping board can be placed on the top of the soil cell to form a base to deposit the subbase material. The firm and stable subbase can then support the new paving slabs. The paving slabs will be designed with gaps or holes to allow entry of water and air into the soil underneath.

The existing paving and soil will be removed down to +8.1 mPD (Slides 18 and 19). The base will be compacted to support soil cells, which in turn will support the hard paving. A 600 mm layer of high-quality fabricated soil mix will fill the interstices of the soil cells. The OVT's roots can travel from the two tree strips to enter the New soil crescent. Thus, the soil under the entire area of the New soil crescent, amounting to 285 m^2, does not need to be compacted at all. This excellent growth medium shall permit vigorous and abundant root growth from the OVT. Many new roots generated at the New tree strip will extend into and ramify liberally in the New soil crescent.

3.7. Synopsis of notable soil improvements

The wide range of soil improvements to enhance future OVT growth can be comprehended by comparing the present and future soil attributes, i.e., before or after beneficial soil treatments (Slide 31). The 175 m^2 Existing tree strip will be kept undisturbed, hence the original unsealed soil will remain medium in rating with reference to compaction, porosity, and root density, and harbouring plenty of root stands.

The New tree strip will witness significant and lasting improvements in soil quality. This zone offers 270 m^2 of open soil to increase the rootable soil area by 154%. The transformation will change the land cover from sealed to open to permit free infiltration of water and air into the soil and unobstructed development of new root stands in a mode similar to the Existing tree strip. Soil compaction will be relieved by vertical mulching holes and lateral root paths. With the addition of an excellent fabricated soil mix, the soil quality will be lifted from poor to good. More importantly, soil porosity will be considerably enhanced, with conversion from low to high porosity at the improved locations and in the newly added soil mix. Root density is expected to rise from the present meagre to a medium level. Root stands will shift from none at present to plenty.

The soil at the New soil crescent, covering 285 m^2 and adding 163% of rootable soil area compared with the Existing tree strip, will be completely replaced. The existing poor-quality site soil, beset by heavy compaction, high stone content, little organic matter and plant nutrients, is unsuitable for root growth. This in situ soil will be completely removed, and the vacated site will be filled with a high-quality and uncompacted FSM. The originally sealed area will be converted to new paving slabs that allow entry of water and air into the new soil. The soil compaction status will be transformed from heavy compaction to uncompacted. Soil quality in general will change from poor to excellent. Soil porosity will be raised from the present low level to a high level typical of the best soil for plant growth. Root density is anticipated to shift from the present trace to the future high level. As this site will be paved, it is not designed for root stand development.

The soil that will fill the New soil crescent will be the highest quality among the three soil-rooting zones. It will serve as a main source of water and nutrient supply to boost the OVT's future performance. The best practice high-quality fabricated soil mix based on my research findings (Slide 32) will be applied (cf. Section 4 for its specification).

The most critical attribute that is gravely inadequate in urban planting sites is soil porosity. The improvement in terms of equivalent porosity and equivalent rootable soil area has been calculated (Slide 33) based on my recent research findings (Slide 34). The New tree strip is envisaged to bring an additional 192% of new soil porosity to root growth, and the New soil crescent will bring an additional 185%. They represent plenty of pore openings in the soil to allow water and air infiltration and transmission, storage and release of plant-available nutrients, and unimpeded drainage and aeration. These essential attributes for root growth will be instrumental in boosting the OVT's vigour and vitality.

Overall, the 555 m^2 TPZ will be divided into two zones. As much as 48.6% of the TPZ will be designated for the OVT's exclusive use in the New tree strip, which will not allow visitor access. Only the remaining 51.4% will be allocated for the New soil crescent for joint use by the Plaza and the OVT.

3.8. Proposed implementation strategy for the Scheme

The Scheme involves a series of steps that can be scheduled logically to deliver a smooth implementation. The following sequence is proposed together with the critical stages at which the ITE will inspect the site and the associated works:

(1) Removing the hard paving and subbase in the New tree strip and the northern circa 2.5 m belt of the New soil crescent. *[ITE site inspection of the paving removal step at the New tree strip]*

(2) Excavating in four sequential phases to install the balustrade footings by forming 30-degree cut slopes around them.

(3) Preserving roots exposed in excavating the southern belt of the New tree strip by resting them on the 30-degree cut slope.

(4) Cutting roots at the interface between the New tree strip and the New soil crescent. *[ITE site inspection of the root cutting work]*

(5) Installing the balustrade footings and associated posts and the above-ground beam.

(6) Ordering the fabricated soil mix (FSM) in advance according to specifications (Section 4) and arrange for in-time delivery.

(7) Ordering bark mulch materials inoculated with *Trichoderma*.

(8) Ordering the modular soil cell system with the required load-bearing capacity and height to hold a 600 mm deep soil layer, and arrange for in-time delivery.

(9) Ordering the paving slabs to pave the New soil crescent area, with connection details to allow entry of water and air into the new soil, to be equipped with a removable design.

(10) Filling the northern belt of the New tree strip with FSM to the finished sloping level, to be slightly tamped to a dry bulk density of about 1.3 Mg/m^3. *[ITE site inspection before backfilling the New tree strip with FSM]*

(11) Refilling with FSM the excavated southern belt of the New tree strip to the finished sloping level and restoring the preserved root to their approximate original positions, to be slightly tamped to a dry bulk density of about 1.3 Mg/m^3.

(12) Removing the hard paving and subbase in the remaining part of the New soil crescent.

(13) Removing the site soil in the New soil crescent down to circa +8.1 mPD.

(14) Compacting the bottom of the New soil crescent area to a prescribed maximum dry density that can support the load of the soil cells and the paving to create a flat finished base at +8.1 mPD. *[ITE site inspection before installing the soil cells]*

(15) Installing the soil cells to fill the New soil crescent area.

(16) Filling the interstices of the soil cells with FSM, to be slightly tamped to a dry bulk density of about 1.3 Mg/m^3.

(17) Inserting the load-bearing soil cell cap with the required load-bearing capacity.

(18) Laying the geotextile sheet on the soil cell cap.

(19) Installing the porous subbase.

(20) Installing the paving slab.

(21) Installing the automatic drip irrigation system for the New tree strip.

(22) Producing the final version of the post-construction OVT maintenance manual, which includes a maintenance schedule.

4. Preparation of the high-quality fabricated soil mix (FSM)

The proposed New tree strip and New soil crescent offer wonderful opportunities to improve the soil quality and volume for the OVT. It is essential to ensure that the best soil specifications and designs are prescribed to offer a new lease of life for the trapped large tree. The proposed fabricated soil mix (FSM) has been specially designed to provide optimal physical, chemical and biological properties to foster root growth. It makes use of locally available mineral materials, the completely decomposed granite (CDG) and mature organic compost (MOC) to prepare the mix.

4.1. Specifying the FSM

(1) The surface layer of the new tree strip and the entire soil replacement portion of the new soil crescent shall be filled by a high-quality soil layer analogous to the topsoil in

mature natural tropical forests, characterised by organic matter enrichment and sufficient nutrient reserve.

(2) The FSM, composed of two ingredients, shall be prepared: completely decomposed granite (CDG) and mature organic compost (MOC). Please refer to Sections 4.2 and 4.3 for the specifications for these two key ingredients.

(3) The two ingredients shall be mixed thoroughly off-site with a mechanical rotary mixer in an 80:20 v/v ratio. Mixing shall only be conducted when the constituent materials are in the air-dry moisture state.

(4) If stockpiling is necessary after mixing, waterproof covers shall protect the material from the elements. Do not allow the prepared FSM mixture to be stockpiled for over five days. It should be applied to the landscaping sites as soon as possible.

(5) The FSM shall have a good soil structure that can supply a balanced distribution of macropores, mesopores and micropores conducive to root growth, with sufficient capacity to hold plant-available moisture and nutrients. It shall also permit unimpeded infiltration of rain and irrigation water to replenish the soil moisture, drain excess water away from the rooting zone, and exchange air between the atmosphere and the soil.

(6) There shall be enough nutrient reserves held in the partly decomposed humic substances of the MOC. Upon decomposition, the MOC will release plant-available nutrients to support tree growth. The organic matter shall have a specified amount of two essential nutrient elements, often in short supply in tropical soil. The MOC shall furnish a sufficient and sustained nitrogen and phosphorus supply.

(4) The FSM shall have the following essential properties that are favourable to tree growth:

(a) Final bulk density after settlement lies in the 1.35 to 1.40 Mg/m^3 range, aiming to supply circa 50% total porosity v/v.

(b) Stone (> 2 mm diameter) content not more than 10% by weight.

(c) Free from stones > 30 mm in diameter.

(d) Sandy loam texture (US Department of Agriculture definition, evenly textured, with no more than 70% (w/w) sand particles (0.05–2.0 mm diameter), and not less than 15% (w/w) clay particles (< 0.002 mm diameter).

(e) Free-flowing, friable, loose, and non-sticky consistency.

(f) Well aggregated with granular and/or fine blocky soil structure class (US Department of Agriculture definition).

(g) Free from impurities and undesirable constituents such as cement, concrete, plaster, brick, asphalt, sticky clay, grasses, weeds, vegetative materials (woody roots and branches), oil, chemical, glass, plastic, paper, waste wood, and other rubbish, artifacts and deleterious substances.

(h) Soil reaction (pH in 1:2.5 soil:water ratio w/w and glass electrode) in the range of 5.5 to 6.5.

(i) Electrical conductivity (1:5 soil:water extract and conductivity meter) not more than 2.0 dS/cm.

(j) Total nitrogen content (Kjeldahl method or equivalent) not less than 2% by weight for topsoil.

(k) Total phosphorus (Perchloric acid digestion and colorimetry) not less than 200 mg/kg for topsoil.

4.2. Specifying ingredient I: Completely decomposed granite (CDG)

(1) Granular, free-flowing, friable and loose consistency.
(2) Free from stones with a diameter >30 mm.
(3) Taken from the upper part of the granite weathering crust, free from unweathered or partly weathered core stones or rock fragments.
(4) Uniform composition for the entire supply batch.
(5) Free of impurities and ingredients harmful to plants, humans or animals.

4.3. Specifying ingredient 2: Mature organic compost (MOC)

(1) Fully mature compost material.
(2) Composed of not less than 90% organic matter.
(3) Uniform and consistent composition for the entire supply.
(4) Granular and free-flowing.
(5) Free from materials containing pathogens or other toxic ingredients known to be detrimental to plants, humans, or animals.
(6) Does not emit toxic or obnoxious fumes.
(7) Free from unpleasant odour.
(8) Does not generate heat that will raise the temperature to >5°C above the ambient air temperature.
(9) With a carbon-nitrogen ratio in the range 25–50.

5. Method statements for soil and root works

5.1. Soil treatments at the northern belt of the New tree strip

(1) The existing impermeable hard paving shall be carefully removed, taking precautions to minimise disturbing the roots and soil lying underneath.

(2) Hand-held manual drilling tools shall be employed to break the hard paving and the underlying compacted subbase layer.

(3) Care should be taken to avoid excessive breaking of the hard paving into too small fragments and fine particles.

(4) The broken paving fragments shall be removed from the soil surface.

(5) The exposed soil shall be scarified manually down to 10 cm with a horticultural rake. Care should be taken not to sever or damage roots with >10 mm diameter.

(6) The exposed soil shall be covered by wet hessian to prevent drying out.

(7) Within two days of completing the above scarification step, the exposed soil shall be covered by FSM to form a finished sloping surface as shown in Slides 18 and 19. The filled soil shall be lightly tamped with a spade to bring a bulk density of about 1.3 Mg/m^3.

(8) Precautions shall be adopted to avert undue compaction and smearing of the FSM during installation.

(9) Within one day of completing the FSM filling, the exposed surface shall be covered by a 5-cm layer of bark mulch to protect the soil from wind and water erosion, stop rain splash structural damage, suppress weed growth, prevent high soil temperature, and conserve soil moisture by suppressing evaporation. The mulch material shall be treated with *Tricoderma* to control the spread of Brown Root Rot disease.

(10) Immediately after completing the above tasks, the soil area shall be cordoned off to prevent unnecessary intrusion by humans, materials, vehicles, and machines.

Special precautions: It is essential to install the FSM promptly after paving removal to avoid the risks of soil degradation and loss during the exposed period. The soil work shall only be conducted on days without rainfall. If the Hong Kong Observatory predicts heavy rain, all soil work shall stop. After rainfall, the soil shall be allowed to shed the excess soil moisture by drainage and evaporation to eliminate the wet soil state. The soil works shall not resume until the site soil has become dry to moist.

5.2. *Soil treatment and root preservation at the southern belt of the New tree strip*

(1) The existing impermeable hard paving shall be carefully removed, taking precautions to minimise disturbing the roots and soil lying underneath.

(2) Hand-held manual drilling tools shall be employed to break the hard paving and the underlying compacted subbase layer.

(3) Once the underlying site soil is exposed, the ensuing excavation shall be conducted with proprietary Air Spade equipment (https://www.airspade.com/) that can remove the mineral particles whilst preserving most of the roots.

(4) Special precautions must be taken to avoid aerial spread of suspended fine soil particles during excavation. The accompanied air suction equipment must be used properly in conjunction with the supersonic pneumatic excavator.

(5) The land surface shall be lowered to form a 30-degree slope to build the balustrade footings as shown in Slides 18 and 19.

(6) To minimise impacts on the OVT, the excavation to build the balustrade footings shall be conducted in four phases as illustrated in Slide 20. A three-week recuperation period shall be inserted between two consecutive phases.

(7) All structural roots >10 cm diameter exposed by the Air Spade excavation must not be cut or harmed. They shall be manually lowered to the rest on the finished 30-degree slope surface, covered by four layers of hessian, which shall be kept continuously moist by water sprays. This procedure is illustrated by Slide 21.

(8) No human traffic, building materials or construction machines or tools shall be allowed to contact the preserved roots covered by hessian.

(9) A prominent cordon shall be established around the excavation area to exclude disturbances.

(10) At the interface of the New tree strip and the New soil crescent, the exposed roots >10 mm diameter shall be cut by a clean and sharp arborist secateur or saw. The cut surface must be perpendicular to the root, flat and smooth. No tissue fraying or tearing shall be permitted. All fresh-cut root surfaces shall immediately be painted with a proprietary arboricultural fungicide.

(11) During the building of the balustrade footings, all exposed soil surfaces shall be shielded by a protective sheet against the elements.

(12) The exposed soil shall be covered by wet hessian to prevent drying out.

(13) Within two days of completing the balustrade footing work, the soil surface layer shall be scarified manually down to 10 cm with a horticultural rake. Care should be taken not to sever or damage roots with >10 mm diameter, and not to disturb the preserved roots.

(14) Within two days of completing the scarification task, FSM shall fill the 30-degree cut slope to a new finished level indicated by Slides 18 and 19. The filled soil shall be lightly tamped with a spade to bring a bulk density of about 1.3 Mg/m^3.

(15) Within one day of completing the FSM filling, the exposed surface shall be covered by a 5-cm layer of bark mulch to protect the soil from wind and water erosion, stop rain splash structural damage, suppress weed growth, prevent high soil temperature, and conserve soil moisture by suppressing evaporation. The mulch material shall be treated with *Tricoderma* to control the spread of Brown Root Rot disease.

(16) Immediately after completing the above tasks, the soil area shall be cordoned off to prevent unnecessary intrusion by humans, materials, vehicles, and machines.

Special precautions: All procedures involving preserving and cutting roots must only be conducted by an arborist who has relevant working experience in root work. Ordinary construction workers must not carry out such work.

5.3. Installing 18 vertical mulching holes in the New tree strip

(1) After completing the excavation and balustrade footing works explained in Sections 5.1 and 5.2, the New tree strip is ready for installing two types of soil improvements, namely vertical mulching and lateral root paths.

(2) The exposed soil shall be covered by wet hessian to prevent drying out.

(3) The New soil strip shall be divided into seven segments, namely five core segments and two wider edge segments, as shown in Slide 22.

(4) In the middle of each core segment, two vertical mulching holes shall be opened with an Air Spade. At each of the edge segments, four vertical mulching holes shall be opened. The holes shall be situated 1.8 m from the northern and southern long edges of the New tree strip.

(5) Each hole shall have a diameter of 10 cm, go down to 70 cm depth, and be inclined at 20 degrees towards the south side (i.e., pointing towards the New soil crescent) (Slide 22b).

(6) After removing the site soil in the excavation hole, the vacated space shall be filled by FSM, to be slightly tamped to a bulk density of about 1.3 Mg/m^3.

(7) Within one day of completing the vertical mulching works, the exposed surface shall be covered by a 5-cm layer of bark mulch to protect the soil from rain splash, running water and wind. The mulch material shall be treated with *Tricoderma* to control the spread of Brown Root Rot disease.

5.4. Installing six lateral root paths in the New tree strip

(1) After completing the excavation and balustrade footing works explained in Sections 5.1 and 5.2, the New tree strip is ready for installing two types of soil improvements, namely vertical mulching and lateral root paths.

(2) Referring to Slide 22, six lateral root paths in the form of trenches shall be opened with Air Spade at the boundaries of the New tree strip segments.

(3) Each trench shall measure 15 cm wide and 70 cm deep, to be excavated vertically and oriented perpendicular to the long axis of the New tree strip (Slide 22c).

(4) The >10 mm diameter structural roots encountered in the course of excavating the trenches shall be kept and moistened by water sprays.

(5) Within one day of removing the soil in the trench, the vacated space shall be filled by FSM, to be slightly tamped to a bulk density of about 1.3 Mg/m^3.

(6) Within one day of completing the lateral root path works, the exposed surface shall be covered by a 5-cm layer of bark mulch to protect the soil.

(7) After completing the soil improvement work, an automatic irrigation system using proprietary trickle heads shall be installed to supply supplementary water to the trees. A rainfall detector shall be installed to stop the watering when a given amount of rainfall has been received.

Special precautions: All procedures involving preserving and cutting roots must only be conducted by an arborist who has relevant working experience in root work. Ordinary construction workers must not carry out such work.

5.5. Soil replacement and soil cell installation in the New soil crescent

(1) The paving and subbase in the New soil crescent shall be removed.

(2) The site soil shall be removed down to circa +8.1 mPD (Slides 18−19).

(3) The bottom of the excavated area shall be compacted to form a finished firm base at +8.1 mPD to support the soil cells (Slides 27−30), which shall in turn support the new hard paving.

(4) Assemble the modular soil cells to the required height.

(5) Insert the FSM up to the top of the soil cells.

(6) Slightly tamp the FSM to a resulting bulk density of about 1.3 Mg/m^3.

(7) Install the top porous cap.

(8) Install the geotextile sheet.

(9) Install the porous subbase.

(10) Install the paving slabs, with a removable design to allow management of the soil held in the soil cell interstices (design details to be determined in due course).

Special precautions: Acquire a soil cell system with a finished height to match our 600 mm soil depth need, and with a strong top cap to support the subbase and the paving slabs.

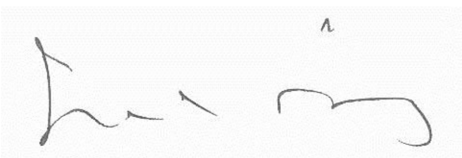
6. Summary and conclusion

The Scheme can realize two goals: protection and rehabilitation of the OVT, and provision of a new plaza in the dense and heavily patronized commercial precinct, which hitherto has only one small town square (Slide 35). The gist of the proposed OVT protection-cum-rehabilitation scheme is condensed below (Slide 36):

(1) The tailor-made OVT protection-cum-rehabilitation scheme is based on detailed tree and site assessment and understanding of the unique banyan growth habit.
(2) The open soil area compared to the large tree with a sprawling crown is piteously tiny and grossly inadequate.
(3) Despite the legendary banyan vigour and tenacity, the tree's growth form has been severely constrained and shaped by the narrow Existing planting strip.
(4) The tree has exhausted the capacity of the limited soil body, and its growth has reached the allowable upper ceiling.
(5) With evident tree decline in recent years and a dim prognosis, keeping existing growth conditions largely unaltered or applying routine treatments cannot help.
(6) The emaciated OVT demands innovative rehabilitation measures to arrest its decline and revive its health.
(7) The only soil improvement area lies in the Plaza, but it has heavily compacted soil sealed by impermeable paving, which is unsuitable for root growth.
(8) This Scheme adopts innovative soil rehabilitation by improving rootable soil area, soil continuity, connectivity, and quality.
(9) It achieves synergies among the tree, Plaza, and citizens, and co-existence among tree conservation, town planning, and urban amenity.
(10) It offers a rare opportunity to accomplish a substantial OVT rehabilitation case in the dense core of Hong Kong.
(11) It furnishes a fine example of co-using a piece of precious urban land in our compact city for both hard and soft landscaping.

A new lease of life for OVT WCH/1 in the commercial development on IL No. 8945, Causeway Bay, Hong Kong

PowerPoint presentation (36 slides)



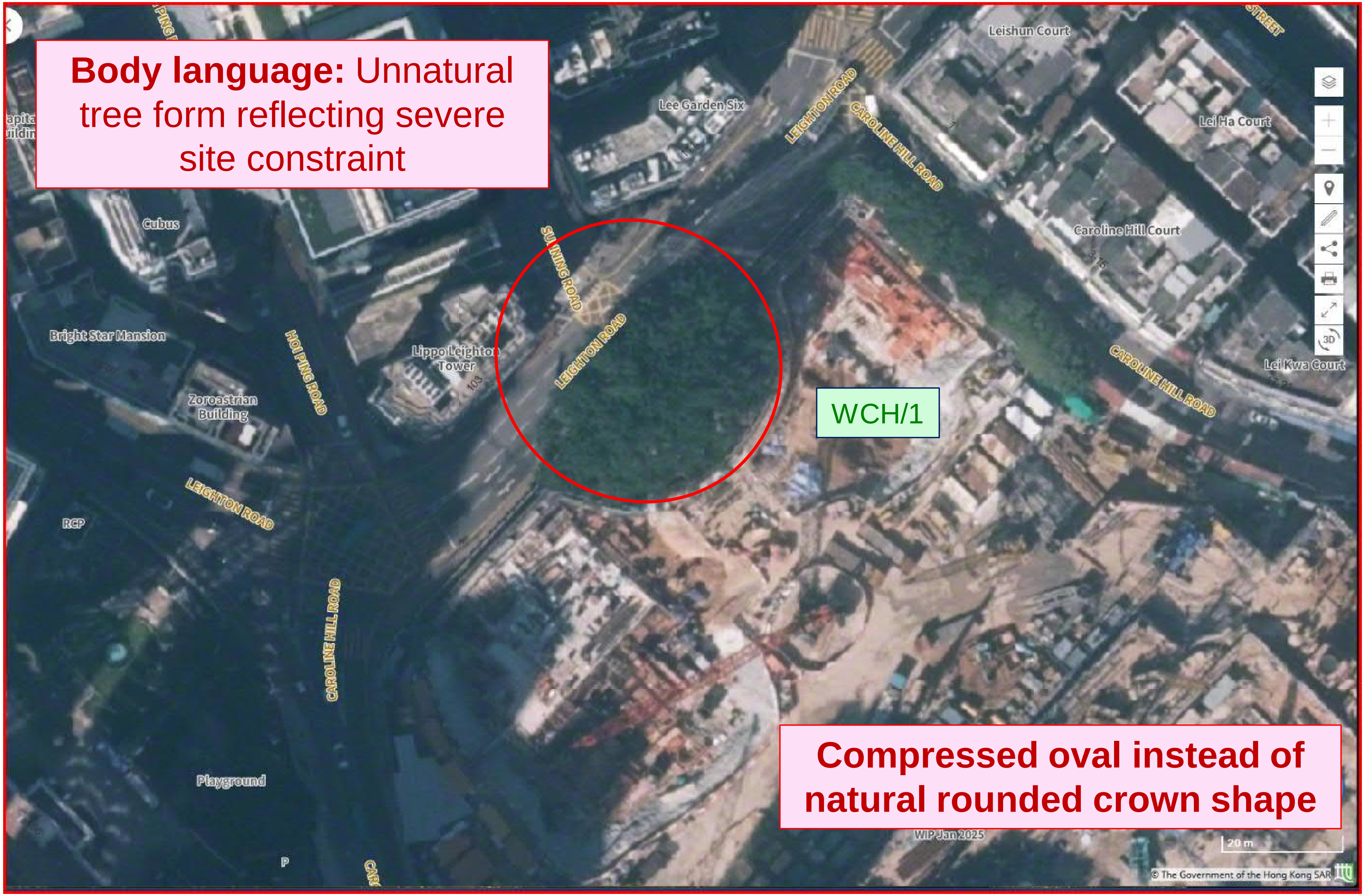
Prepared by Professor C.Y. Jim
Independent Tree Expert
27 August 2025

A new lease of life for OVT WCH/1 in the commercial development on IL No. 8945 Causeway Bay, Hong Kong

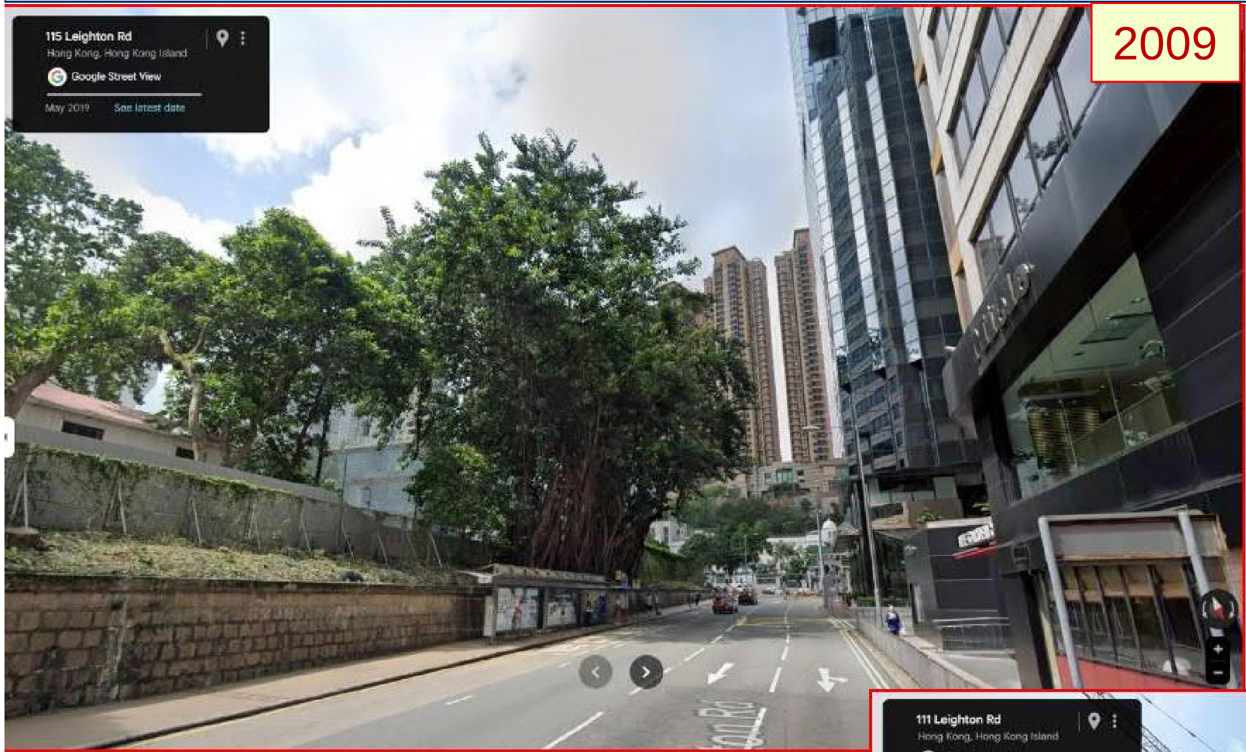
CY Jim
Independent tree expert

Version 5 20250813

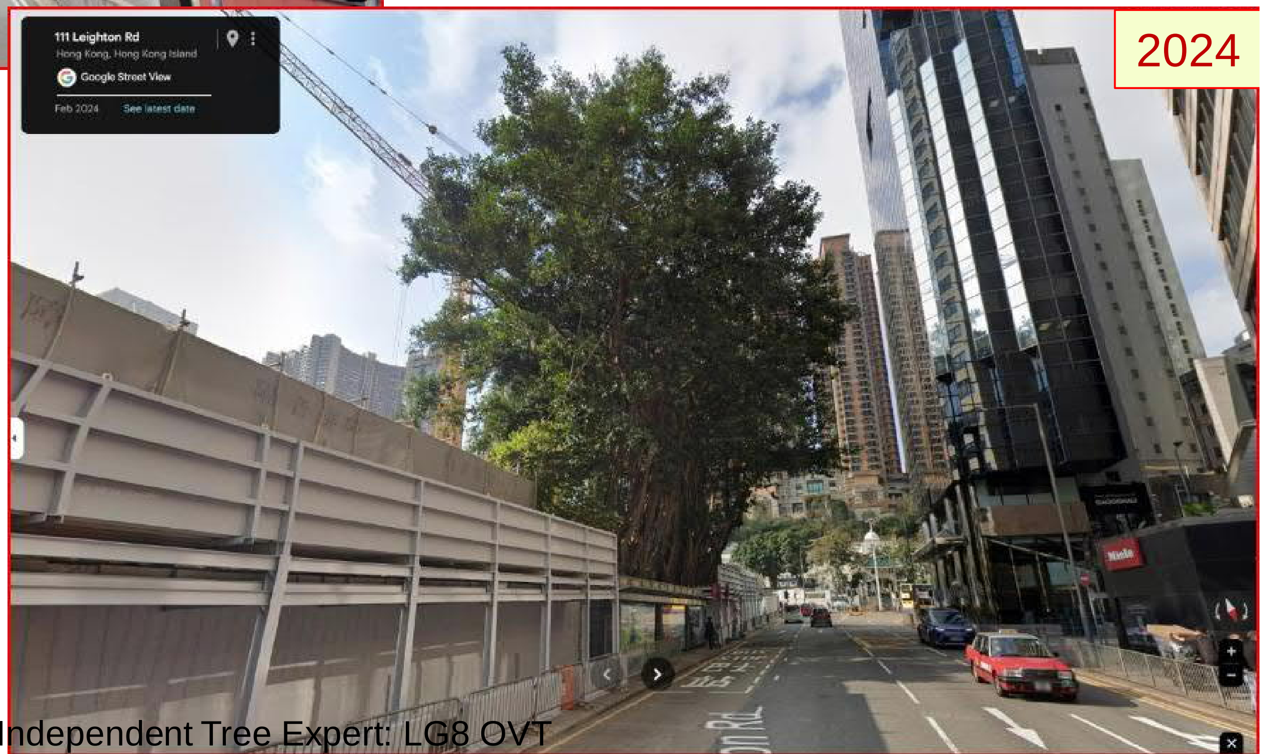
Slide 1. Aerial view of the development site and the WCH/1 OVT in 2024. The circle indicates normal crown growth without the physical site constraints.



Slide 2. Lateral view of OVT WCH/1 in May 2009 and Feb 2024 (Google Street View), indicating limited growth increment in 15 years.



Stagnated tree growth:
Limited by extreme soil constraint



Slide 3. OVT WCH/1 has shown decline symptoms in recent years (Google Street View May 2019 and Feb 2024), with evident reduction in foliage density.

2019

Evident tree decline:

Has exhausted the capacity of the limited soil resource

Compromised by Brown root rot disease and moth attack

June 2024 moth attack

2024

Slide 4. The open soil area available for root stand development is confined to the narrow Existing tree strip, constraining the tree's ability to anchor itself securely.

Asymmetrical oval crown development and unbalanced weight distribution:

- Major axis 44 m
- Minor axis 26.4 m
- Crown area 912 m^2
- 38.4% on Road side
- 61.6% on Plaza side

- The plaza will attract heavy visitor patronage for a long duration every day especially on weekends and holidays

- Need to find effective and long-term ways to abate the risk of tree failure, such as branch breakage, to pedestrians

- Especially that the tree is infected and weakened by brown root rot disease

Slide 5. The linear belt of dense and extensively fused (inosculated) root stands of OVT WCH/1 (Google Street View May 2022) support the wide oval-shaped crown.

Slide 6. Cramped development of the root stands of the large OVT WCH/1 trapped in the narrow (c. 3.5 m width) Existing tree strip (Google Street View May 2022).

Slide 7. A narrow hanging metal receptacle installed at the top of the masonry wall has been occupied by the vigorous root stand growth of OVT WCH/1 (Google Street View May 2022).

Slide 8. Proactive rehabilitation of OVT can replace passive protection.

中文百科全書
https://www.newton.com.tw › wiki › 古樹名木養護復壯技術

古樹名木養護復壯技術 - 中文百科全書

古樹名木養護復壯技術

摘 要：古樹名木是中華民族悠久歷史與文化的象徵，是綠色文物、活的化石，是自然界和前人留給我們的無價珍寶,具有重要的歷史價值和科研價值。但長期以來，由於環境、人為、自然災害、病蟲危害等原因，造成古樹名木衰老及死亡。因此必須採取搶救性措施，加強對古樹名木的管理和養護來延緩古樹名木的衰老。

2.4換土

Innovative rehabilitation: Soil replacement

古樹幾百年甚至上千年生長在一個地方，土壤肥分有限，常呈現缺肥症狀，如果採用上述辦法仍無法滿足，或者由於生長位置受到地形、生長空間等立地條件的限制，而無法實施上述的復壯措施，可考慮更新土壤的辦法。如北京市故宮園林科從1962年起開始用換土的方法搶救古樹，使老樹復壯。典型的例子有：皇極門內寧壽門外的一株古松，當時幼芽萎縮，葉子枯黃，好似被火燒焦一般，職工們在樹冠投影範圍內，對大的主根部分進行換土，挖土深0.5m（隨時將暴露出來的根用浸濕的草袋子蓋上），以原來的舊土與沙土、腐葉土、大糞、鋸末、少量化肥混合均勻之後填埋其上，換土半年之後，這株古松重新長出新梢，地下部分長出2～3cm的鬚根，終於死而復生。另外如1975年對一株瀕於死亡的古松的採取的換土處理，這棵樹換土時深挖達1.5m，面積也超出了樹冠投影部分。同時挖深達4m的排水溝，下層填以大卵石，中層填以碎石和粗砂，上面以細砂和園土填平，以排水順暢。目前，故宮裡凡是經過換土的古松，均已返老還童，鬱鬱蔥蔥，很有生氣。此法很值得學習推廣。

Slide 9. Recent extensive OVT rehabilitation conducted in China’s Jilin Province.

搶救復壯古樹名木「一樹一策」煥生機

2025年07月31日 10:40

據中國吉林網報道，自今年開展全省古樹名木搶救復壯工作以來，共搶救復壯瀕危衰弱古樹19株，使古樹得到了有效保護，讓古樹名木重新煥發了生機。

在吉林省汪清縣紅日村有一株老白榆樹，樹齡大約200多年，有豐富的歷史和文化價值。但由於土壤貧瘠、立地環境較差等多方面因素影響，目前古樹枝葉稀疏，整體長勢衰弱，病蟲危害嚴重。

汪清縣林業局生態修復科科長洪正日說：「今年在省林業和草原局的資金扶持和技術指導下，我們邀請相關專家對白榆進行『會診』，經過綜合分析和研究，制定了詳細的復壯方案。首先，在古樹名木樹幹3米外設立大理石保護圍欄，防止古樹名木遭受人畜破壞。其次，進行地上和地下生長環境改良，包括樹洞修補、清理腐爛木質部及對蛀干害蟲滅殺、更換透氣鋪裝、挖設復壯溝、鋪置透氣管等。我們對樹體安裝支撐架進行加固，排除了安全隱患。同時，我們還加強了日常的巡查和養護工作，定期對古樹名木進行病蟲害防治、枯枝修剪、施肥等養護，確保它們的健康生長。」

Slide 10. A meritorious example of heritage tree rehabilitation in Tokyo.

Extensive soil improvement to revive old Camphor tree in Tokyo University

Slide 11. Soil refurbishment of the entire street to revamp soil conditions for trees.

Wholesale soil replacement and soil cell installation to overhaul soil volume and quality for urban trees

Slide 12. Research informing practice:
High quality growth medium to improve New tree strip and New soil crescent.

Socio-Ecological Practice Research (Jim 2019)

Socio-Ecological Practice Research (2019) 1:41–53
https://doi.org/10.1007/s42532-018-00005-z

PERSPECTIVE ESSAY

Resolving intractable soil constraints in urban forestry through research–practice synergy

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Abstract
In compact urban areas, grey infrastructure tends to prevail over green infrastructure. The tight urban fabric challenges tree growth and restricts development of greener and healthier cities. The admirable forest-city goal demands innovative methods and solutions tailor-made to tackle inherent constraints. Research findings could be more proactively transformed and transferred into practices. The aerial tree growth space, relatively less difficult to ameliorate, attracts more attention. The more intractable subterranean constraints of confined soil volume acutely restrict root growth, root spread and tree health and contribute extensively to premature decline and tree hazard. Soil surface sealing by impermeable paving is associated with compaction, organic matter deficit, low nutrient and water holding capacity and meagre nutrient stock. Scanty application of research findings has kept practice quality at a low level, rendering the persistent soil problems in the bane of urban forestry. A systematic survey of state of play provides hints on novel solutions derived from existing knowledge and proposes new research practice. A package of measures with generic connotations has been distilled from the survey of chronic, critical yet widely neglected urban soil management issues. Urban forest managers and researchers can jointly adopt out-of-the-box thinking and generate actionable translational research. Policy makers and practitioners can more promptly be informed by new harvests of research–practice synergy. Intimate and reciprocal interactions between science and practice can be proactively nurtured to raise the quality of urban landscape.

Keywords Urban soil constraint · Bane of urban forestry · Soil volume limitation · Soil sealing · Re-naturalization in urban forestry · Landscape altruism

1 The intractable soil constraints and the knowledge–practice gaps

In dense city areas, the artificial paving and structures dominate the land cover (Arnold and Gibbons 1996, pp. 245–247; Salvati et al. 2016, pp. 424–425). Trees are sequestered and literally squeezed out of the compact built-up fabric (Jim et al. 2018, pp. 3–6). The conflicts between trees and the urban matrix have attracted the attention of urban forest researchers (McPherson et al. 2001, pp. 22–23; Jim and Chan 2016, pp. 77–79), often focusing on the above-ground part and neglecting the below-ground soil component (Haan et al. 2012, pp. 318–319; McGrath and Henry 2014, pp. 111–113).

The limited urban soil management tends to concentrate on chemical properties, especially soil fertility, echoing a legacy from agricultural practice (Sarah et al. 2015, pp. 395–396; Musielok et al. 2018, pp. 274–276). The physical soil properties have been studied extensively by researchers, yet they are commonly neglected at the practice front (Perry 1994, pp. 4–7; Sanders and Grabosky 2014, pp. 302–303). The critical tree growth issues include soil structure, aggregate stability, bulk density, porosity (Jim 1998a, pp. 237–242; Puskás and Farsang 2009, pp. 270–271), soil volume restriction and soil sealing (Jim 2017, pp. 274–278; Just et al. 2018, pp. 143–144). Their prevention and amelioration have remained scanty and ineffectual (Koeser et al. 2013, pp. 655–656).

The lack of soil volume for tree roots is a common problem facing tree managers in compact urban areas (Urban et al. 1988, pp. 59–61; Casey Trees 2008, pp. 2–3; LANDCOM 2008, pp. 16–18). The critical soil attributes, associated constraints and consequences on soil properties and

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Table 1 Main neglected physical constraints of urban tree planting and proposed research–practice agenda to fill the knowledge–practice gaps

		Consequence													Knowledge-practice gap					
		Soil									Root									
Soil attribute	Constraint	Confined soil depth	Confined soil width	Limited available moisture	Restricted infiltration	Restricted permeability	Restricted evaporation	Poor drainage	Limited aeration	Elevated soil temperature	Root suppression	Shallow rooting	Poor anchorage	Cracked & heaved paving	Basic research	Planting site design	Drainage design	Soil amelioration	Soil design	Tree species selection
(a) Soil volume restriction: Natural composition	Stony soil			✔							✔		✔			×		×		
	Subsurface stone layer	✔									✔	✔	✔			×		×		
	Large boulder	✔	✔	✔							✔		✔			×				
	Shallow rocky base	✔		✔				✔			✔		✔			×				
	Excessively sandy soil			✔							✔		✔					×		×
	Excessively clayey soil			✔				✔	✔		✔		✔				×	×		×
(b) Soil volume restriction: Material organization	Dense or compacted soil	✔		✔	✔	✔		✔	✔		✔	✔	✔	✔	×			×		
	Textural discontinuity			✔		✔		✔			✔	✔	✔		×			×		
	High water table	✔						✔			✔	✔	✔		×		×			×
	Shallow solum	✔		✔							✔	✔	✔	✔				×		×
	Subsurface hardpan	✔		✔		✔		✔			✔	✔	✔					×		
(c) Soil volume restriction: Structure & porosity	Unstable aggregates			✔	✔	✔		✔	✔		✔		✔		×			×	×	
	Limited total porosity			✔	✔	✔		✔	✔		✔		✔		×			×	×	
	Lacking macropores (>60 μm)				✔	✔		✔			✔				×			×	×	
	Lacking mesopores (0.2– 60 μm)			✔							✔				×			×	×	
	Lacking micropores (<0.2 μm)										✔				×			×	×	
(d) Soil volume restriction: Artificial installation	Buried rubble layer	✔		✔		✔		✔			✔	✔	✔					×		
	Buried paving	✔		✔		✔		✔			✔	✔	✔					×		
	Buried utility line	✔	✔								✔		✔			×				
	Buried utility duct	✔	✔								✔	✔	✔			×				
	Buried utility box	✔	✔								✔		✔			×				
	Basement	✔	✔	✔				✔			✔	✔	✔			×	×			
	Building foundation	✔	✔	✔				✔			✔	✔	✔			×	×			
	Concrete root barrier	✔	✔								✔		✔		×					
(e) Soil volume restriction: Planting site design	Small tree pit	✔	✔	✔							✔	✔	✔	✔		×			×	×
	Small container	✔	✔	✔				✔			✔	✔	✔			×	×		×	×
	Narrow tree strip		✔								✔		✔			×			×	×
	Shallow tree strip	✔		✔							✔	✔	✔	✔		×			×	×
	Narrow planter		✔								✔		✔			×			×	×
	Shallow planter	✔		✔							✔	✔	✔			×	×		×	×
(f) Soil sealing: Paving	Impervious pour concrete	✔		✔	✔		✔		✔	✔	✔	✔	✔	✔	×	×				×
	Impervious asphalt	✔		✔	✔		✔		✔	✔	✔	✔	✔	✔	×	×				×
	Clogged porous material	✔		✔	✔		✔		✔	✔	✔		✔	✔	×	×				
	Clogged pervious material	✔		✔	✔		✔		✔	✔	✔		✔	✔	×	×				
(g) Soil sealing: Soil degradation	Compacted soil in open unit pavers			✔	✔				✔		✔		✔		×			×	×	
	Compacted surface soil			✔	✔				✔		✔		✔					×	×	
	Surface crusting			✔	✔		✔		✔		✔		✔		×			×	×	

Slide 13. Research informing practice:
Resolving the bane of urban forestry: Soil limitations and rootability confinement.

Plant Soil (2023) 483:153–180
https://doi.org/10.1007/s11104-022-05728-3

RESEARCH ARTICLE

Check for updates

Rootability confinement and soil-husbandry solutions for urban trees in sealed and insular sites

C. Y. Jim

Plant and Soil (Jim 2023)

Received: 25 July 2022 / Accepted: 29 September 2022 / Published online: 12 October 2022

Abstract
Aims Cramped and sealed sites common in compact city areas limit tree growth due to multiple physical restrictions and physiological stresses. Fast urbanization and densification have intensified the pressure on urban trees, demanding innovative methods and solutions. The subaerial tree-growth space attracts more attention, but the more intractable subterranean rootability constraints are often overlooked. They are expressed as external (macro-scale) soil-body volume and internal (micro-scale) soil-pore volume limitations. The double jeopardy of urban soil insularity acutely restricts root growth, root spread, tree health, and stability.
Methods Some novel solutions can be distilled from a comprehensive review of recent research findings to bring effective relief.
Results Pedestrians and vehicles can co-use the expanded soil area in dense urban areas. Various creative soil expansion techniques can allow tree roots to break out from conventional confined tree pits or tree strips. Subsurface connections can link a planting site to an adjacent one or a nearby green patch. The soil union could be realized by subsurface soil conduits (large-diameter buried pipes) or subsurface soil corridors covered by pier-supported paving. In the spirit of landscape altruism, soil sharing by neighbor trees optimizes using the scarce rootable soil resource. Internal soil volume expansion can be accompanied by high-quality soil mix and compaction-prevention measures to resolve porosity and rootability deficit.
Conclusions Urban tree managers can adopt out-of-the-box thinking in managing critical physical soil deficiencies. New research findings can more promptly inform policymakers and practitioners. Close interactions between science and practice can be proactively cultivated.

Keywords Urban soil insularity · Soil porosity · Soil sealing · Soil compaction · Available soil volume · Soil sharing

Responsible Editor: W Richard Whalley.

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Introduction

People living in cities experience different levels of detachment from nature. Some cities are well-endowed with natural enclaves with rich nature contents to bring many ecosystem services to inhabitants. Others could be deprived of nature and its multiple benefits (European Commission 2015; Elliot et al. 2022). Detachment from nature could degrade the quality of life, well-being, welfare, and happiness. Over half of the human population lives in cities (The World Bank 2020), which is expected to reach 70%

Type		Site		Location			Expansion[b]			Connection				Geometry
Type and variant	Planting site epithet	Pit	Strip	Footpath	Carriageway	Proximal green patch[a]	Elongation	Widening	Linkage	Open-soil pit or strip	Open-soil peninsula[c]	Subsurface soil conduit[d]	Subsurface soil corridor[e]	Planar configuration of tree pit or strip and their expansions and connectors[f]
1	***Contiguous pit expansion***													
1a	Pit original	✓		✓										
1b	Pit elongation	✓		✓			✓							
1c	Pit widening	✓		✓				✓						
1d	Pit enlargement	✓		✓			✓	✓						
1e	Pit enlargement to chamber	✓		✓	✓									
2	***Contiguous strip expansion***													
2a	Strip original		✓	✓						✓				
2b	Strip elongation		✓	✓			✓			✓				
2c	Strip widening		✓	✓				✓		✓				
2d	Strip enlargement		✓	✓			✓	✓		✓				
3	***In-situ pit connection by subsurface soil conduit***													
3a	Pit original–conduit linkage	✓		✓					✓			✓		
3b	Pit elongation–conduit linkage	✓		✓			✓		✓			✓		
3c	Pit widening–conduit linkage	✓		✓				✓	✓			✓		
3d	Pit enlargement–conduit linkage	✓		✓			✓	✓	✓			✓		
4	***In-situ pit connection by subsurface soil corridor***													
4a	Pit original–corridor linkage	✓		✓					✓				✓	
4b	Pit elongation–corridor linkage	✓		✓			✓		✓				✓	
4c	Pit widening–corridor linkage	✓		✓				✓	✓				✓	
4d	Pit enlargement–corridor linked	✓		✓			✓	✓	✓				✓	

Fig. 5 External soil volume solutions: Key geometric enhancement measures of six principal types and 26 variants based on soil-body expansion and connection (Source: the author)

Slide 14. Research informing practice:
Innovative techniques to improve rootable soil volume, connectivity and quality.

Soil volume restrictions and urban soil design for trees in confined planting sites

Journal of Landscape Architecture (Jim 2019)

Chi Yung Jim Education University of Hong Kong

Abstract

Urban trees often suffer from poor soil conditions, compromising their health and safety and raising management issues. In compact development areas, planting sites are beset by critical physical soil constraints, especially confined soil volume on narrow roadsides. These include internal (micro-scale) restrictions due to compaction and excessive coarse fractions such as gravels, and external (macro-scale) restrictions due to limited soil depth and width. *Soil area provision* (SAP) is assessed based on the moisture need of trees. A creative soil design scheme is proposed to expand soil volume, based on the principle of *soil volume sharing*, *subsurface soil conduits*, and *subsurface soil corridors* supplementing the routine open soil corridor. SAP could extend from the narrow footpath to the adjoining carriageway as a *soil peninsula* and green space as *offset soil volume*. The study aimed at knowledge exchange among science, policies, and practices, with implications for the sustainable management of many roadside trees in cities.

Soil compaction / soil area provision / subsurface soil conduit / subsurface soil corridor / offset soil volume / soil volume sharing

Introduction

Soils in human settlements are subject to drastic and intensive disturbances due to the addition, removal, mixing, and transformation of soil constituents. Such unnatural processes can disturb or arrest normal pedogenesis and soil horizon development.[1] With different modes and magnitude of impacts, urban soils tend to be highly variable from natural to disturbed and to entirely artificial types.

Accidental or intentional human actions have altered urban soils in terms of composition, organization, properties, and behaviour. As planting media, the heterogeneous technogenic soils[2] suffer from multiple physical and chemical limitations. Artificial materials, including demolition wastes and construction rubble,[3] induce poor plant growth.[4] Poor urban soils undermine the growth rate, health, vigour, establishment, and long-range welfare of urban trees,[5] imposing fundamental stress factors in arboriculture.[6]

Urban green infrastructure, including urban green spaces and constituent trees, offers multiple ecosystem services and nature-based solutions for liveable and sustainable cities, and prepares cities for climate-change impacts.[7] In compact cities, the keen competition for developable land has suppressed the space available for greening and lowered the urban landscape quality.[8] The dense urban fabric is restrictive to tree growth, especially on roadsides, where the soil and aboveground environments confine both root and shoot expansion.[9]

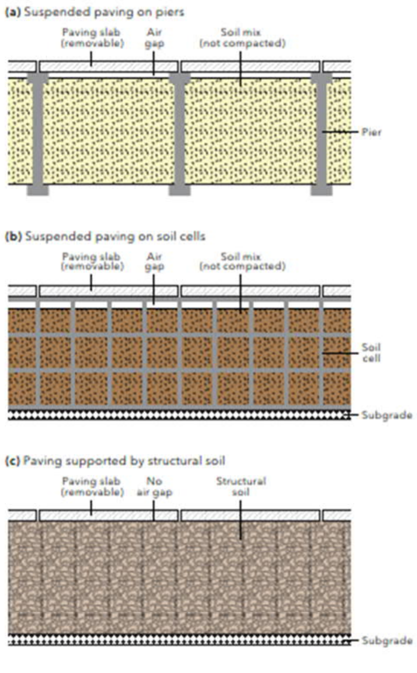


Figure 7 Three innovative methods to avoid soil compaction and enhance tree growth at confined sites: (a) suspended paving on piers, (b) suspended paving on soil cells, and (c) paving supported by load-bearing structural soil.

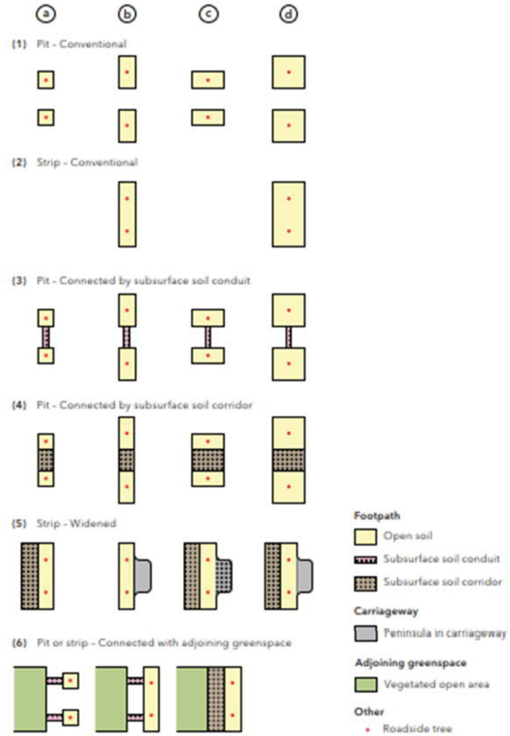


Figure 8 Innovative three-dimensional roadside soil design scheme (SDS) to improve the geometry and connectivity of soil volume to facilitate root spread and tree growth. The six types (1 to 6) of soil designs are each subdivided into two to four subtypes (a to d) to provide a comprehensive synopsis of enhancement options. The first subtype (a) denotes the restrictive situation, and the other subtypes (b to d) indicate the possibilities for improved soil volume design.

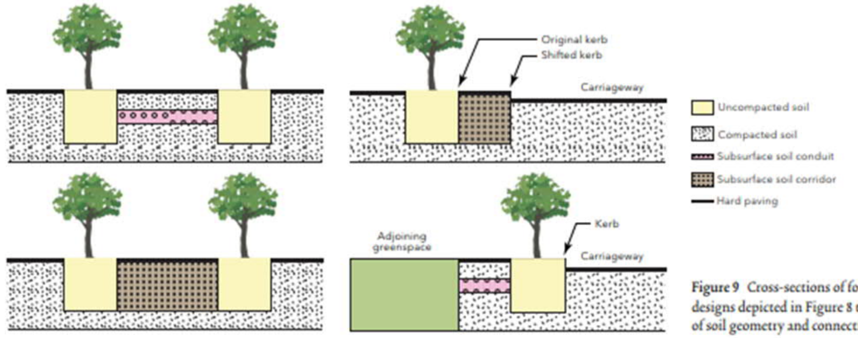


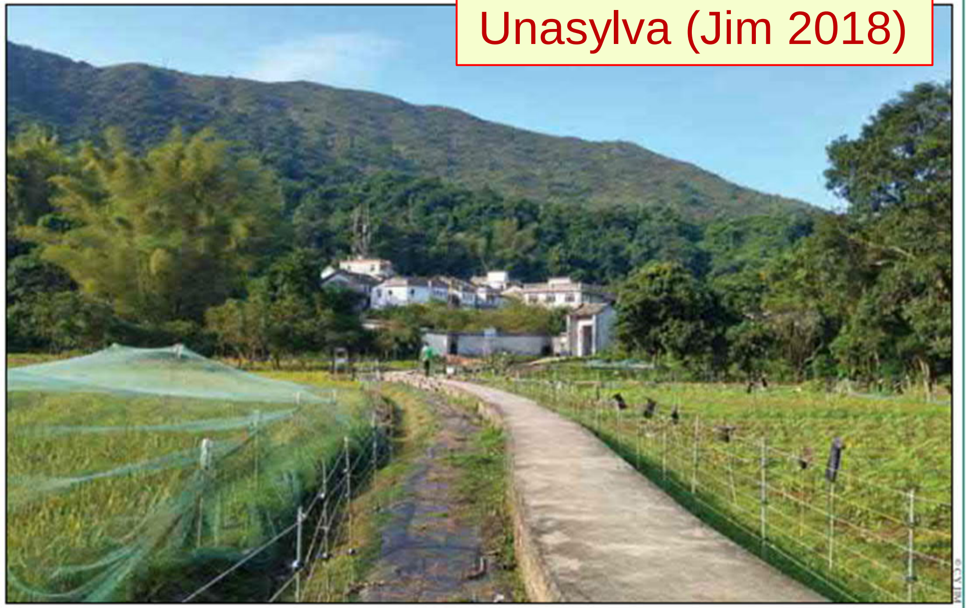
Figure 9 Cross-sections of four selected roadside soil designs depicted in Figure 8 to illustrate the methods of soil geometry and connectivity improvements.

Slide 15. Research informing practice:
Understanding OVT constraints to find tailor-made and sustainable solutions.

Protecting heritage trees in urban and peri-urban environments

C.Y. Jim

Unasylva (Jim 2018)



Some individual trees perform especially important cultural functions, and strong community involvement is crucial for their conservation and management in urban settings.

People have held trees in high esteem and awe since antiquity. Primitive peoples recognized that trees were notably bigger, stronger, more majestic and longer-lived than most other organisms. Intimate interactions with nature have increased human awareness of trees progressively; over time, particular trees have instilled in people a sense of fraternity, fear, generosity, providence, ubiquity, immortality, eternity and divinity.

As benevolent providers and protectors of humans, certain trees have acquired special status. Beginning with admiration and respect, attitudes evolved to adoration and reverence and then to veneration and worship (Taylor, 1979; Dafni, 2006). Traversing geographical, temporal and cultural divides, tree worship is common in many ancient polytheistic belief systems. Many mythologies, legends and folklores are associated with beloved or feared trees, indicating a continued and widespread human deference to them. Many indigenous cultures have bestowed a sacred standing on individual trees and groves, seeing them as deities or the abodes of certain spirits.

The pragmatic contributions of trees to farming communities in soil and water conservation and microclimatic amelioration are well recognized. In East Asia, such contributions have been practised systematically as feng shui or geomancy (Han, 2001; Coggins *et al.*, 2012). Such

Above: Traditional villages in southern China are protected by upslope feng shui (geomancy) groves. This photo shows the well-preserved tradition in the village of Lai Chi Wo, Hong Kong

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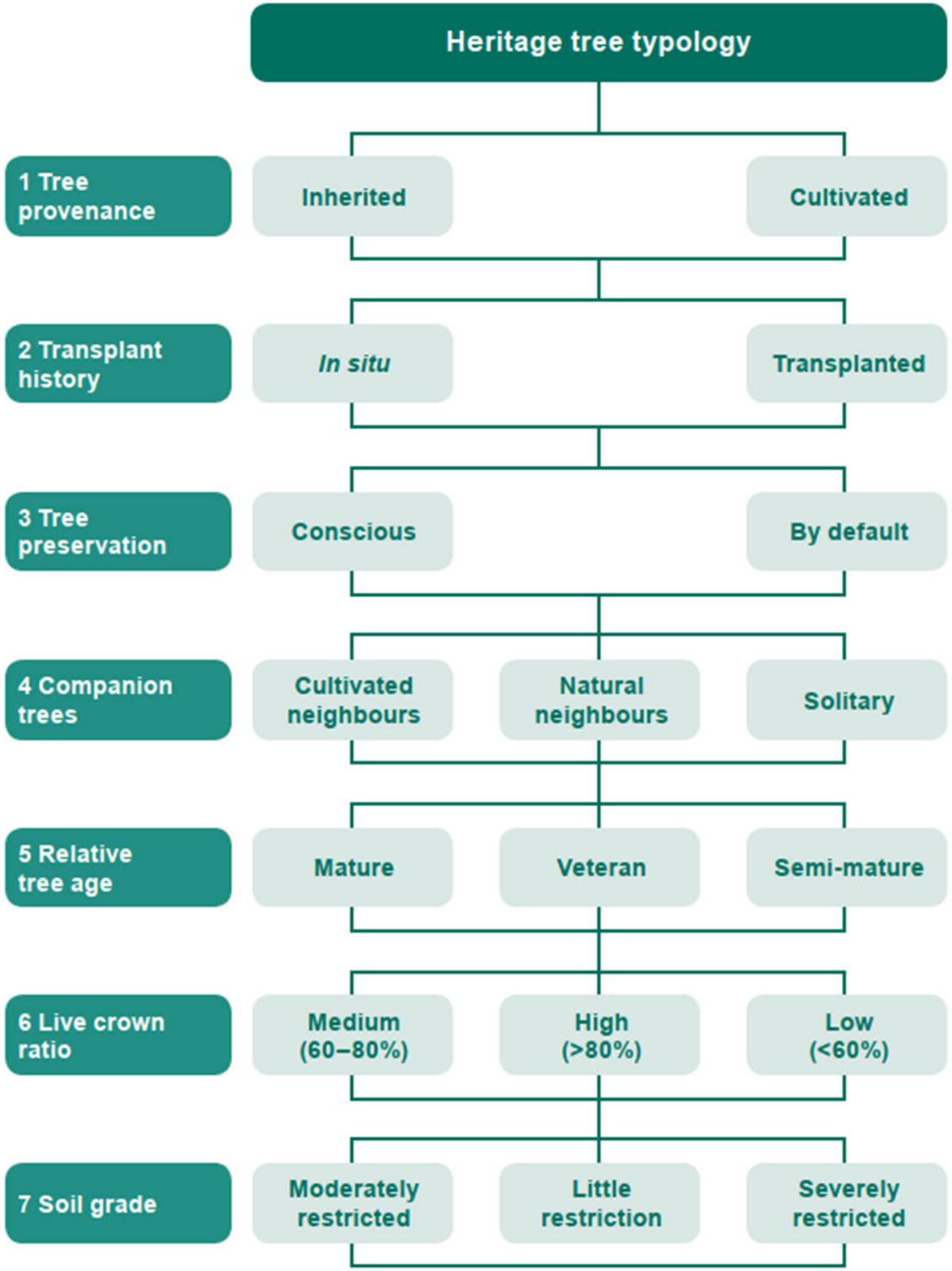


Slide 16. The bulk of the site is sealed by hard paving with underlying heavily compacted soil unsuitable for root growth. This proposal to improve soil conditions can significantly foster growth of subterranean roots and root stands.

Limited rootable soil (c. 44 m length)

Existing tree strip (3.5 m wide)

Tree protection zone (TPZ) with impermeable hard paving sealing underlying heavily compacted soil (maximum 15.5 m wide)

The OVT desperately needs a new lease of life:
Solution: OVT *protection-cum-rehabilitation scheme* by improving soil volume, connectivity and quality

Increasing the rootable soil area by over four times from 19% of crown area to 80%

Devoting 49% of the 555 m^2 designated tree protection zone (TPZ) for exclusive use by the OVT

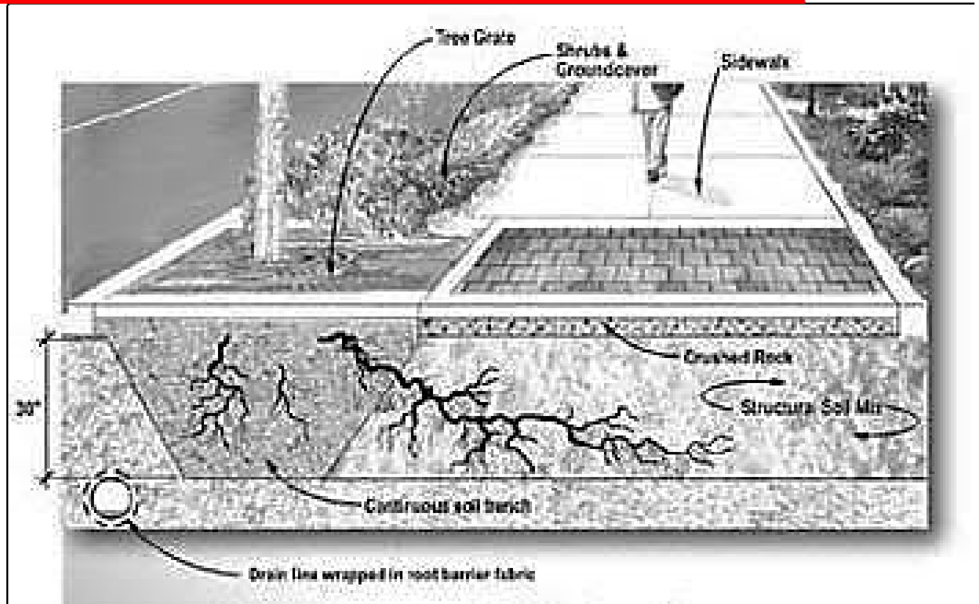
Percent of crown area	Three soil-rooting zones (c. 44 m length)
19%	Existing tree strip (3.5 m wide, 175 m^2)
30%	New tree strip (5.7 m wide, 270 m^2)
31%	New soil crescent (max. 9.8 m wide, 285 m^2)
Total=80%	

Slide 17. Application of rootability rehabilitation: Root trench connection to adjacent soil areas.

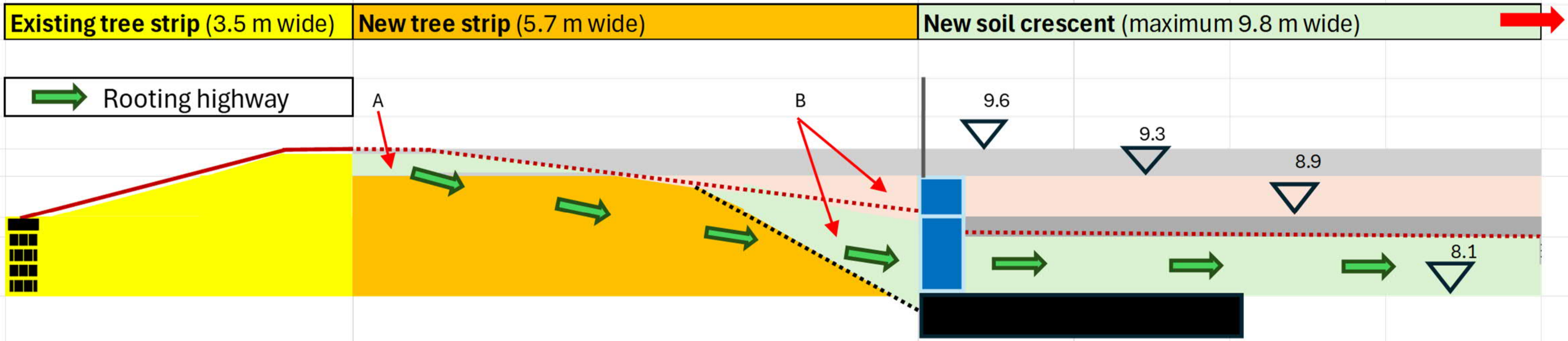
6	***Ex-situ pit or strip connection with proximal green patch by subsurface soil conduit or soil corridor***									
6a	Pit original–conduit linkage to green patch	✓	✓	✓	✓			✓	✓	
6b	Pit elongation–conduit linkage to green patch	✓	✓	✓	✓	✓		✓	✓	
6c	Pit enlargement–conduit linkage to green patch	✓	✓	✓	✓	✓	✓	✓	✓	
6d	Pit original–corridor linkage to green patch	✓	✓	✓	✓			✓		✓
6e	Pit elongation–corridor linkage to green patch	✓	✓	✓	✓	✓		✓		✓
6f	Pit enlargement–corridor linkage to green patch	✓	✓	✓	✓	✓	✓	✓		✓

Application of the soil continuity principle

Connect the three soil-rooting zones



Slide 18. Proposed design for rootable soil expansion and improvement in the three soil-rooting zones: At the balustrade footing position.

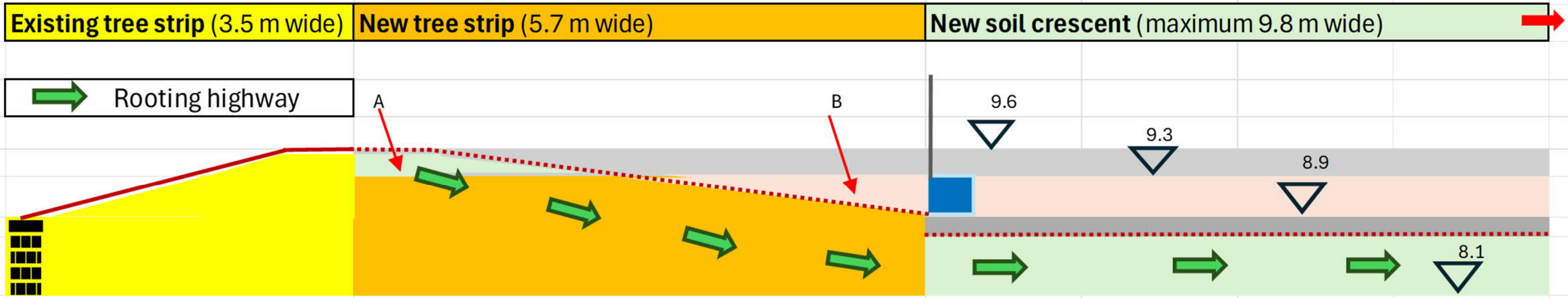


Retain existing soil surface	Form new soil surface (dotted red line) and expand rootable soil area under TPZ with improved soil	
Do not disturb the moderately compacted existing soil on the slope, which is filled with abundant subsurface roots and root stands.	Remove existing paving and the soil on the right side (B area pink and green) to form the required 30 degree slope (black dotted line) for safe excavation to install the blustrade footing; add new soil on left side (A area); after builidng the balustrade, refill with fabricated soil mix (B area green); improve the soil by adding vertical mulching and lateral root paths.	Remove existing paving and underlying compacted soil down to 8.1 mPD; build the balustrade footing (black feature, dimensions to be determined); install the soil cells (in gree area); fill the interstices of soil cells with good-quality tree growth medium (a fabricated soil mix); install the new hard paving (dark gray layer).

Site-specific design:
Expand soil catchment area
Establish soil continuity and connectivity
Improve rootable soil quality

Interface between New tree strip and New soil crescent:
7 posts each 0.4 m thick = 2.8 m
(2.8 m/44.0 m) x 100 = 6.4%, very limited obstacle to root growth

Slide 19. Proposed design for rootable soil expansion and improvement in the three soil-rooting zones: Between the balustrade footing position.



Retain existing soil surface	Form new soil surface (dotted red line) and expand rootable soil area under TPZ with improved soil	
Do not disturb the moderately compacted existing soil on the slope, which is filled with abundant subsurface roots and root stands.	Remove existing paving and the soil on the right side (B area); add new soil on left side (A area); improve the soil by adding vertical mulching and lateral root paths.	Remove existing paving and underlying compacted soil down to 8.1 mPD; build the balustrade beam (black feature); install the soil cells (in gree area); fill the interstices of soil cells with good-quality tree growth medium (a fabricated soil mix); install the new hard paving (dark gray layer).

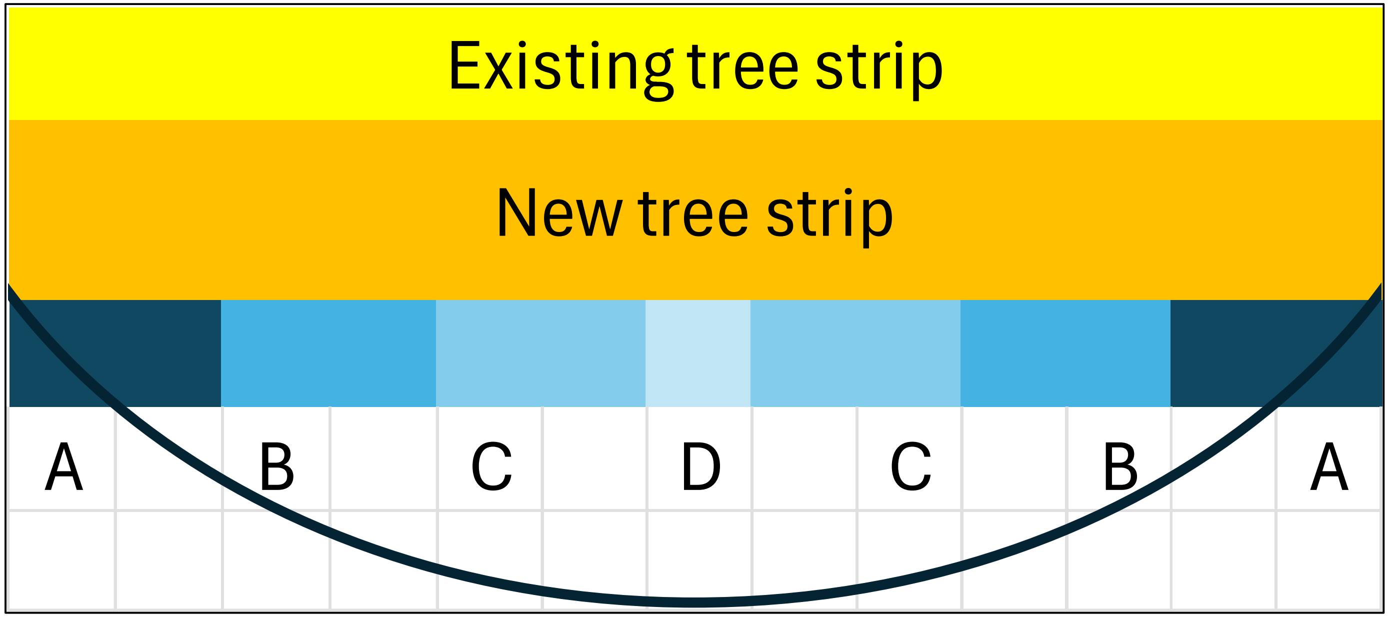
Site-specific design:

Expand soil catchment area

Establish soil continuity and connectivity

Improve rootable soil quality

Slide 20. Proposed phased soil excavation to install seven balustrade footings at the northern edge of the New soil crescent, in sequence from A to D, with a three-week recuperation interval between consecutive phases.



Site-specific design:

Extend soil excavation duration

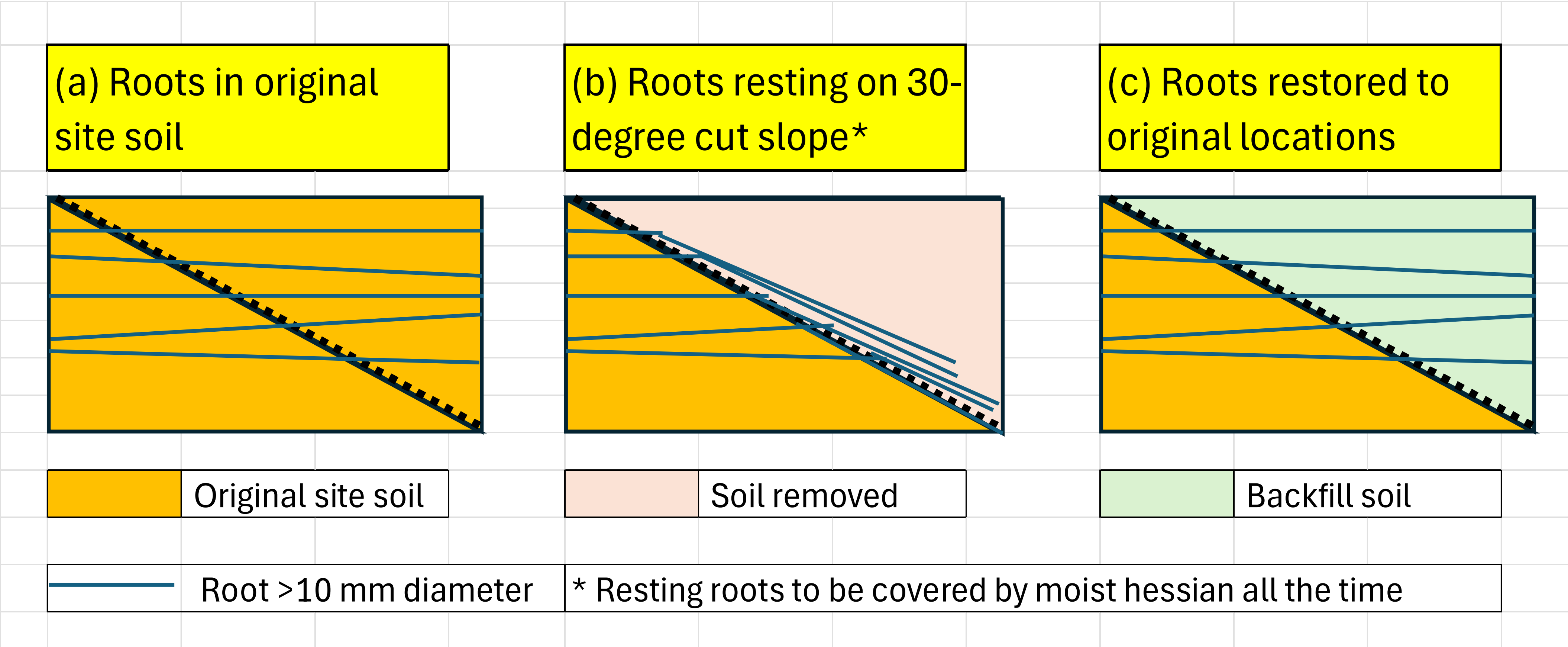
Insert three-week recuperation gap

Minimise impact on OVT

Keep roots >10 mm diameter for excavation in the New tree strip

Refill excavation in the New tree strip promptly with high-quality soil

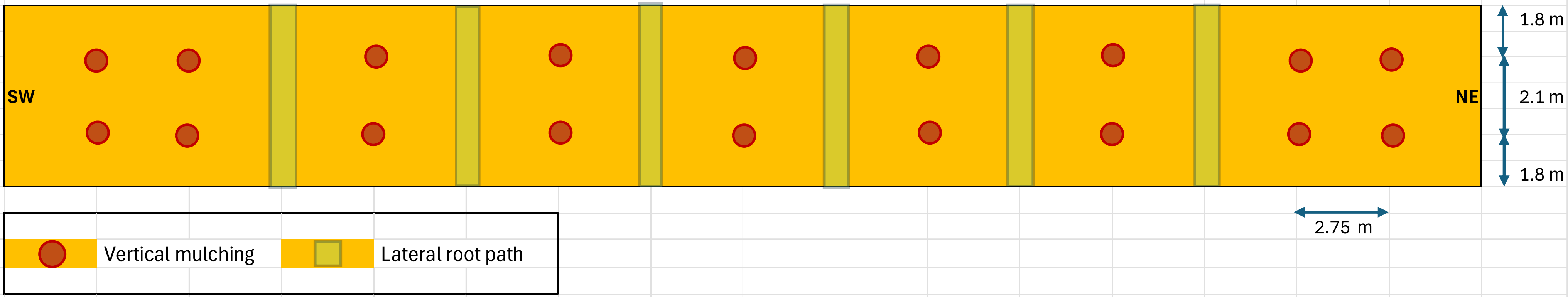
Slide 21. Proposed method to preserve roots in the southern portion of the New tree strip during excavation to form the 30-degree slope to install the balustrade footings.



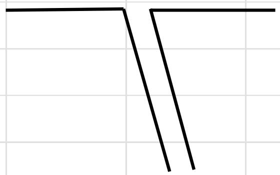
Application of root protection measures:
Salvage roots in the excavated soil
Keep soil moist all the time under hessian cover
Backfill with high-quality soil as soon as possible

Slide 22. Schematic design of vertical mulching and lateral root path to be installed at the New tree strip.

(a) Installation patterns of 18 vertical mulching holes and 6 lateral root paths between the balustrade footings

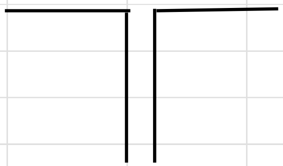


(b) Section of vertical mulching hole



10 cm diameter cylindrical hole, remove soil in the hole and fill with a fabricated soil mix
70 cm length
20 degree inclination towards the New soil crescent

(c) Section of lateral root path



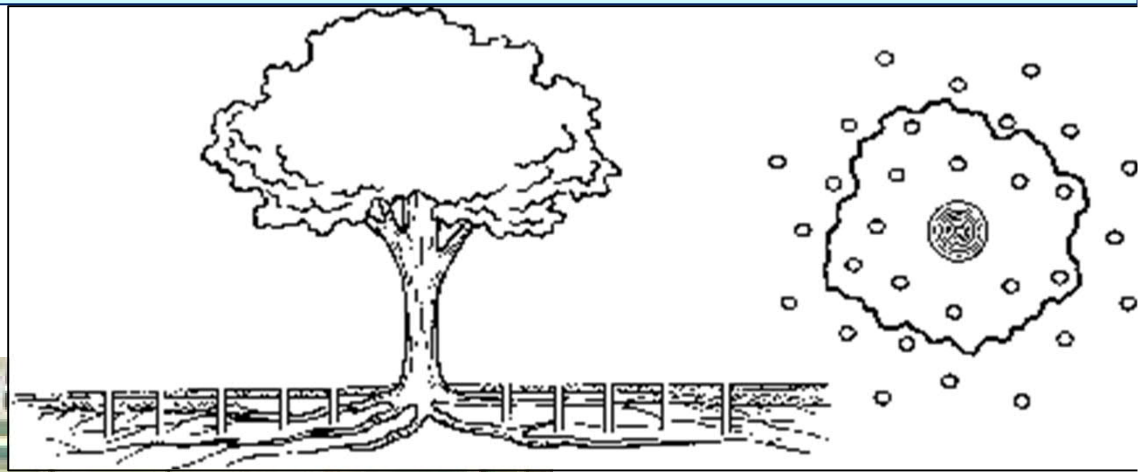
15 cm width trench, remove soil in the trench and fill with a fabricated soil mix
70 cm depth
Trench perpendicular to the New tree strip

(d) Excavation method

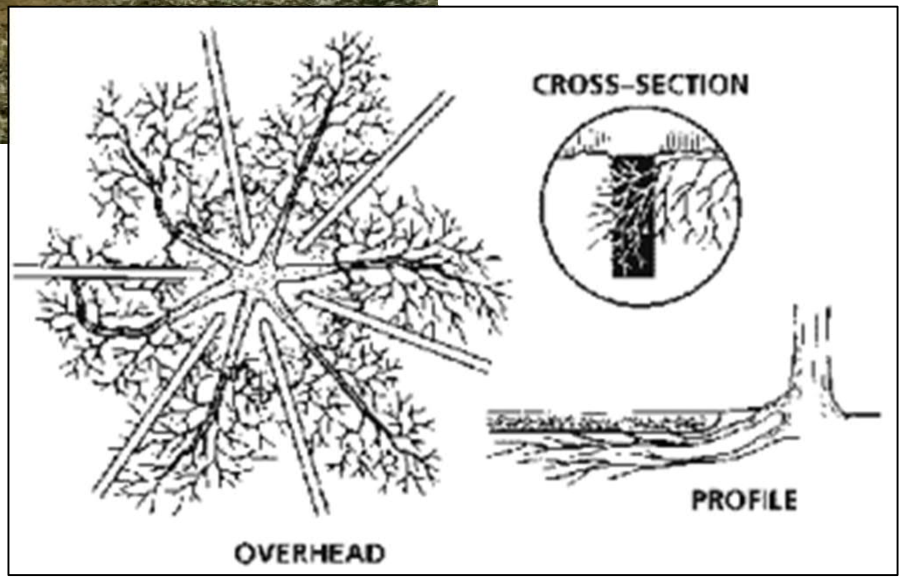
An Air Spade equipment (https://www.airspade.com/) is preferred. Special precautions must be taken to avoid aerial spread of suspended fine soil particles during excavation. The proprietary air suction equipment must be used in conjunction with the supersonic pneumatic excavator. All structural roots >10 cm diameter must not be cut or harmed during excavation. Before filling with fabricated soil mix, these exposed roots should be kept continuously moist by water sprays.

Site-specific design:
Improve soil quality
Channel roots towards New soil crescent

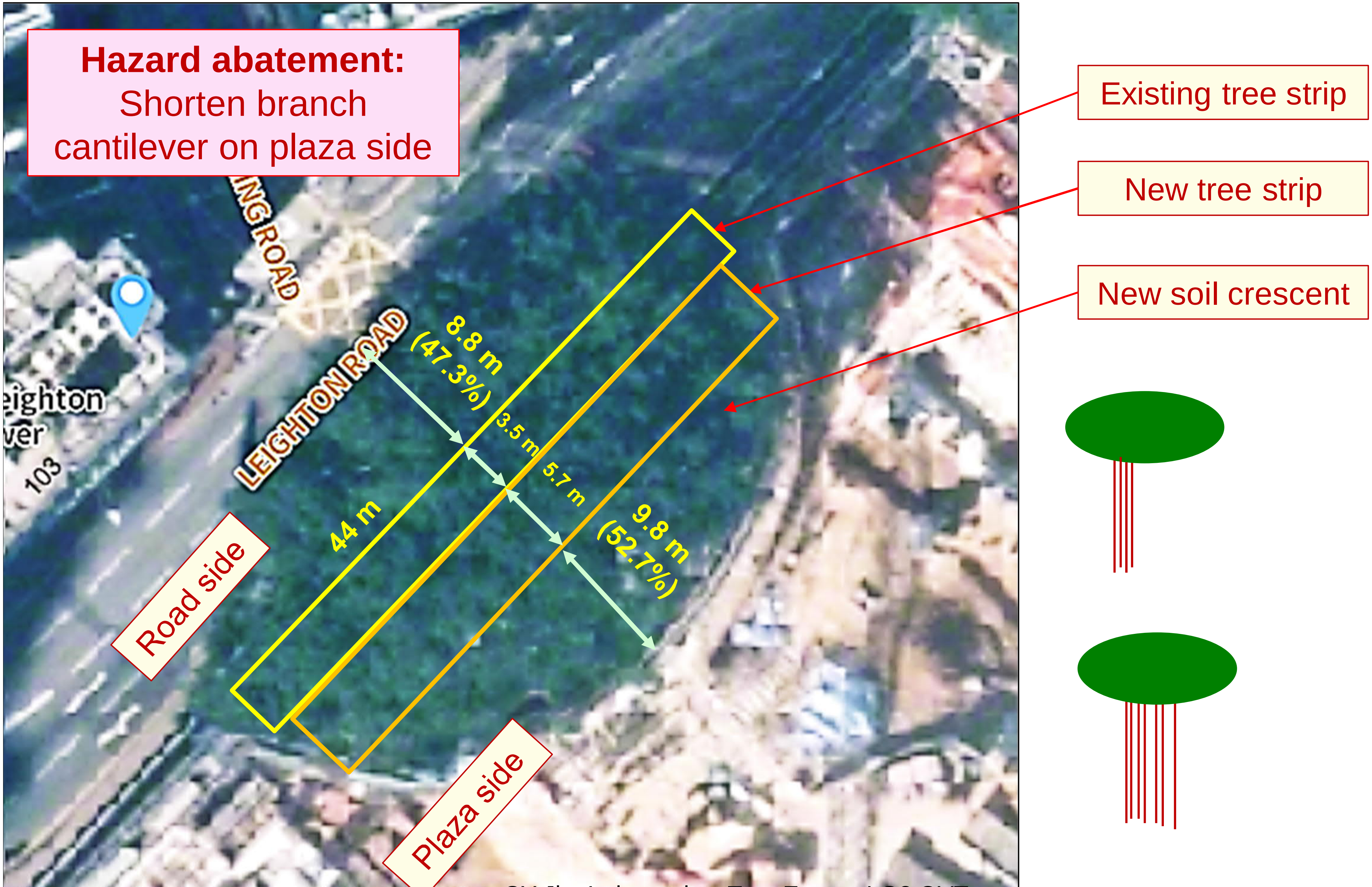
Slide 23. An example of rootability rehabilitation: Vertical mulching by air spade.



Slide 24. An example of rootability rehabilitation: Trenching by air spade.

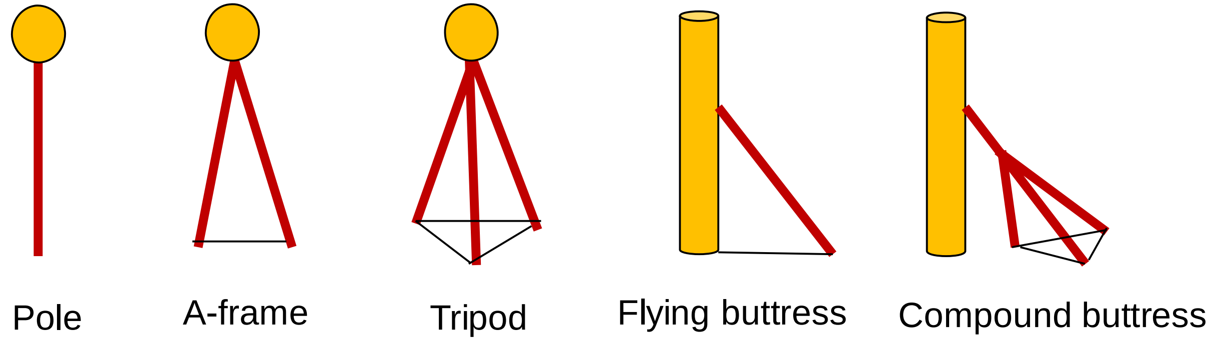


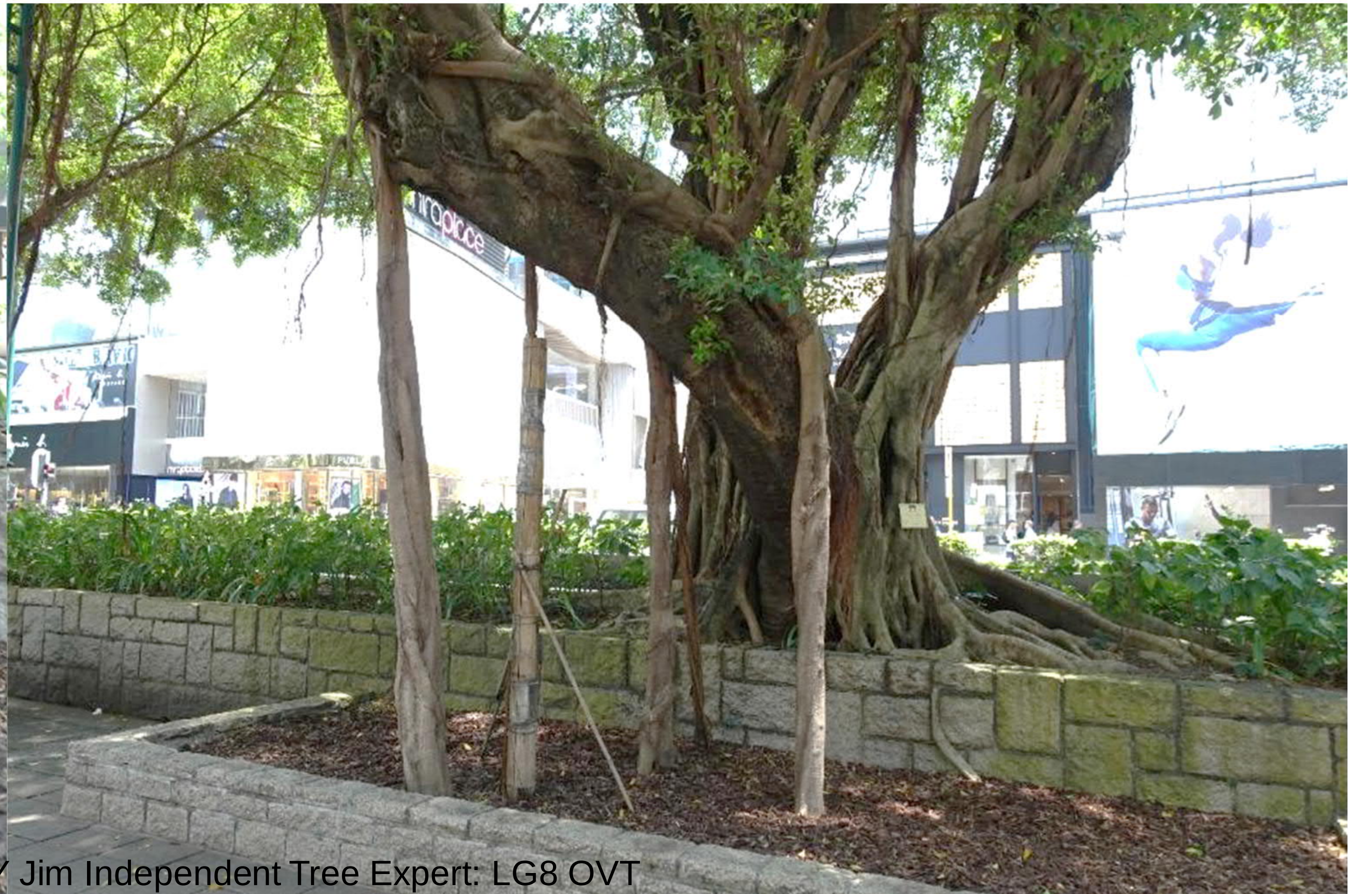
Slide 25. The open soil area available for root stand development will be be increased by nearly four times to significantly enhance the stability and safety of the large OVT hanging above the future plaza.



Slide 26. Proposed innovative sculpting of future root stands in the New tree strip to reinforce the mechanical support of the OVT crown situated above the plaza.

Innovative application of tree science: Aerial root lignification and inosculation

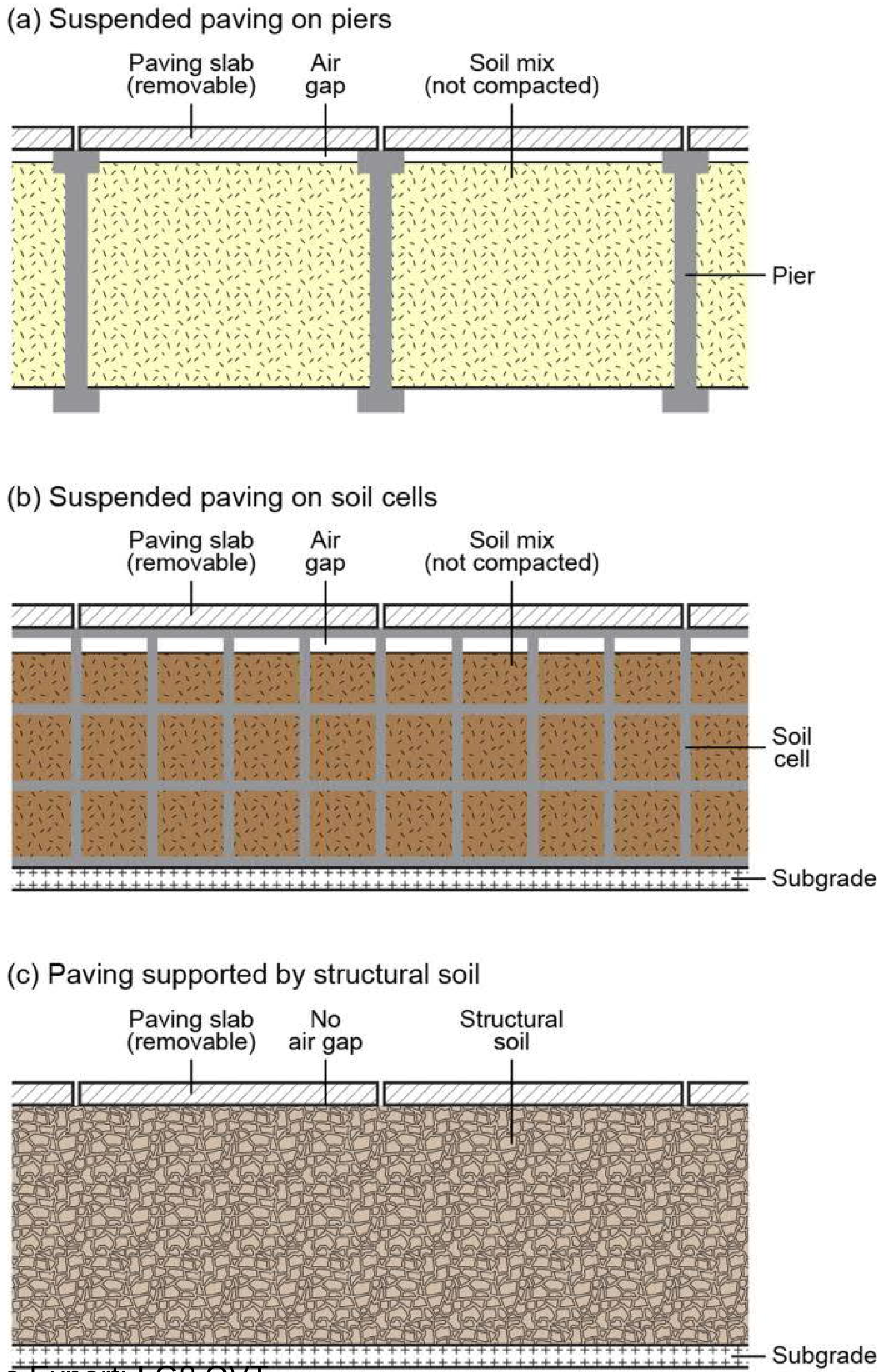




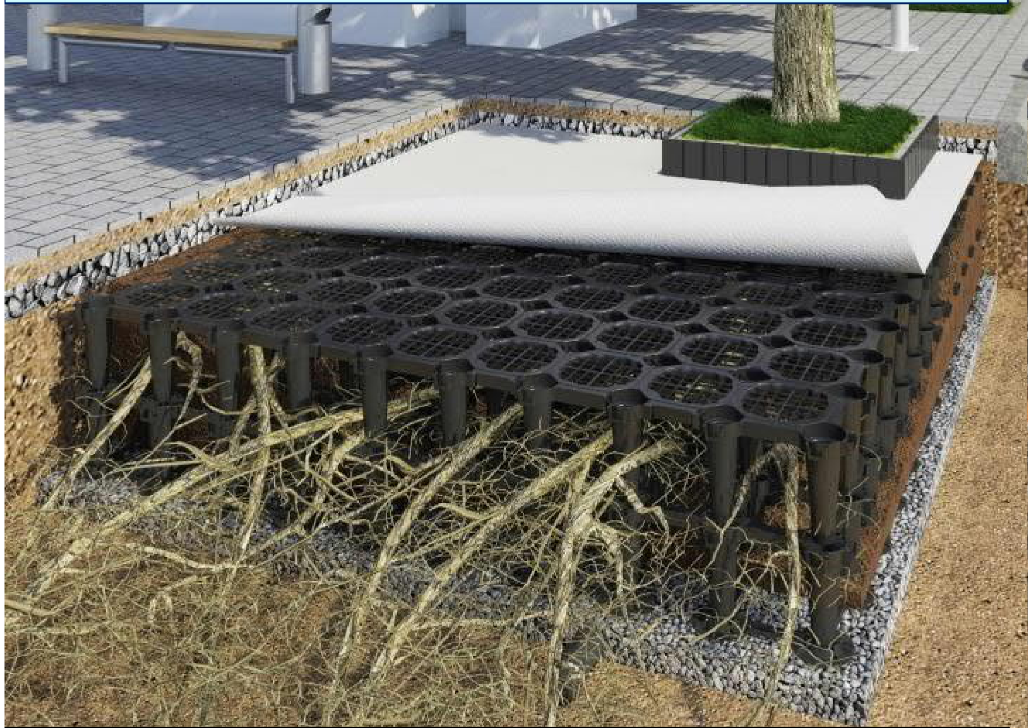
Slide 27. Three available techniques for suspended paving to improve soil conditions for tree growth.

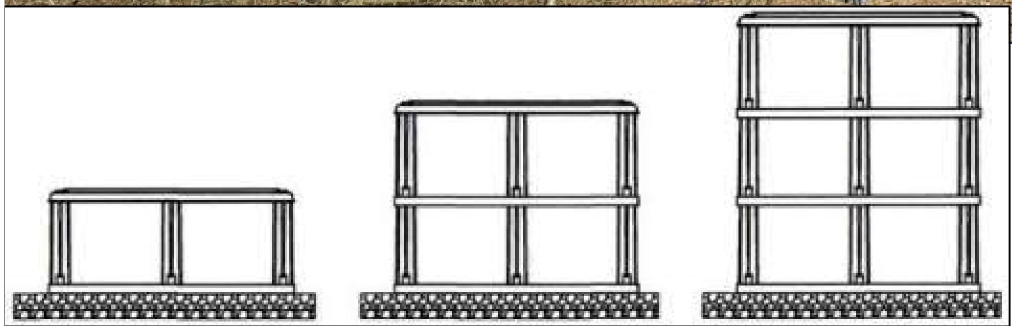
Adopting the modern soil cell method to co-use the plaza land:

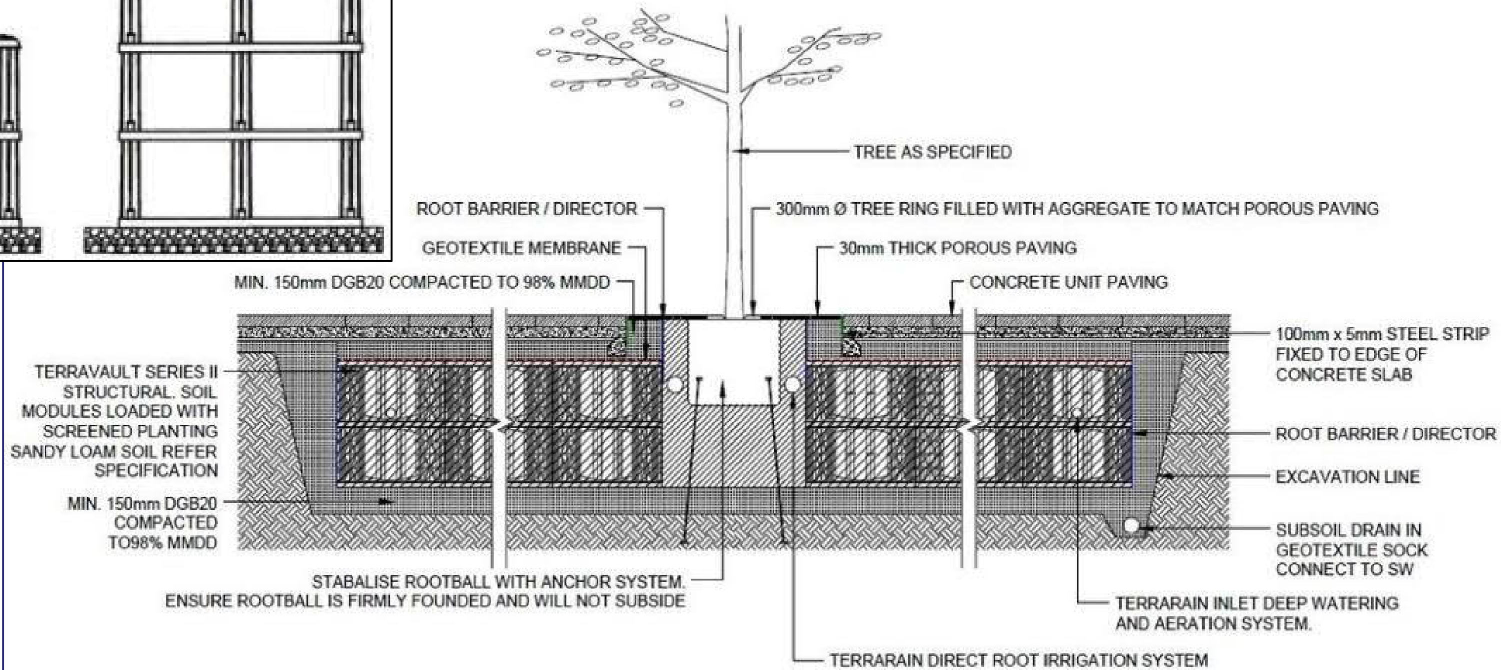
- ➢ Supporting the paving for hard landscape
- ➢ Accommodating uncompacted soil underneath for soft landscape to foster root growth



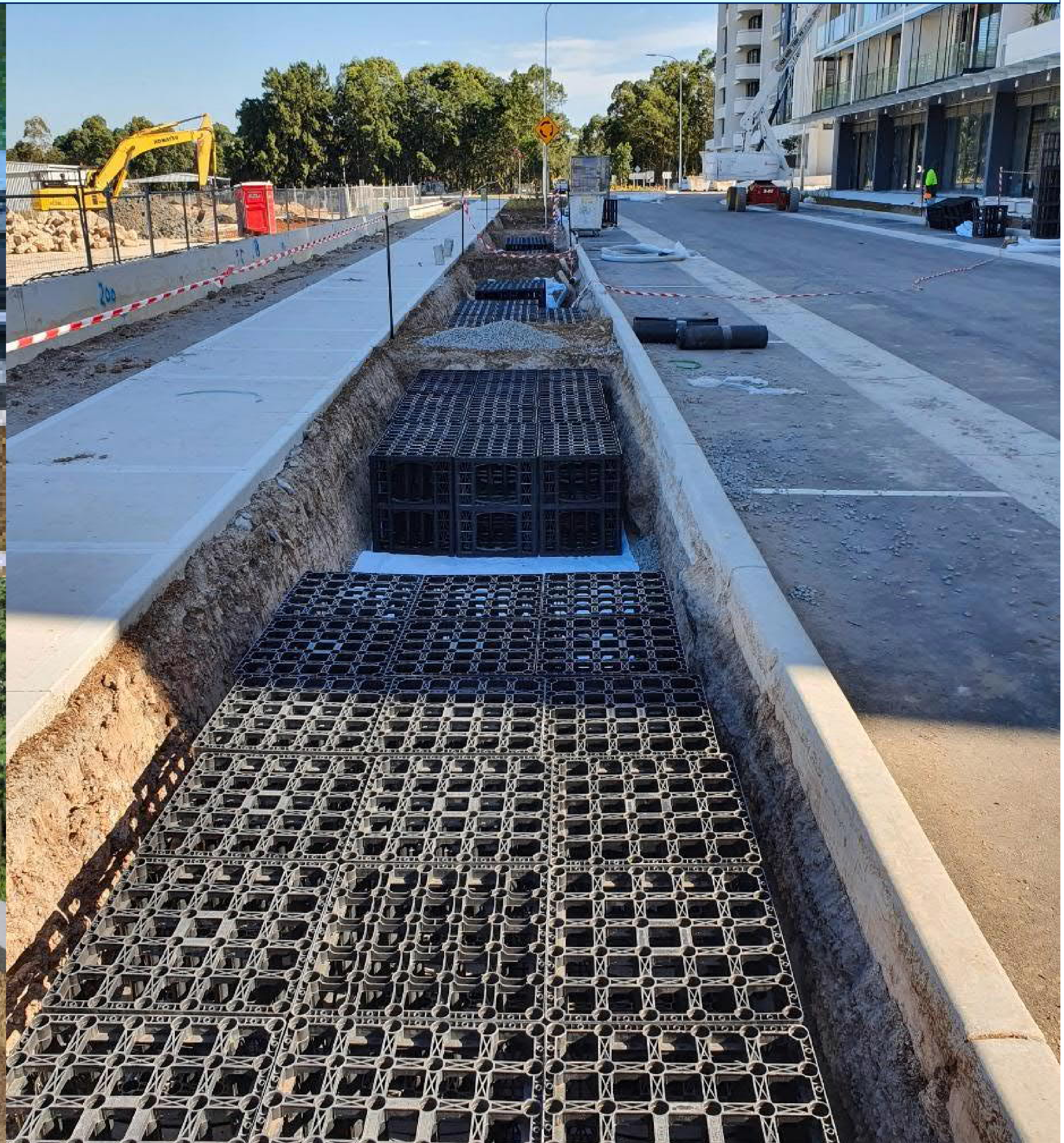
Slide 28. Some examples of soil cells.



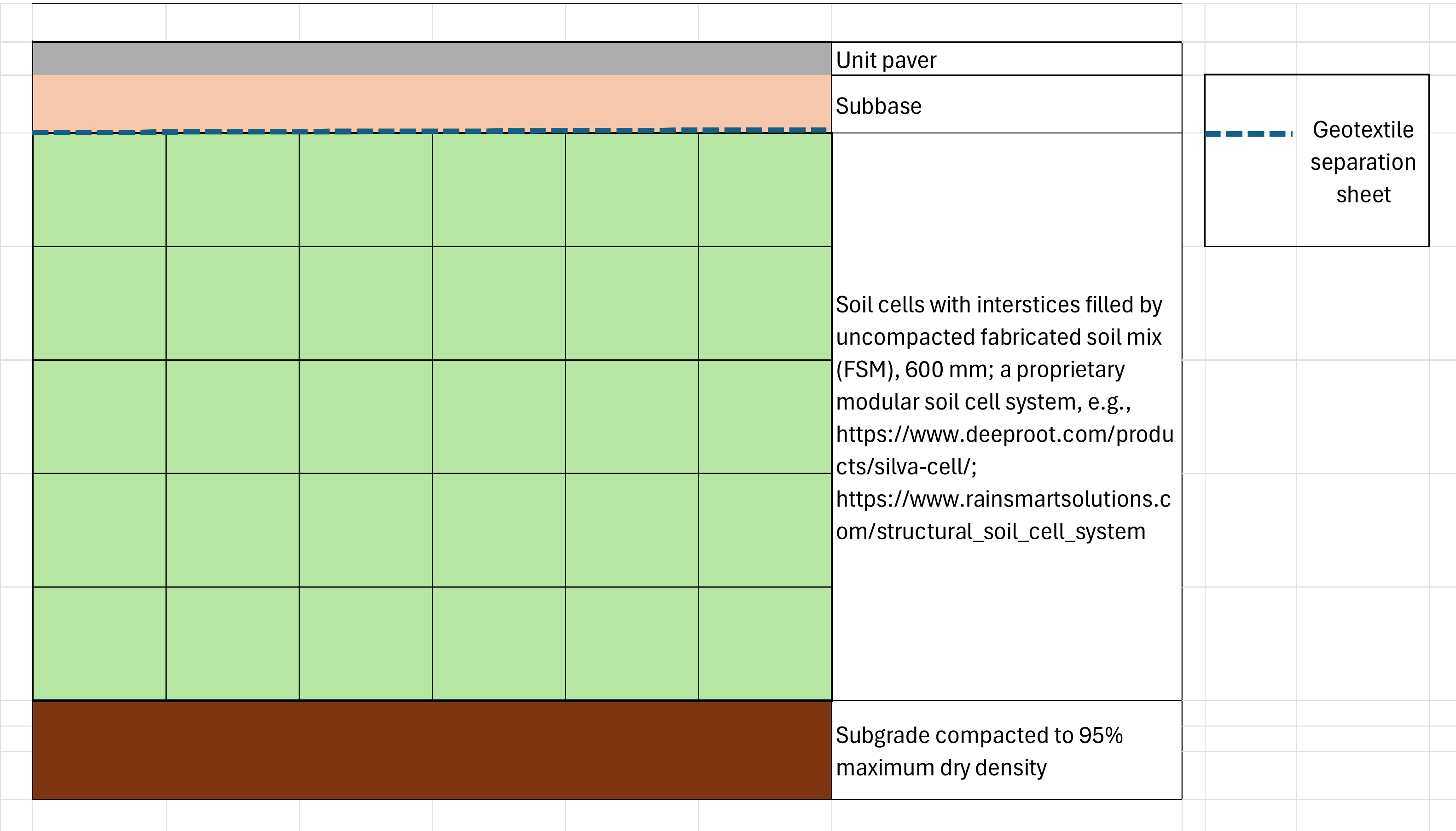




Slide 29. Examples of soil cell applications at road areas demanding a high load bearing capacity.



Slide 30. Schematic section of the soil cell to be installed at the New soil crescent.



Application of modern soil cell technique:

Support the paving and pedestrian load

Provide room for uncompacted soil

Allow rainwater and air infiltration

Facilitate soil management

Slide 31. Synopsis of the substantial improvements in soil volume and quality by soil treatments tailored-made for the New tree strip and New soil crescent.

Soil-rooting zone	Zone dimension			Soil origin	Soil sealing		Soil compaction	
	Width (m)	Area (m^2)	Area (%)		Present	Future	Present	Future
1 Existing tree strip	3.5	175	100	Original	Open	Open	Medium	Medium
2 New tree strip	5.7	270	154	Improved	Sealed	Open	High	Medium to high
3 New soil crescent	Max. 9.8	285	163	Replaced	Sealed	Permeable	High	Uncompacted
Total		730	417					

Soil-rooting zone	Soil quality		Soil porosity (%)		Root density		Root stand	
	Present	Future	Present	Future	Present	Future	Present	Future
1 Existing tree strip	Fair	Fair	38 (medium)	38 (medium)	Medium	Medium	Plenty	Plenty
2 New tree strip	Poor	Good	27 (low)	27 (low) & 50 (high)	Meagre	Medium	Nil	Plenty
3 New soil crescent	Poor	Excellent	27 (low)	50 (high)	Trace	High	Nil	Nil

Site-specific design:
Overcome present serious soil constraints
Enhance soil volume and quality significantly
Allow more growth of subterranean roots
Foster development of more root stands
A new lease of life for the OVT

Slide 32. Research informing practice:
Good quality growth medium to improve New tree strip and New soil crescent.

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Landscape and Urban Planning

Research Paper

Improving soil specification for landscape tree planting in the tropics

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Check for updates

Landscape and Urban Planning (Jim 2021)

H I G H L I G H T S

- Tropical urban forestry beset by infertile soil demands dedicated soil specifications.
- Local and international specifications are critically reviewed to inform improvements.
- Critical concerns and general principles of soil specification design are elucidated.
- Selected soil attributes and assessment methods are justified in a new specification.
- The new specifications provide keystone and multiplier benefits to landscape plants.

A R T I C L E I N F O

Keywords:
Urban forest
Urban soil quality
Urban soil limitation
Fabricated soil mix
Soil specification
Knowledge transfer

A B S T R A C T

Tree growth in urban areas is beset by multiple stresses, of which the soil component has imposed severe constraints. In the tropics, the inherently infertile and acidic soils present challenges that demand dedicated solutions. Yet, the key edaphic issues have remained poorly understood and often inadequately evaluated and improved. Where site soil is poor or absent, a soil specification usually prescribes a fabricated soil mix. Unfortunately, these documents frequently include non-essential attributes or exclude essential ones. The specified ranges and thresholds tend to detach from soil science concepts or are irrelevant to local conditions. Some projects would adopt specifications prepared for other local or international sites without modifications to match site requirements. Errors tend to be copied and propagated in different documents. Knowledge transfer from researchers to practitioners can improve the soil specifications to resolve a significant and chronic weakness in urban forestry. Five representative local documents and five from other countries were critically evaluated in detail to distill 21 principal concerns and 20 principles of soil specification design. The knowledge base informed the development of a rationalized and improved soil specification for urban forestry in the tropics. It included the fabricated topsoil mix and fabricated subsoil mix to meet most planting needs, and a dedicated fabricated lightweight mix for planting on rooftops with limited load-bearing capacity. Further explanations justified using local raw materials, soil sampling strategy, soil properties, recommended ranges, and standard laboratory testing methods. Other tropical regions can modify the proposed specification to fit local circumstances and specific landscape needs.

1. Introduction

Soil plays a crucial role in the formative and sustainable growth of landscape trees. The significant departure from nature in cities demands extra efforts to maintain urban trees (Spirn, 1984). Tree growth problems are often associated with poor urban soil quality and restrictive soil volume (Patterson et al., 1980; Craul, 1991; Schindelbeck et al., 2008). The suboptimal tree performance brings cascading consequences on landscape quality, useful life span, tree hazard, management burden, resource utilization and ecosystem service. In many places, the soil remains a tenaciously weak link in arboricultural practice (Jim, 2017, 2019a; Hilbert et al., 2019).

Urban forestry practice can identify tough trees for challenging situations, as well as improve site and soil conditions to avoid stressing trees (Ware, 1988; Kumar & Hundal, 2016). Urban soils suffer from considerable spatial variations and persistent problems (Pavao-Zuckerman, 2008; Greinert, 2015). Trees planted in paved and impermeable areas encounter acute restrictions due to surface sealing, low soil quality and limited soil volume (Mullaney et al., 2015). The widely installed tree pits are often too small with highly confined rooting volume. In

Table 2
The proposed improved specification of growing media for tropical urban forestry.

	Attribute	Test method	Reference	Fabricated topsoil mix[a]	Fabricated subsoil mix[a]	Fabricated lightweight mix[a,b]
				FTM	FSM	FLM
A	***Components and mixing***					
1	Completely decomposed granite CDG (part m/m)	State in Declaration of Compliance		3	6	2
2	Mature compost (part m/m)	State in Declaration of Compliance	Brinton, 2000	1	1	1
3	Exfoliated vermiculite or substitute[c] (5–10 mm) (part m/m)	State in Declaration of Compliance		NA	NA	1
4	Fertilizer rate, slow release (g/m^3)[d]	State in Declaration of Compliance		100	50	100
5	Protection of delivered soil[e]			Required for >5 days of exposure to the elements	Required for >5 days of exposure to the elements	Required for >5 days of exposure to the elements
6	Stockpiling duration (week)[f]	State in Declaration of Compliance		0–4	0–4	0–4
7	Thorough mixing method for <4 m^3	State in Declaration of Compliance		Manual blending is acceptable	Manual blending is acceptable	Manual blending is acceptable
8	Thorough mixing method for >4 m^3	State in Declaration of Compliance		Rotary tumbler	Rotary tumbler	Rotary tumbler
9	Quality of blending	Visual inspection at various locations and depths		Visual inspection of every delivered soil batch to ensure homogeneous blending	Visual inspection of every delivered soil batch to ensure homogeneous blending	Visual inspection of every delivered soil batch to ensure homogeneous blending
B	***Qualitative traits***					
1	Material source information	Source of compost[g]		State in Declaration of Compliance	State in Declaration of Compliance	State in Declaration of Compliance
2	Consistence	USDA scheme	National Soil Survey Center, 2012	Free flowing, friable, non-plastic to slightly plastic, non-sticky to slightly sticky	Free flowing, friable, non-plastic to slightly plastic, non-sticky to slightly sticky	Free flowing, friable, non-plastic to slightly plastic, non-sticky to slightly sticky
3	Soil structure	USDA scheme	Ditto	Mainly granular (>90%)	Mixture of blocky and granular	Mainly granular (>90%)
C	***Qualitative traits: negative vetting***					
1	Free from deleterious ingredients	Synthetic, harmful and undesirable substances[h]		Required	Required	Required
2	Solid debris					
	> 2 mm (% m/m)	Dry sieving of >2 mm fraction		<5	<5	<5
	> 25 mm (% m/m)			Nil	Nil	Nil
3	Free from toxic or obnoxious odour or fumes	Olfactory detection at the time of soil delivery to the site		Required	Required	Required
D	***Quantitative physical limits***					
1	Stone content, general (any axis)					
	> 2 mm (% m/m)	Dry sieving of >2 mm fraction	Soil Survey Division Staff, 1993	<25	<25	<25
	> 25 mm (%, m/m)			<10	<10	<10
	> 50 mm (%, m/m)			Nil	Nil	Nil
2	Stone content, special (any axis, mm)[i]					
	> 2 mm (% m/m)	Dry sieving of >2 mm fraction	Ditto	<10	NA	<10
	> 25 mm (%, m/m)			Nil	NA	Nil
	Stone shape	Visual comparison with stone shape chart	National Soil Survey Center, 2012	No stone in angular and very angular categories	No stone in angular and very angular categories	No stone in angular and very angular categories
3	Soil particle size distribution	USDA scheme	Ditto			
	Sand (0.05–2.0 mm) (% m/m)	Hydrometer	Gee & Or, 2002	40–70	40–70	40–70
	Silt (0.002–0.05 mm) (% m/m)			15–35	15–35	15–35
	Clay (<0.002 mm) (% m/m)			10–30	10–30	10–30
4	Soil textural class	USDA scheme	National Soil Survey Center, 2012	Sandy loam, followed by loam and sandy clay loam	Sandy loam, followed by loam and sandy clay loam	Sandy loam, followed by loam and sandy clay loam
5	Bulk density (Mg/m^3)	Core method, cylinder minimum 5 cm diameter and 10 cm height	Grossman & Reinsch, 2002	1.2–1.4	1.2–1.4	1.2–1.4
6	Aggregate stability (% m/m)	Wet aggregate stability	Nimmo & Perkins, 2002	>75	>75	> 75
E	***Quantitative chemical limits***					
1	pH	1:2.5 soil:water extract, glass electrode	Thomas, 1996	5.5–7.0	5.5–7.0	5.5–7.0

(continued on next page)

Slide 33. Calculated soil porosity volume and equivalent porosity and rootable soil area of the three soil-rooting zones after soil improvement or replacement.

Soil-rooting zone	Width (m)	Area (m^2)	Tree rooting depth (m)	Soil volume (m^3)	Estimated bulk density (kg/m^3)[a]	Porosity (%)[b]	Porosity volume (m^3)	Equivalent porosity (%)	Equivalent rootable soil area (m^2)[d]
1. Existing tree strip	3.5	120	1.0	120	1650	37.7	45.2	100.0	122.0
2. New tree strip	5.7	230	1.0	230	1935	37.7	86.7	191.7	233.8
3. New soil crescent	9.8[e]	280	0.6	168	1330	50.0	84.0	185.7	226.5
Total		630		518			216.0	477.3	582.4
Increase (%)[f]		525		432			477.3	477.3	477.3

[a] The soil in the existing tree strip is somewhat compacted to stabilize the slope, with an estimated bulk density of 1650 kg/m^3 and 37.7% porosity. For the new tree strip that occupies the existing sports ground with hard paving, the underlying subbase is assumed to be compacted to 90% of maximum dry density. With a common particle density of 2650 kg/m^3 and a maximum dry density of 2150 kg/m^3, the bulk density is calculated to be 1935 kg/m^3, with 27% porosity. The soil mix to be placed in the new soil crescent is not compacted to provide optimal conditions for root growth, with a bulk density of 1330 kg/m^3 and 50% porosity.

[b] The formula to calculate porosity in soil physics is: Porosity = 1 - (Bulk density/Particle density) x 100.

[c] The formula to calculate the porosity volume of a soil-rooting zone is: Porosity volume = Soil volume x (Porosity/100)

[d] The equivalent rootable soil area uses the existing tree strip soil as the baseline to calculate the contribution of the additional porosity volume of the new tree strip and new soil crescent.

[e] the new soil crescent has a base length of 44 m and a width (approximate radius) of 12 m.

[f] The increase (%) uses the existing tree strip as the baseline to calculate.

Site-specific design:

Considerable increase in soil porosity to pump-prime root growth

Slide 34. Research informing practice:
Critical contribution of soil porosity to tree growth.

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Porosity of roadside soil as indicator of edaphic quality for tree planting

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Critical pore-volume threshold
Continuous coarse matrix principle

ABSTRACT

Roadside tree pits commonly suffer from small size, poor soil, and heavy compaction. Their three soil types with different properties, respectively site soil, backfill and rootball, could constrain tree establishment and long-term growth. Sixty-nine soil samples were taken from 19 tree pits, with multiple artificial layers sampled separately, at roadside sites in Hong Kong. They were analyzed for profile characteristics, pH, bulk density and particle-size distributions. Pores were divided by into three classes: (1) unavailable moisture UM at < 0.2 µm (also known as micro-pores); (2) available water AW at 0.2–60 µm (meso-pores); and (3) and air capacity AC at > 60 µm (macro-pores). Critical pore-volume thresholds, namely extreme, marginal and optimal, assessed soil-porosity quality. Site soils were heavily compacted with < 40% and < 30% total porosity, denoting respectively marginal and extreme thresholds, equivalent to bulk density exceeding 1.6 and 1.9 Mg/m³. The upper soil zone was more compacted than middle and lower zones to generate undesirable surface sealing. Backfill and rootball soils had less stressful porosity and bulk-density limitations. Long-term root growth into site soil would be hampered to suppress tree health and stability. The excessively sandy texture, upon compaction to a certain degree, generated a continuous coarse matrix. It established inter-granular contacts and high load-bearing capacity to arrest further compaction. Some AW pores could be sustained for available-water storage to support tree growth. The findings could inform porosity specification in urban soil management to foster roadside tree performance.

1. Introduction

1.1. Urban greening and soil limitations

With increasing population and preference to live in cities, urbanization has progressed at a fast pace in various places. Many cities in developing countries are expanding by sprawling into green fields or raising development intensity in urbanized areas. Some cities in the developed world have adopted densification of built-up lands by in-filling (Lehmann, 2010). As cities are becoming more compact, the attendant problems of degraded environmental quality and livability have aggravated. The urban heat island effect, poor ventilation and low air quality have become common urban maladies. Municipal administrations are attempting to prevent or cure them (Burton, 2002; OECD, 2012; Shi et al., 2016).

Urban greening offers a cost-effective way to improve urban livability and sustainability. A comprehensive urban green infrastructure has been advocated by planting trees and associated vegetation in a city-wide green-space system (Benedict and McMahon, 2002). Greenery can be inserted into the urban matrix through different means (Svendsen et al., 2012; Young and McPherson, 2013). A green infrastructure typology could include inherited and created natural areas, as well as conversion from brown fields and gray fields of building roofs and walls (Jim, 2017a). The roadside strip has been widely enlisted for linear tree planting to penetrate cramped neighborhoods. For some compact built-up areas, the roadside is often the only plantable space for trees.

Roadside planting areas, however, are beset with multiple constraints and stresses to tree growth (Jim, 2017b; Richter, 2007). Above ground, trunk and crown expansion could be physically obstructed by adjoining buildings and their appurtenances, street lighting, traffic signs, advertisement signs, railings, fire hydrants, street furniture, vehicle clearance, sightline clearance for traffic safety, and adequate passage for pedestrian movement. Below ground, the restrictions are equally stifling. If a dedicated tree strip of sufficient width is designated with freedom from underground utility lines and installations, the soil condition for tree growth is usually more favorable (Bieller, 1992). Nevertheless, many roadside sites are not wide enough to furnish it. Instead, inadequate tree pits are often dug in the footpath to induce stifled tree growth, establishment failure, premature decline, and high mortality (Haan et al., 2012; McGrath and Henry, 2014).

Worldwide, millions of roadside trees are accommodated in tree

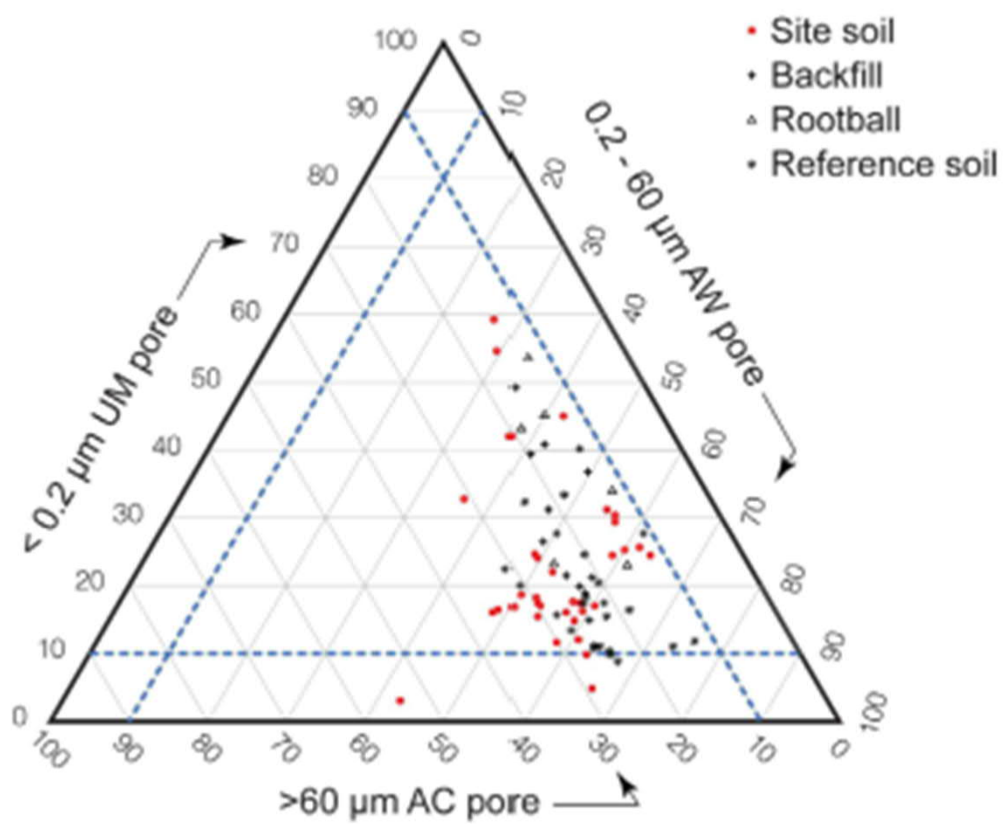
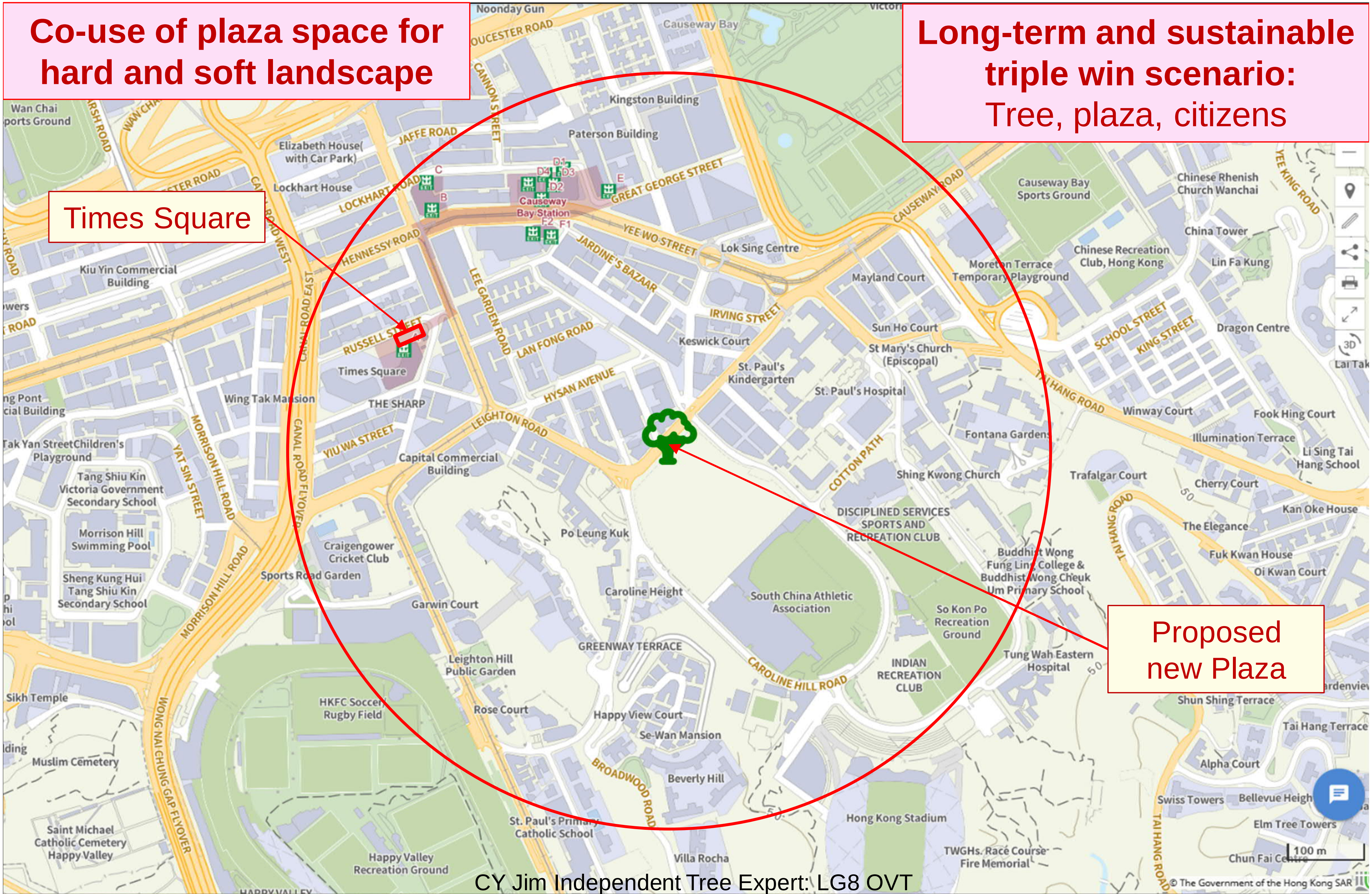


Fig. 2. The porosity triangle showing distributions of four types of soil samples by three cardinal pore-size classes, respectively unavailable moisture (UM), available water (AW) and air capacity (AC) pores. The 10% extreme critical pore-volume thresholds (CPT) for the three pore-size classes have been marked as dashed blue lines. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Slide 35. Only one small town square is found within 500 m radius (covering 78.54 ha) of the proposed plaza in the heavily patronised commercial precinct.



Slide 36. Summary of the proposed OVT protection-cum-rehabilitation scheme.

(1) The tailor-made OVT *protection-cum-rehabilitation scheme* is based on detailed tree and site assessment and understanding of the unique banyan growth habit.

(2) The open soil area compared to the large tree with a sprawling crown is piteously tiny and grossly inadequate.

(3) Despite the legendary banyan vigour and tenacity, the tree's growth form has been severely constrained and shaped by the narrow Existing planting strip.

(4) The tree has exhausted the capacity of the limited soil body, and its growth has reached the allowable upper ceiling.

(5) With evident tree decline in recent years and a dim prognosis, keeping existing growth conditions largely unaltered or applying routine treatments cannot help.

(6) The emaciated OVT demands innovative rehabilitation measures to arrest its decline and revive its health.

(7) The only soil improvement area lies in the Plaza, but it has heavily compacted soil sealed by impermeable paving, which is unsuitable for root growth.

(8) This Scheme adopts innovative soil rehabilitation by improving rootable soil area, soil continuity, connectivity, and quality.

(9) It achieves synergies among the tree, Plaza, and citizens, and co-existence among tree conservation, town planning, and urban amenity.

(10) It offers a rare opportunity to accomplish a substantial OVT rehabilitation case in the dense core of Hong Kong.

(11) It furnishes a fine example of co-using a piece of precious urban land in our compact city for both hard and soft landscaping.

End of presentation
Thank you

Questions and comments are welcome