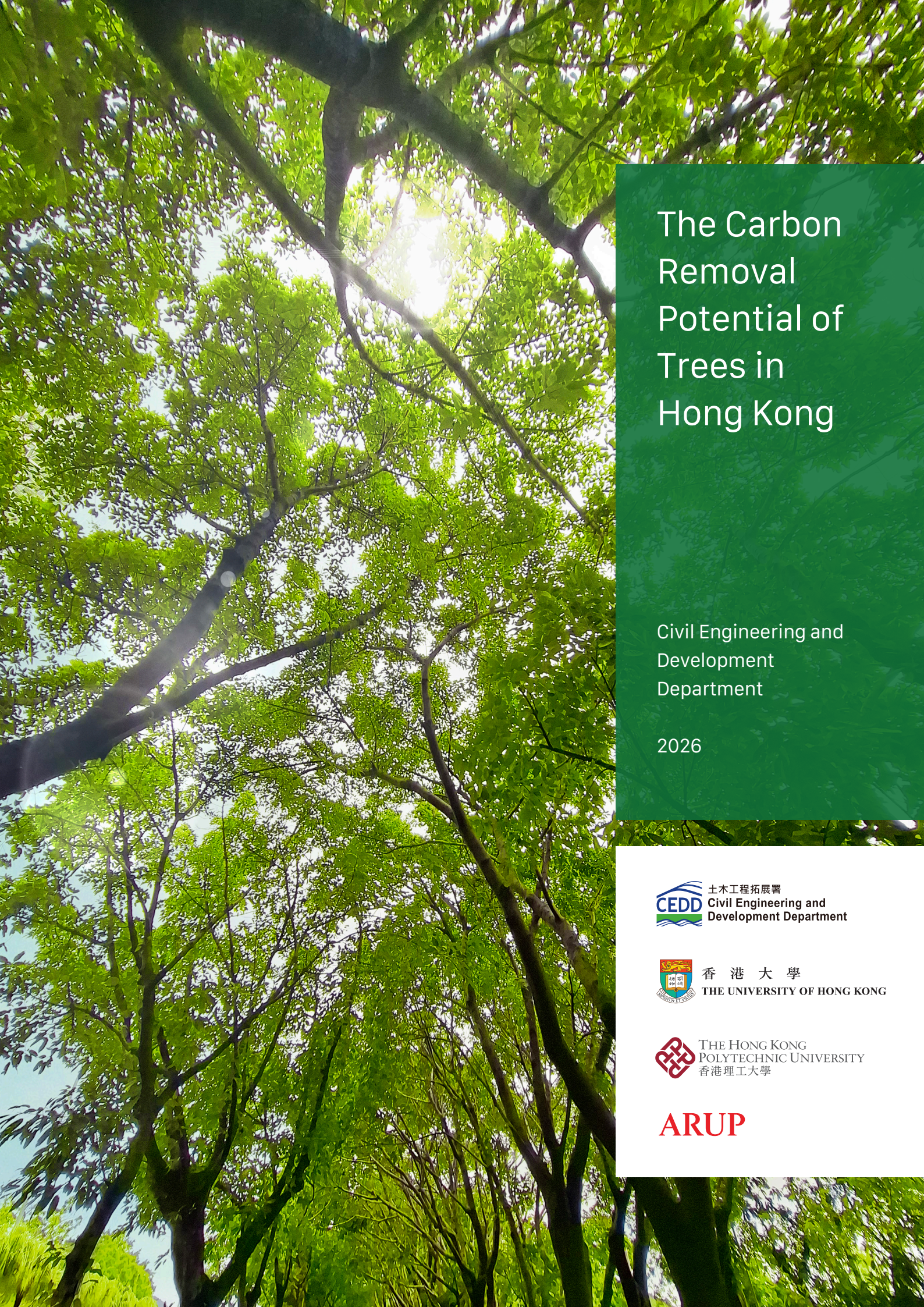

The Carbon Removal Potential of Trees in Hong Kong

Civil Engineering and Development Department

2026

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Preface



Hong Kong is striving towards its ambitious goals of achieving carbon neutrality, the role of nature-based solutions, particularly our urban forests, has never been more critical. The Civil Engineering and Development Department (CEDD) is at the forefront of creating sustainable, green, and resilient New Development Areas (NDA). This Booklet underscores our commitment to integrating enhanced ecological functions into our planning and construction processes.

Planting trees is not for the sole purpose of aesthetic pleasing, they are powerful carbon sinks, essential for mitigating climate change, improving air quality, and enhancing biodiversity. This Booklet highlights the specific carbon removal potential of various tree species for consideration within Hong Kong's unique environment, providing valuable data to guide our landscape design. By understanding and harnessing these natural capabilities, we can significantly boost the carbon sequestration capacity of our NDA and urban greening initiatives. With the hand-in-hand collaboration of renowned academia and local experts, the University of Hong Kong, the Hong Kong Polytechnic University, and Ove Arup & Partners Hong Kong Limited, we have taken these initiatives to another level.

Our study is a pioneer trial with an aim to filling the information gap in Hong Kong. The Booklet offers practical insights for landscape architects, engineers, and planners to better ensure our infrastructure projects contributing more actively to a greener and healthier Hong Kong. I encourage all stakeholders to utilise these findings to their fullest potential but at the same time noting the limitations of the study.

Looking ahead, I see the genuine need to expand the database to include a wider range of species in conjunction with other major ongoing projects. I hope to meet our common goal of planting not just trees, but a sustainable future for generations, making Hong Kong a global leader in green development.

Mr. FONG Hok-shing, Michael, JP.
Director of Civil Engineering and Development

1

Introduction

Chapter 1
Introduction

1.1 Background and Purpose of the Research

As Hong Kong continues to switch to clean energy for electricity generation and electrify transport, all new development areas (NDAs) are aspired to be further enhanced to carbon-neutral communities in the medium and long run. Achieving carbon neutrality hinges on multiple factors, including electricity generation, building energy efficiency, and transportation decarbonization. However, the vital role of trees and green spaces in offsetting carbon emissions deserve greater emphasis. Some signature NDA projects incorporate central parks and extensive planting areas, providing nature-based solutions for removing residual emissions.

Current local guidelines may not fully leverage the carbon removal potential of trees, underscoring the need for accurate estimates and landscape design guidelines to enhance carbon sequestration through strategic tree selection. The absence of precise data on the carbon storage and removal potential of local tree species has prompted this study to address this knowledge gap. To this end, the Civil Engineering and Development Department (CEDD), in collaboration with the University of Hong Kong, the Hong Kong Polytechnic University, and Ove Arup & Partners Hong Kong Limited, has initiated a study to evaluate the practical carbon storage and removal potential of common tree species in Hong Kong.

1.2 Scope and Objectives of the Booklet

This booklet presents a scientifically validated approach along with the compiled data on the carbon storage and removal potential of local tree species evaluated in this study. It aims to offer some insights for informed planting strategies that balance carbon neutrality goals with other key considerations, including ornamental value and species diversity, by integrating carbon sequestration into landscape planning to maximise environmental benefits.

1.3 Disclaimer

This study provides valuable insights, revealing that the carbon removal potential of trees may exceed current benchmarks in local guidelines. However, this potential varies significantly across species. It is critical to note that the field measurements and laboratory data underlying this study are specific to the sampled tree species and their local growth conditions. As such, the findings may not fully capture the diversity of local species or the range of environmental conditions in Hong Kong. This limitation emphasises the need for continued data collection and expansion of the species database to enhance the accuracy and applicability of carbon removal potential estimates. Users are encouraged to view these findings as informative but not exhaustive, supplementing them with additional data and professional judgment for practical applications, e.g. carbon reduction contributing from the urban forest for project-level carbon appraisal within specific development. It should also be noted that the findings are not intended to inform, or be aggregated into Hong Kong's territory-wide GHG Inventory.

2

Basis and Principles of Research

Chapter 2
Basis and Principles of Research

2.1 How Trees Capture and Store Carbon

Trees naturally absorb carbon dioxide (CO_2) from the atmosphere and convert it into organic matter within their wood, roots, and leaves. This process, known as carbon sequestration, is a key natural mechanism that helps reduce greenhouse gases and moderate climate change.

The Carbon Capture Process

Through photosynthesis, trees utilise sunlight to convert CO_2 and water (H_2O) into sugars such as glucose ($C_6H_{12}O_6$):

$$6\,CO_2 + 6\,H_2O \rightarrow C_6H_{12}O_6 + 6\,O_2$$

These sugars are used for respiration, growth, and storage. Over time, they are polymerised into cellulose, hemicellulose, and lignin — the key components of wood and bark that hold carbon for decades.

Where Does the Mass of a Tree Come From?

While it may seem intuitive that a tree's weight comes from the soil, over 95% of its dry mass actually originates from the air. Roots draw in water and nutrients, yet those minerals form only a tiny fraction of total biomass. The bulk — carbon, hydrogen, and oxygen — comes from CO_2 and H_2O absorbed during photosynthesis.

From Air to Wood — How Carbon Adds Up

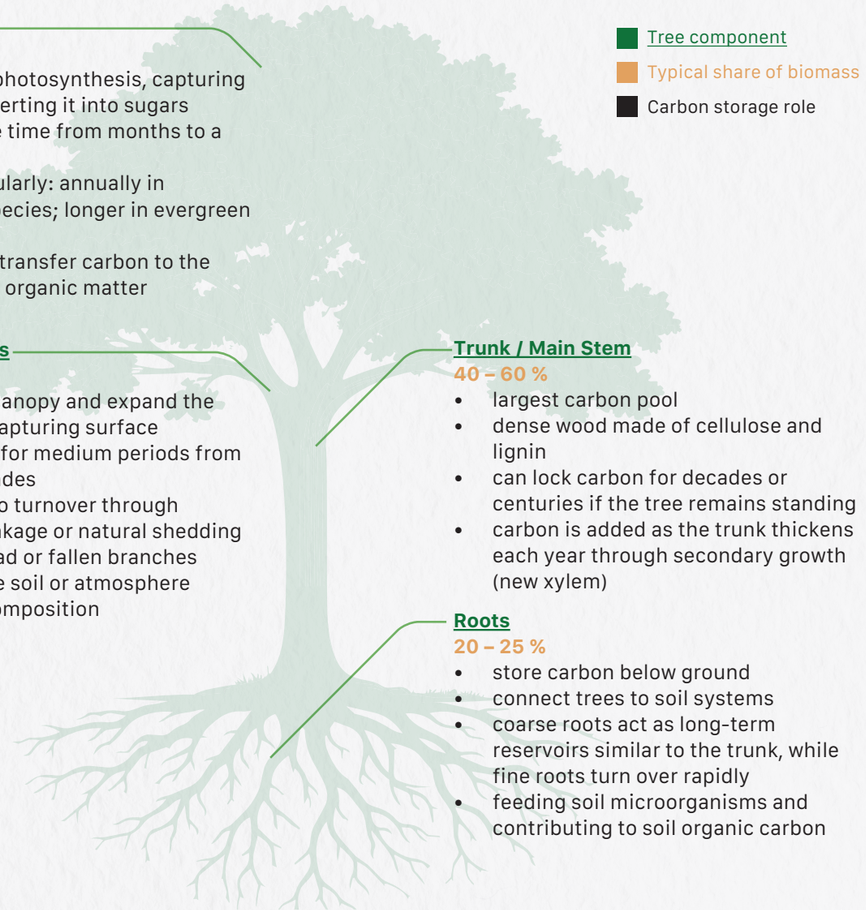
On average, half of oven-dry wood is carbon. Because CO_2 is heavier than pure carbon, each tonne of carbon fixed in wood corresponds to 3.67 tonnes of CO_2 removed from the air:

$$1\ \text{kg dry wood} \approx 0.5\ \text{kg } C \times 44/12 = 1.8\ \text{kg } CO_2 \text{ removed}$$

Each kilogram of dry wood corresponds to approximately 1.8 kg of CO_2 removed from the atmosphere. This factor is used internationally in forest-carbon inventories by the Intergovernmental Panel on Climate Change (IPCC) and the Food and Agriculture Organization of the United Nations (FAO).

Where is Carbon Stored in a Tree?

After capture, carbon is distributed among different parts of the tree — a process known as carbon allocation.



Younger trees supply more carbon to leaves and fine roots; mature trees invest mainly in trunks and coarse roots, which store carbon longer.

Evergreen vs Deciduous Trees: Different Carbon Pathways

Both evergreen and deciduous trees sequester carbon, but the fate of that carbon differs.

Species	During Growing Season	Long Term
Evergreen *(e.g. Cinnamomum camphora* (樟樹), *Machilus chekiangensis* (浙江潤楠), *Schima superba* (木荷)*)*	• retain foliage year-round, but their photosynthetic activity drops during the cool, dry winter when sunlight and temperature are limiting • lower annual carbon removal in comparison with fast-growing deciduous species • continue to assimilate carbon for a longer period of the year	• act as steady carbon holders • dense wood and long-lived leaves • carbon remains stored for longer periods
Deciduous *(e.g. Liquidambar formosana* (楓香), *Rhus succedanea* (野漆樹)*)*	• produce new foliage in spring and grow vigorously • leaves with high photosynthetic capacity, allowing rapid CO_2 uptake • high short-term carbon removal rates	• act as rapid carbon processors • fix CO_2 quickly during the wet season • much carbon returns to the atmosphere through leaf decomposition • replenish soil organic matter and support nutrient cycling that sustains long-term productivity

How Carbon Accumulates and Turns Over as Trees Age

Trees store carbon differently throughout their lives. When young, they grow rapidly, producing new leaves, shoots, and fine roots each year. During this stage, photosynthesis far exceeds respiration, and biomass — and therefore carbon storage — increases quickly. As trees mature, their growth rate slows. More of the living tissue becomes non-photosynthetic (such as bark, heartwood, and large roots), which still respires but no longer captures new CO_2. The tree continues to grow in size, but the net annual carbon gain becomes smaller. Mature trees therefore act as large, steady carbon reservoirs: their dense wood locks in carbon captured over decades, even though yearly additions become smaller.

At full size, a greater share of the tree's energy is spent maintaining existing tissues rather than building new ones. Lower or shaded leaves photosynthesise less, and respiration costs rise (more living tissues to maintain). Eventually, the balance between carbon gain and loss stabilises. In very old individuals, mortality and decay can gradually offset new growth, causing total carbon stocks to level off or decline slightly.

Over time, all trees shed branches, lose roots, and eventually die. When wood decomposes naturally, most of its carbon is slowly released back into the atmosphere as CO_2, though a small fraction becomes soil organic matter. If wood is burnt or decays rapidly in warm, moist conditions, this release happens faster. When wood is reused in long-lasting products such as furniture or construction, the stored carbon remains locked away for longer.

In both natural and urban landscapes, large mature trees provide stability in the carbon cycle. They hold the greatest total carbon and buffer annual fluctuations. In Hong Kong's urban environment, trees are often replaced, extending the lifespan of existing trees through good soil management, root protection, and careful pruning is an effective way to sustain long-term carbon storage.

Key Takeaways

- Carbon sequestration is the long-term storage of atmospheric carbon in tree biomass and soil.
- Over 95% of a tree's dry mass originates from CO_2 in the air, not the soil.
- 1 kg dry wood ≈ 1.8 kg CO_2 removed.
- Around 20–25% of total tree carbon is stored below ground in roots.
- Deciduous species recycle carbon rapidly through leaf fall; evergreens provide stable, long-term storage.
- Older trees remain significant carbon reservoirs even with slower annual growth.

2.2 Factors Affecting Tree Carbon Removal

Not all trees capture and store carbon at the same rate. The amount of carbon a tree can remove from the atmosphere depends on its physical traits, growth pattern, and the environment in which it grows.

Understanding these factors helps in selecting suitable species for different planting sites in Hong Kong and in interpreting differences in measured carbon performance among species.

Wood Density

Wood density reflects how much solid material (dry mass) is contained within a given volume of wood. Trees with dense wood such as *Syzygium hancei* (韓氏蒲桃) or *Cyclobalanopsis* spp. (青岡屬) store more carbon per unit of wood volume because their wood contains more carbon compounds.

However, dense-wood species usually grow more slowly and take longer to reach maturity. By contrast, species with lighter wood (for example *Bombax ceiba* (木棉)) grow faster and remove carbon quickly in the early years but often have lower total storage over time.

The balance between density and growth rate determines whether a species functions as a rapid carbon capturer or a long-term carbon holder.

Maximum Size and Growth Rate

The ultimate size a tree can reach — its height and diameter — sets the upper limit of how much carbon it can store.

Large, tall species have a far greater carbon capacity than smaller or shrubby ones simply because they contain more biomass.

The growth rate affects how quickly a tree approaches that size. Fast-growing species accumulate carbon rapidly in their early years but often level off sooner, while slower-growing species continue adding biomass steadily for many decades.

In Hong Kong, trees planted in compact urban soils or shallow slope pits rarely reach their natural maximum size, which means their potential carbon storage is often lower than in natural forests. Also, some species such as *Ficus microcarpa* (細葉榕) are able to reach their natural maximum size more often than other species in urban areas.



Age, Lifespan, and Mortality Risk

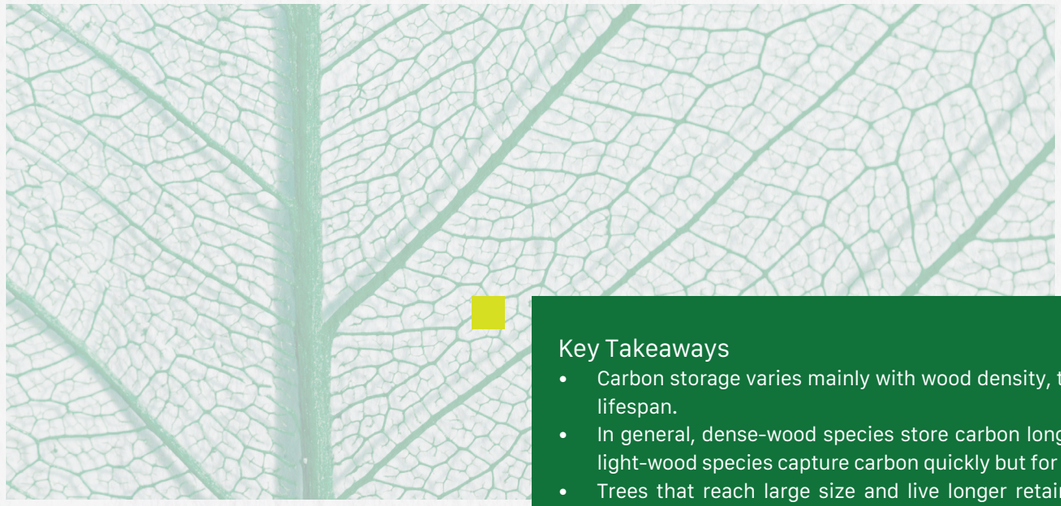
The age of a tree determines its carbon balance. Trees accumulate carbon throughout their lives, with storage rates increasing as they grow larger. While young trees may grow rapidly, it is the large, mature individuals that add the most carbon annually.

Lifespan — how long it remains healthy — is crucial for long-term carbon storage. Lifespan varies species by species; some trees live only 40 - 50 years, while others exceed a century. In urban environments, factors like poor soil, pruning, root damage, or disease can shorten lifespan.

Mortality risk refers to the likelihood of a tree's death or removal within a given year. High mortality risk, whether from typhoons, decay, or construction, can lead to the rapid release of stored carbon. Effective soil management and careful maintenance can mitigate these risks and help keep carbon locked in trees for longer.

Longevity and Structural Stability

Longevity depends on both genetics and the maintenance of a tree's structure and root system. A well-anchored tree in healthy soil can withstand storms and serves as a carbon store for decades. However, frequent removals, heavy pruning, and unstable planting locations can shorten this lifespan and reset carbon accumulation to zero.



Key Takeaways

- Carbon storage varies mainly with wood density, tree size, growth rate, and lifespan.
- In general, dense-wood species store carbon longer but grow slowly, while light-wood species capture carbon quickly but for shorter periods.
- Trees that reach large size and live longer retain the most carbon. Good soil conditions, stable rooting, and careful maintenance are key to keeping carbon locked in the landscape.

2.3 Research Framework and Methodology

This study estimates how much carbon Hong Kong trees store at a given size, and how much carbon they remove from the atmosphere each year as they grow. We estimated above-ground biomass (AGB) and carbon storage in trees using allometric models of Chave et al. (2014). The estimates were validated through field measurements and laboratory testing of trees that were required to be felled under government projects. The research framework is as shown below:

Research Framework

Carbon Storage Estimation by Field Measurements and Laboratory Tests

CO_2 stored = 44/12 x tree volume x ρ x $f_{c.m}$ x 1.265

Where

ρ = wood density = sample dry weight / sample volume

$f_{c.m}$ = measured carbon content %

conversion factor from AGB to total biomass = 1.265 (Luo et al., 2012)

Annual Carbon Removal Potential Estimation

ΔCO_2 (t) = CO_2 (t) - CO_2 (t-1)

Carbon Storage Estimation by Allometric Models

CO_2 stored = 44/12 x AGB x *fc* x 1.265

Where

fc = carbon fraction = 49.37% (Lu et al., 2019)

When height is available

$AGB = 0.0673 \times (\rho \times D^2 \times H)^{0.976}$

When height is not available

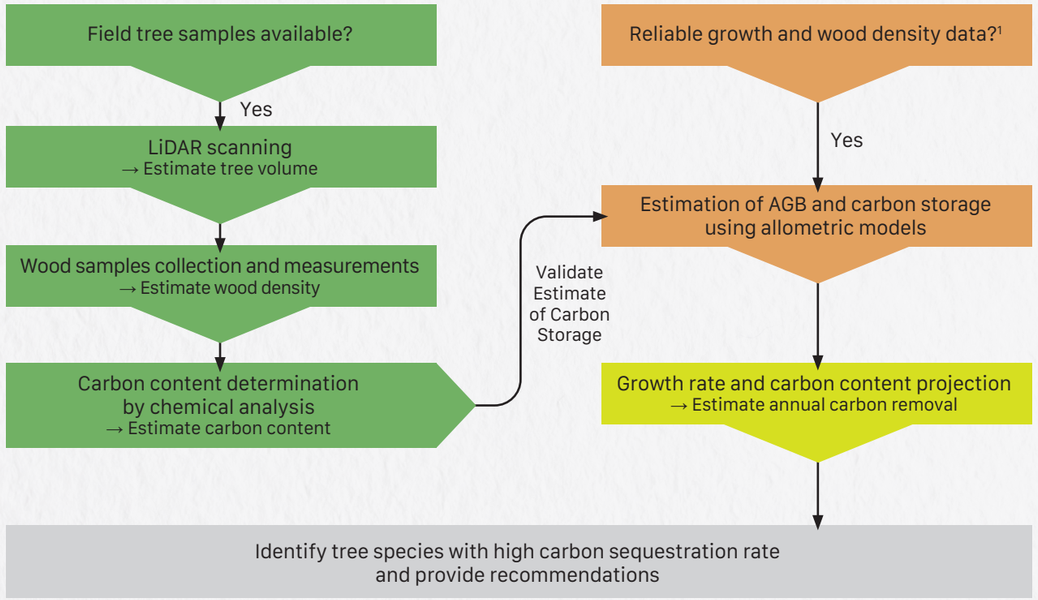
$AGB = \exp(-1.803 - 0.976 \times E + 0.976 \times \ln(\rho) + 2.673 \times \ln(D) - 0.0299 \times (\ln(D))^2)$

ρ = wood density

D = DBH

H = height

conversion factor from AGB to total biomass = 1.265 (Luo et al., 2012)



1. *Data fulfills the three requirements listed in Paragraph 1 of Chapter 3.*

Carbon Storage Estimation by Allometric Models

We utilise trunk diameter (Diameter at breast height, DBH) with wood density and apply a single, peer-reviewed allometric framework to convert tree size → biomass → carbon → CO_2 in a systematic way across species.

There are many published biomass allometric equations worldwide (often species- or family-specific). Those equations work best within their original range, but can be inconsistent across multiple species and sites. To ensure comparability, we adopt the pantropical allometric models of Chave et al. (2014), which were developed using a large, harvested global dataset and explicitly include wood density and either tree height or an environmental parameter. This reduces overfitting and keeps estimates consistent across taxa.

To ensure that this study reflects the environmental and management conditions of Hong Kong, we collected tree data from various sources to estimate the AGB, including:

- **Managed Tree Inventory:** The primary data source comprises trees in urban and plantation settings managed by the Government. Large individuals were primarily focused to ensure that the maximum carbon storage performance of each species was captured.
- **Previous Research Data:** In order to expand the data range in the model, datasets from previous research studies were also integrated. Only trees with repeated measurements from these sources were included, allowing for a broader range of native species to be analysed.

When height is available:

$$AGB = 0.0673 \times (\rho \times D^2 \times H)^{0.976}$$

When height is not available (environmental parameter approach):

$$AGB = \exp(-1.803 - 0.976 \times E + 0.976 \times \ln(\rho) + 2.673 \times \ln(D) - 0.0299 \times (\ln(D))^2)$$

where D = DBH (cm), H = height (m), ρ = wood density (g cm^{-3}), E = environmental stress parameter (In Hong Kong, it is taken as 0.261 according to Chan et al. 2021).

From AGB to total biomass (TB) (including roots):

$$\text{Total Biomass} = AGB \times (1 + 0.265)$$

We include below-ground biomass (BGB) using a root:shoot factor representative of evergreen broad-leaved forests in China (mean BGB/AGB ≈ 0.265) (Luo et al., 2012).

From biomass to carbon and CO_2 absorbed:

Carbon = f_c × Total Biomass (TB)	CO_2 = 44/12 ×C

We adopt a carbon fraction f_c = 49.37% based on Chinese broadleaf measurements (Lu et al., 2019).

Carbon Storage Estimation by Field Measurements and Laboratory Testing

To validate the carbon storage estimated by allometric models, an alternative method was adopted to measure the carbon stored in trees with samples available. In this method, advanced Light Detection and Ranging (LiDAR) technology was employed to collect in-situ LiDAR point cloud data from trees (Fig. 2.1a). High-resolution 3-Dimensional (3D) models were then generated to estimate accurate tree volume (Fig. 2.1f, 2.1g). Moreover, tree samples (including leaves, branches, stem and roots) were collected via destructive sampling in the field for laboratory measurements of wood density and AGB (Fig. 2.1b – 2.1e). Finally, chemical analysis was conducted to determine the carbon content of the collected samples and thus total carbon storage in the individual trees (Fig. 2.2).



Fig. 2.1 - Field measurement and laboratory testing: (a) mobile LiDAR scanning; (b) tree felling; (c) wood samples; (d) over-drying of samples; (e) sample weighing; (f) tree point cloud model; (g) tree 3D model

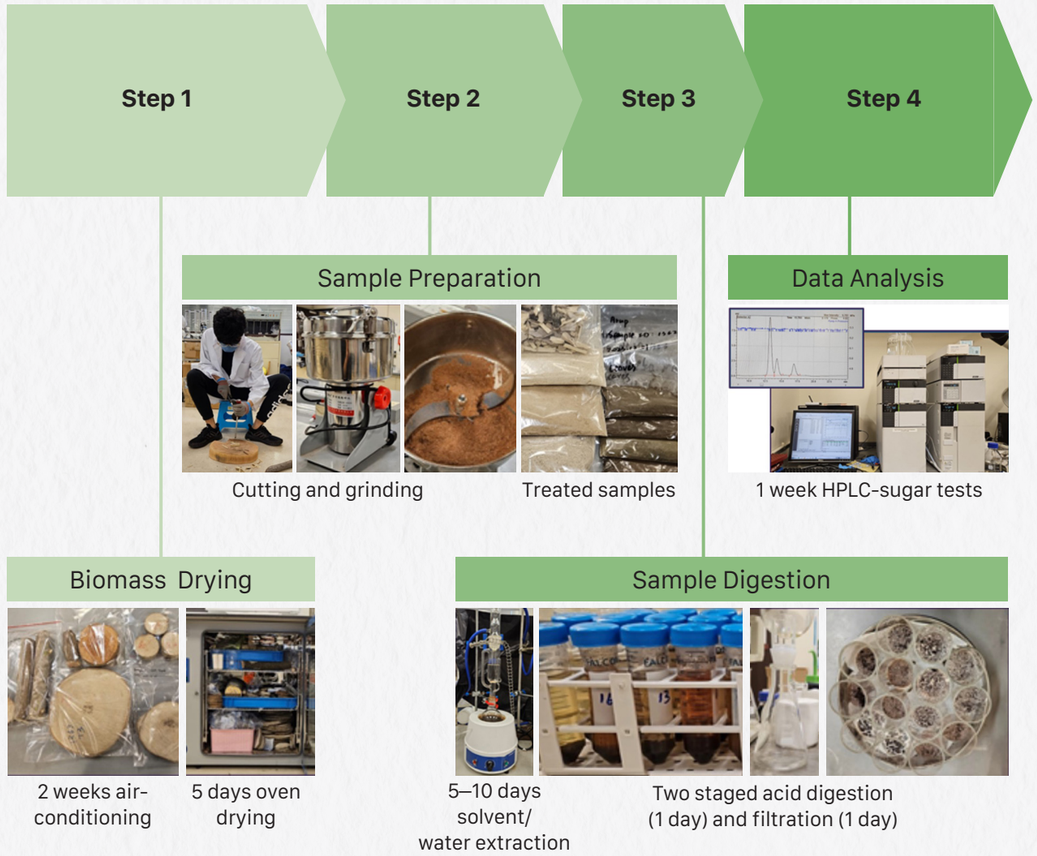


Fig. 2.2 - Chemical composition analysis

This methodology integrates field measurement techniques, such as LiDAR scanning and sample collection, with comprehensive lab tests and data analysis processes, including point cloud analysis, sample processing, and chemical composition analysis. It offers a reproducible framework for estimating AGB and carbon storage of trees in Hong Kong. The detailed guidelines for field measurement and laboratory testing are shown in Appendix A1.

Annual Carbon Removal Potential (Based on Growth Data)

Annual carbon removal is the year-to-year increase in a tree's carbon stock. To estimate it, we trace how trunk diameter (DBH) changes over time with a simple growth curve, then convert each year's DBH into biomass and carbon using the equations above.

Why a Growth Curve?

Field records usually give DBH at a few points in time (e.g. 2019, 2022, 2024), but not every year. A growth curve fills the gaps and gives a smooth, realistic DBH trajectory — fast when the tree is young, slowing as it nears its maximum size.

We describe diameter through time with the von Bertalanffy form (Dale et al., 1985):

$$d(t) = a \times (1 - e^{-kt})$$

where d(t) is DBH at time t, a is the maximum DBH under local conditions, and k is a growth constant. This represents rapid early growth that slows as the tree approaches its maximum size.

How Do We Get the Growth Constant (k)?

To calculate species-specific growth constants (k), we selected trees with repeated DBH measurements (e.g. recorded in 2020 and again in 2023) so that actual diameter increments over time under local conditions were captured in the model. For each modelled species, we examined how much each tree's DBH moved toward its typical maximum size over the measurement interval, then averaged these values across many individuals to derive the species' growth constant (k).

- If trees thicken quickly between measurements, k is higher (faster gains in CO_2).
- If they thicken slowly, k is lower (steadier, longer-term accumulation).

Annual Carbon Removal

For each year t, we compute biomass from d(t), then convert to carbon and subsequently to CO_2. The annual carbon removal for year t is simply the difference between year t and year t−1:

$$\Delta CO_2\,(t) = CO_2\,(t) - CO_2\,(t-1)$$

Key Takeaways

- We convert simple measurements (DBH and wood density) into biomass, then carbon content and CO_2 removed from the atmosphere, using allometric equation developed by Chave et al. (2014).
- Annual CO_2 removal is derived from a growth curve: repeated DBH readings of the same trees indicate a species' growth rate (k), letting us estimate year-by-year DBH, biomass, and CO_2.

2.4 Information Gap in the Local Context

Hong Kong's tree diversity is exceptionally high, with over 400 native and commonly planted species, yet detailed biological data for most of them remain limited. While government departments have collected extensive information on tree location, health condition and size, key parameters required for accurate carbon estimation are still incomplete.

Growth-rate Profiles and DBH Increment Data

For most tree species in Hong Kong, growth rate patterns — that is, how DBH and height change with age — are not well understood. It is still unclear whether different species follow a linear, S-shaped, or other growth profile under local conditions. Repeated DBH measurements exist for a subset of trees through Tree Risk Assessment (TRA), but these data are available for only a proportion of species and usually cover limited time spans.

Without longer-term repeated measurements, it is difficult to define how rapidly trees approach maturity or how their growth responds to environmental factors such as soil constraints, slope conditions, and pruning. Developing a local database of growth-rate curves for common species would allow more accurate projections of annual carbon accumulation and total carbon stock over time.

Maximum Tree Size of Local Species

Accurate modelling of tree growth and carbon storage requires knowing the maximum size (height and/or DBH) a species can reach under mature conditions. However, determining this parameter is challenging in Hong Kong because of its historical deforestation and relatively young secondary woodlands. Most of today's trees were established after the 1950s–1970s, meaning few individuals have yet reached their biological size limits. Old-growth specimens over 100 years old — those that define a species' true maximum size — are rare or absent in many species.

A systematic survey of the largest existing individuals of each species across Hong Kong's parks, woodlands, and country parks would help refine local growth models and improve carbon stock projections.

Wood Density Data for Hong Kong Species

Wood density (ρ) is a key variable in many allometric equations to estimate tree biomass. Wood density data were derived primarily from local specimen measurements, supplemented by data from a Taiwan-based study (Chao et al. 2022) and the Global Wood Density Database (Fischer et al., 2026) for species lacking local measurements.

Even within a single species, wood density can vary with climate, site quality, or growth conditions. Relying solely on global averages may therefore lead to bias in biomass estimates.

Collecting and publishing locally measured wood densities for common native and planted species would immediately enhance the accuracy of biomass and carbon models used in Hong Kong projects.

Allometric Equation

- Allometric equations estimate a tree's biomass from simple measurements taken in the field. They use trunk DBH, height and wood density (ρ) to estimate AGB, which we then convert to carbon and CO_2. For example, Chave et al. (2014) suggested that, biomass increases with ρ × DBH^2 × height, so thicker, denser trees store much more carbon even if they look similar in height.

Lifespan and Mortality Rate of Tree Species

The longevity of a tree — how long it can remain alive and structurally sound — is central to its carbon-storage potential.

A species that grows quickly but has a high mortality rate may never reach its full storage capacity, whereas long-lived species accumulate and retain carbon for many decades.

At present, species-specific mortality data for Hong Kong's urban and slope trees are scarce. Most mortality information is incidental, recorded through tree removal, storm damage, or disease reports rather than long-term monitoring.

Without this information, models may overestimate total carbon capture, especially in NDAs where young trees experience high mortality before maturity.

Quantifying typical survival curves for common species — under different site types (roadside, park, slope, woodland) — would help correct projections and improve species selection for long-term planting success.

Key Takeaways

- Reliable carbon estimates require local data on tree growth, size, wood density, and lifespan.
- In Hong Kong, these key parameters remain incomplete for most species, limiting the accuracy of carbon models.
- Building a local database with repeated measurements, verified wood densities, and species-specific survival rates would greatly improve future carbon assessments and species planning for new developments.

This information gap restricts the precision of allometric models and may cause either overestimation or underestimation of carbon sequestration potential. Addressing this gap would greatly enhance the reliability of future carbon appraisal and improve species selection for new developments.

3

Research Results and Analysis

Chapter 3
Research Results and Analysis

The information gap mentioned in Chapter 2 restricts the number of tree species for which we can assess carbon performance. To ensure reliable estimates of carbon storage and annual carbon removal, rigorous data screening was applied. As a result, only 51 species with data satisfying all the following quality requirements were identified, modelled and reported in this study:

1. repeated DBH measurements of the same individual trees were available from reliable local datasets, enabling accurate growth-curve fitting and calculation of annual CO_2 sequestration;
2. species-specific wood density values were confirmed from local measurements or peer-reviewed literature (an essential input parameter for the allometric biomass equations); and
3. a verified record of maximum attainable DBH was available to constrain the upper limit of the growth model.

These 51 species included commonly planted and nursery-available species, native and exotic species, and covered species of different mature size classes to reflect natural woodland structures. The detailed modelled results, including carbon storage and annual carbon removal of these 51 species, are summarised in **Appendix A2.**

3.1 Data Interpretation and Limitations

It is essential to recognize that carbon stock estimations vary across studies, as they are influenced by the methodology, data sources and environmental contexts of each study. While various publications (e.g., Ng et al., 2025) provide valuable insights into tree performance, results may differ from this analysis due to several key factors:

- **Sampling Strategy:** This study utilises data primarily from trees in urban and plantation settings managed by the Government, supplemented by datasets from previous research studies. Large trees of native species in fung shui woods and mature secondary forests are less represented in our dataset, which may lead to a different species composition and size distribution compared to other studies.
- **Sample Size and Statistical Representation:** For certain species, the available sample size within our dataset may be limited. This could exclude exceptionally large individuals present in Hong Kong that were not captured in our dataset. As a result, the carbon performance for these species may be conservatively estimated.

- **Growth Rate and Annual Removal:** Analytical focuses vary across the literature. While some researches (e.g. Ng et al., 2025) prioritise the largest known individuals to demonstrate the potential carbon stock of a species, this study evaluates performance based on growth rates, annual removal rates and total stored carbon. This approach accounts for the varying rates at which different species sequester carbon throughout their lifecycle.

3.2 Variation in Carbon Removal Capacities among Tree Species

Not all trees remove carbon at the same rate or consistently over time. From the modelled results, we identified two distinct growth patterns that influence long-term carbon performance:

- **Continuously Accumulating Species:** Carbon accumulation continues into late maturity (within the 100-year modelling timeframe).
- **Early Plateauing Species:** Carbon removal peaks early in life, and then levels off, with minor increases thereafter.

These patterns reflect ecological growth strategies observed across tropical and subtropical forests: long-lived, late-successional species tend to accumulate more biomass over time, while pioneer or early-successional species grow quickly but plateau after early maturity (Poorter et al., 2008; Brienen et al., 2020).

Continuously Accumulating Species

These trees typically exhibit conservative life-history traits. They grow gradually in early stages but continue expanding in trunk diameter and biomass for many decades. Their annual CO_2 removal often increases into mid- and late maturity (Stephenson et al., 2014; Mildrexler et al., 2020).

Key characteristics of this group include:
- High wood density, allowing more biomass per unit volume;
- Longer lifespans and low annual mortality;
- Shade tolerance or late-successional species, forming canopies of woodland.

Examples include *Ficus virens* (大葉榕), *Albizia lebbeck* (大葉合歡), *Pterocarpus indicus* (紫檀), *Ficus elastica* (印度榕), *Litsea monopetala* (假柿木薑子) etc.

These trees tend to have dense wood, expansive crowns, and huge ultimate size, and are often late-successional species (Stephenson et al. (2014)). Their long-term carbon value far exceeds fast-growing trees, even if their early growth is modest.

While these species are described as 'continuously accumulating' in this study, this refers only to trends within the 100-year modelling timeframe. In reality, all trees will eventually reach biological limits where growth and carbon removal slow or stop. However, some species can live for several hundred years under favourable conditions, with growth only plateauing at much later stages beyond the scope of this analysis.

Early Plateauing Species

These species grow rapidly when young, generally reaching maximum annual removal by age 20 - 50 as shown in Charts A2-1 to A2-3. Beyond this point, their carbon accumulation plateaus, with minimal subsequent growth. Their lifetime carbon stock is considerably lower.

Biologically, these species show traits associated with fast-return strategies:

- Lower wood density, enabling rapid but short-lived growth;
- Shorter lifespan;
- Generally smaller in size;
- Shade-intolerant and early-successional species, adapted to open, disturbed environments such as landslides.

Examples include *Acacia confusa* (台灣相思),*Sterculia lanceolata* (假蘋婆), *Syzygium hancei* (韓氏蒲桃), etc.

Although their carbon removal potential cannot compare to the continuously accumulating species, they serve important ecological and landscape functions, such as slope stabilisation, early canopy, and biodiversity support. They also provide fast, early contribution to carbon sequestration.

Practical Implications for Urban Forestry

In the *Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings* (EPD and EMSD, 2026), a removal factor of 23 kg CO_2/tree/year is suggested to be applicable to all trees commonly found in Hong Kong which are able to reach at least 5 metres in height[2] within 5 years. While this is a useful baseline for planning and carbon reporting, our analysis suggests many continuously accumulating species exceed this rate, particularly as they get mature as shown in **Charts A2-1** and **A2-2** at **Appendix A2**. Examples include *Albizia lebbeck* (大葉合歡), *Cinnamomum camphora* (樟樹), *Ficus elastica* (印度榕), etc.

By contrast, some fast-growing species or early plateauing species are unable to remove 23 kg CO_2/year even after age 50. This suggests that species selection is as important as planting quantity. In areas with limited planting space such as roadside or urban parks, high-capacity and long-lived trees provide far greater carbon return per unit area.

2. *The height growth of a tree is affected by multiple factors, including species traits, site quality, growing environment and climatic conditions*

Key Takeaways

- Trees follow distinct carbon accumulation trajectories: steady accumulators and early plateauing species.
- Continuously accumulating species have a removal rate much higher than 23 kg CO_2/tree/year in mature stages.
- Strategic planting should prioritise long-lived and structurally large species for long-term CO_2 removal.

3.3 Correlation with Field Measurements and Laboratory Tests Results

To evaluate the applicability of the allometric equation (Chave et al., 2014) in Hong Kong, model-estimated carbon stored was compared with that obtained from destructive field measurements and laboratory analysis of the 25 sampled trees[3] (Fig. 3.1).

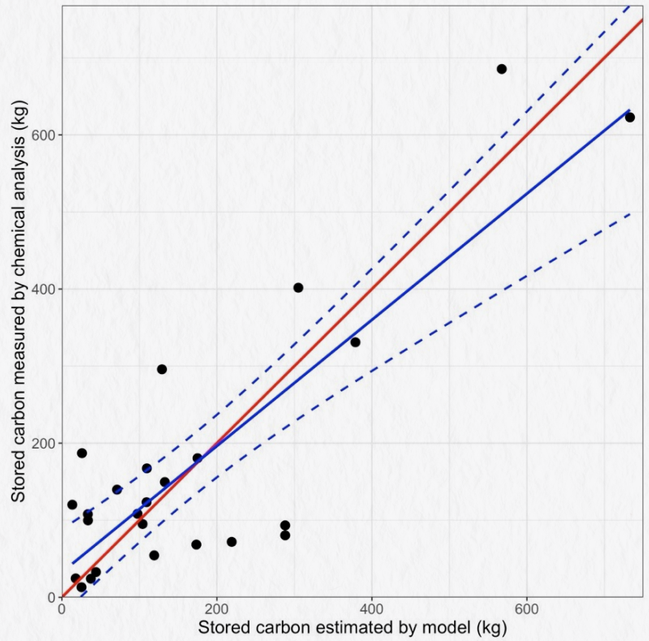


Fig. 3.1 - Comparison between model-estimated and measured carbon stored in sampled trees. The blue solid line shows the fitted linear regression, and the dashed blue lines indicate the 95% confidence interval. The solid red line represents the 1:1 ratio, indicating where the estimated carbon value is exactly the same as the measured value.

Each point in Fig. 3.1 represents one sampled tree, with the x-axis showing the carbon stored estimated by the model and the y-axis showing that measured from field and laboratory testing. Overall, the model-estimated values are generally close to the measured values, as reflected by the fitted regression line (solid blue line) and an R^2 value of approximately 0.70, which indicates that the model explains a considerable proportion of the observed variation in measured carbon stored.

3. *Details of the sampled trees are summarised in Table A2-2 of Appendix A2.*

The figure also includes a 1:1 reference line (solid red line), indicating where the estimated carbon value would be exactly the same as the measured value. Most data points are distributed close to this line. Nonetheless, exact matching between model estimates and laboratory measurements cannot be expected. Several factors contribute to differences between the two approaches:

1. **Differences in Site Conditions and Maintenance**
   Trees of the same species can grow very differently depending on where they are planted and the level of care they receive. Factors such as sunlight, soil condition, water availability and pruning history all affect how much biomass a tree can build. These differences are not fully reflected by DBH alone.
2. **Differences between Open-grown and Isolated Trees**
   Trees growing in open areas usually develop wider crowns and heavier branches. In contrast, trees growing closely together in dense stands tend to form narrower crowns because they compete for light. As a result, two trees with the same DBH and height can still have very different biomass.
3. **Characteristics of General Allometric Models**
   The allometric model was developed using global datasets across many forest types. Its purpose is to provide broadly applicable biomass estimates rather than exact values for individual trees. Structural features such as crown architecture, branching distribution and site-specific growing history are not explicitly included and therefore contribute to deviations from measured values.

Given these constraints, exact matching at the individual level is not realistic. Nonetheless, the R^2 value of approximately 0.7 indicates that the model effectively captures the overall biomass patterns of trees in Hong Kong. This provides a practical basis for estimating above-ground biomass and carbon storage across large areas.

The application of a general model is particularly advantageous in NDAs, where large numbers of trees are planted and destructive sampling cannot be conducted. Because the model relies only on easily measured variables such as DBH and wood density, biomass and carbon storage can be updated regularly as trees grow, supporting long-term monitoring and planning without damaging any trees.

3.4 Key Observations from Species-Level Carbon Modelling

This section summarises the key observations from this study, all of which have implications for tree selection, long-term landscape planning, and carbon-related decision making.

Variation in Carbon Removal Across Species

The modelled results reveal that tree species differ significantly in how much carbon they can store. These differences are driven by species traits such as lifespan, mature size, and wood density.

For example, *Ficus virens* (大葉榕) — a native semi-deciduous species with broad crown — stores over 20 tonnes of CO_2 by age 100 in our model. In contrast, *Rhus succedanea* (野漆樹), a small, fast-growing native species, stores less than 0.2 tonnes over the same period. These differences reflect contrasting life strategies: some species grow large and continue accumulating carbon for decades, while others reach their limit early in life.

Such variation has clear implications for planting design. Choosing trees that grow large and live long can remarkably increase total carbon stored per planting space, especially in compact urban settings.

Many Species Capture over 23 Kg Co_2per Year

A commonly used figure for CO_2 uptake by urban trees is about 23 kg CO_2/tree/year, according to the *Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings* (EPD and EMSD, 2026), This value is suggested to be applicable to trees capable of growing at least 5 m tall and represents an average annual sequestration rate over the life cycle of the trees. It serves as a general reference for typical trees, not a precise rate for every species in all situations. Indeed, the guideline cautions that actual CO_2 removal varies by tree species, climate, and management, and it encourages using species-specific data or recognised methods (e.g. IPCC, 1996) when available. Therefore, the value of 23 kg CO_2/tree/year can serve as a rough estimate of annual carbon removal, but it must be applied with caution and should not be regarded as a universally applicable constant in carbon calculations.

From the models in this study, large canopy trees such as *Ficus virens* (大葉榕) and *Albizia lebbeck* (大葉合歡) capture over 23 kg CO_2/tree/year within their first decade, and continue absorbing CO_2 at several times that rate through maturity. Others, like *Cinnamomum camphora* (樟樹), may start slower but ultimately maintain high annual removal into late maturity. These findings confirm that planting high-performing species can deliver far greater climate value over time - only if trees are supported through maturity. Fig. 3.2 below indicates the annual CO_2 removal rate of the 51 tree species modelled, with species capturing more than 23 kg CO_2/tree/year at age 30 labelled.

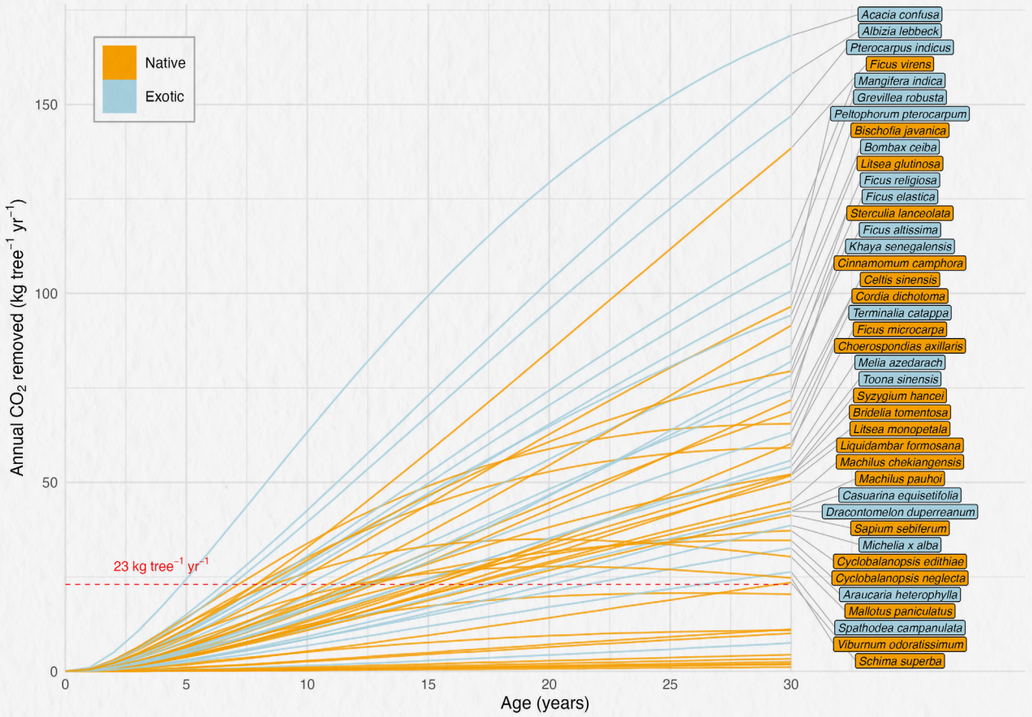


Fig. 3.2 – Annual CO_2 Removal Rates of Trees in Hong Kong

Tree Age Matters – and so Does Retention

Carbon removal is a gradual process. Most trees in the dataset show relatively low annual CO_2 removal during their early years. The majority of long-term carbon benefits occur after age 30–40, once trees have developed substantial biomass.

Species classified in Chapter 3.1 as "continuously accumulating" - such as *Ficus elastica* (印度榕), *Pterocarpus indicus* (紫檀) and *Litsea monopetala* (假柿木薑子) - continue to increase carbon storage well beyond age 75 in the model. These trees remain active in carbon removal even in late maturity.

This implies an important message for urban carbon planning: planting is only the beginning. For trees to deliver meaningful carbon benefits, they must be protected, maintained and allowed to grow old. Retaining large, healthy trees is one of the most effective ways to sustain urban carbon storage.

Key Takeaways

- Tree species vary widely in carbon storage - from under 1 tonne to over 20 tonnes CO_2 by age 100.
- Many tree species exceed 23 kg CO_2/tree/year in carbon removal once mature, especially large-canopy and long-lived species.
- Trees remove far more carbon in late maturity stage - making tree retention just as important as tree planting.

4

Species Showcase: Carbon Removal Performance and Landscape Design Considerations

Chapter 4

Species Showcase: Carbon Removal Performance and Landscape Design Considerations

Tree species differ substantially in their capacity to remove carbon dioxide from the atmosphere. Variations in growth rate, wood density, lifespan, and mature size all influence the amount of carbon accumulated throughout a tree's life cycle. The analysis presented in Chapter 3 showed that some species achieve high annual carbon removal rates early in their life, while others accumulate carbon more steadily but sustain uptake over much longer periods.

The results presented in this chapter were derived from the best available local growth records using the von Bertalanffy growth model. Given their data-driven nature, they should be regarded as indicative only. Tree growth is a dynamic process affected by numerous biophysical and management factors — including soil conditions, nutrient availability, water regime, competition, pruning, pests and diseases, and other environmental factors. Consequently, the actual carbon removal capacity of any species in a given site may vary widely from the values presented here.

The purpose of this chapter is to support informed species selection — integrating carbon storage performance with ecological, aesthetic, and practical landscape design needs in NDAs and other urban contexts.

In this chapter, ten species (five native and five exotic) are presented as a showcase of species demonstrating relatively strong modelled carbon removal performance. Rather than selecting strictly by the highest modelled carbon performance, species were also chosen to represent a diversity of families, growth forms and site applications, and to avoid over-representation of closely-related species (e.g. multiple Ficus spp.) or species with known management concerns (e.g. early senescence or structural risk) despite their high modelled performance. This selection is intended as a resource for understanding the characteristics of various tree species, rather than as a set of definitive recommendations.

Each species profile summarises growth characteristics, ecological traits, and indicative carbon removal performance. Charts illustrate the relationship between tree age and annual CO_2 removal rate, allowing comparison with the reference value of 23 kg CO_2/tree/year (EPD & EMSD, 2026). While this benchmark provides a useful baseline, practitioners should interpret it with caution and adapt species choices according to local site conditions and long-term management considerations.

Cinnamomum camphora (L.) J.Presl (樟樹)



Photo by Hong Kong Herbarium, AFCD

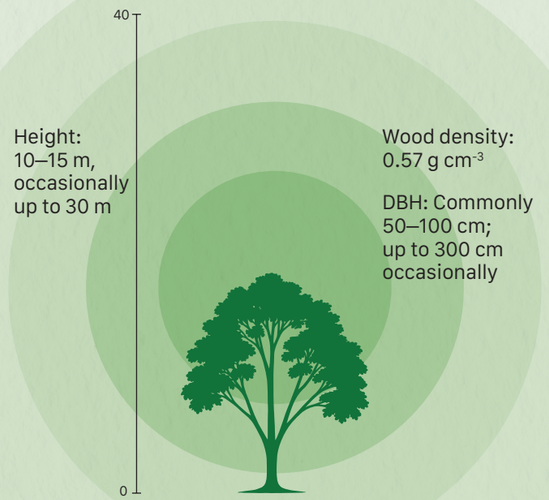
A. Basic Information

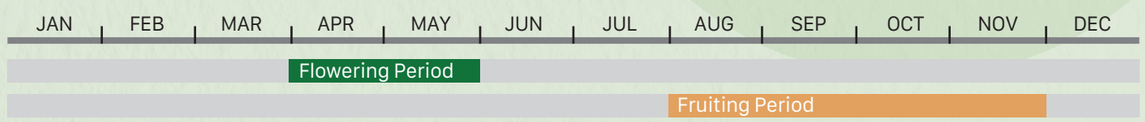
FAMILY Lauraceae

ORIGIN Native to Southern China

HABIT Evergreen tree

FORM Spreading crown





Growth Environment	• Prefers full sun but tolerates light shade; thrives in lowland sparse forest and near villages. • Grows well in moist, loose, slightly acidic soil but shows good adaptability to a wide range of soil textures and urban conditions.
Biodiversity Value	• Host plant of the butterfly *Graphium sarpedon* and *Charaxes bernardus* (LCSD, 2025). • Fruits are consumed by frugivorous birds.
Market Availability	Abundant in the local nursery.

Cinnamomum camphora (L.) J.Presl (樟樹)

B. Carbon Performance Summary

The growth of *Cinnamomum camphora* (樟樹) exhibits a continuous and sustained increase with age. Modelled results indicate that its annual CO_2 uptake exceeds 23 kg CO_2/tree/year after approximately 13 years as shown in the left chart below. By 100 years, an individual tree may remove more than 12 tonnes of CO_2 from the atmosphere. In suitable conditions and when left undisturbed, individuals exceeding 100 years in age are possible, further enhancing the species' long-term value as a stable carbon sink.

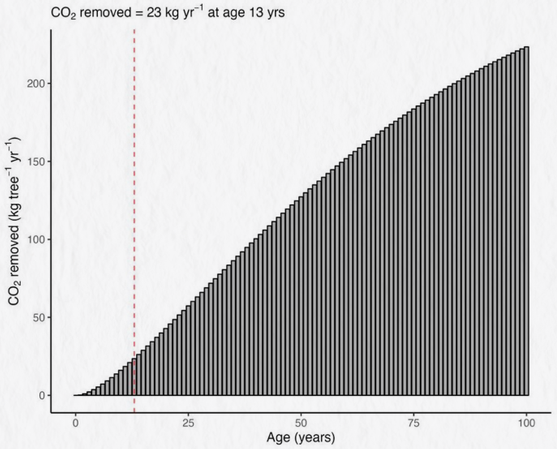


Fig. 4.1 - Annual CO_2 removed by Cinnamomum camphora *over 100 years*

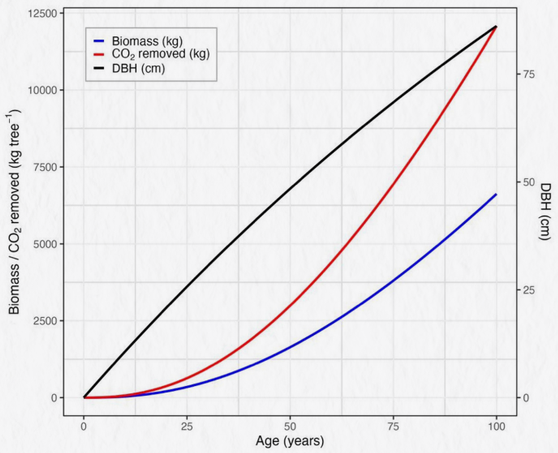


Fig. 4.2 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Cinnamomum camphora *over time*

C. Design and Management Implications

Spacing and Soil Provision

The Old and Valuable Trees (OVT) Register records mature *Cinnamomum camphora* reaching heights up to 27m and crown spreads of 22m. For open planting sites, *Cinnamomum camphora* (樟樹) should be planted at least 10 m spacing (Ng et al., 2025) to ensure sufficient lateral space for long-term canopy and root development. A minimum soil volume of 24 m^3 should be provided for trees with a mature crown spread greater than 8 m (GLTMS, 2023a).

Site Selection and Tolerance

Cinnamomum camphora (樟樹) is widely used in Hong Kong landscapes and is suitable for open sites, parks and woodlands. It performs best under full sun to light shade, tolerating a range of soils from slightly acidic to neutral, but should be avoided in periodic waterlogged or severely compacted sites. It should be planted at more open sites such as parks rather than space-limited sites such as a roadside and central divider.

Lifecycle Management

Given its large mature size and dense crown, regular inspection and pruning are recommended to maintain crown balance and reduce wind load, especially in exposed locations.

Albizia lebbeck (L.) Benth. (大葉合歡)



Photo by Hong Kong Herbarium, AFCD

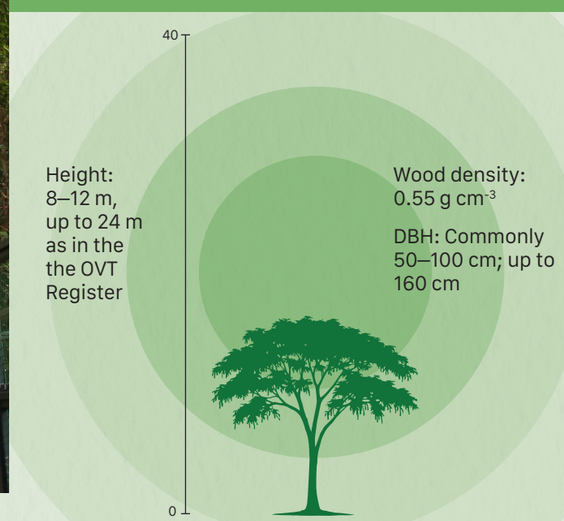
A. Basic Information

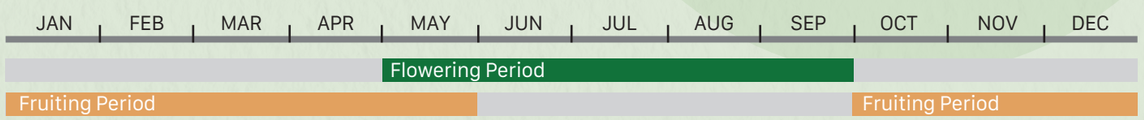
FAMILY Fabaceae

ORIGIN Exotic to Hong Kong; native to Indian Subcontinent to Myanmar

HABIT Deciduous tree

FORM Broad, umbrella-shaped crown





Growth Environment	• Widely cultivated for its broad crown that provides shade in hot summers. • Its frequent use as a street or ornamental tree in Hong Kong suggests good adaptability to urban settings, preferably in exposed sites.
Biodiversity Value	• Host plant of the butterfly *Polyura athamas athamas* (GLTMS, 2021b). • A nectar source for many other insects.
Market Availability	Commonly available in the local nursery.
Other Value	Nitrogen-fixing species, approximately 44% of its nitrogen in plant tissue derived through symbiotic fixation (Kadiata and Mulongoy, 1995).

B. Carbon Performance Summary

Albizia lebbeck (大葉合歡) demonstrates rapid early growth and a high carbon sequestration rate. Annual CO_2 uptake exceeds 23 kg CO_2/tree/year by age 7, increasing sharply through its early decades. By approximately 50 years, cumulative CO_2 removal exceeds 6 tonnes per tree, after which annual uptake begins to level off as growth slows.

Albizia lebbeck (大葉合歡) provides substantial carbon benefits, particularly during the first few decades after planting, offering high early carbon-sequestration performance.

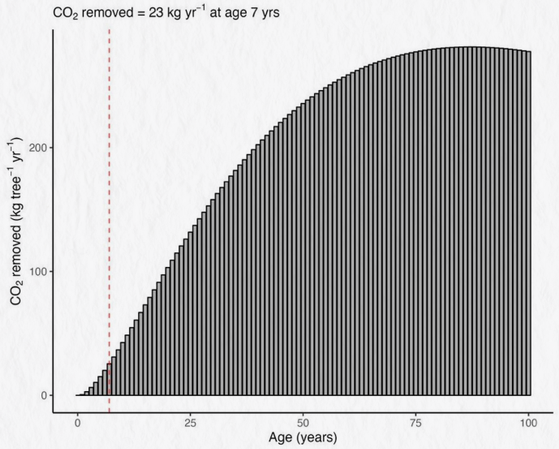


Fig. 4.3 - Annual CO_2 removed by Albizia lebbeck *over 100 years*

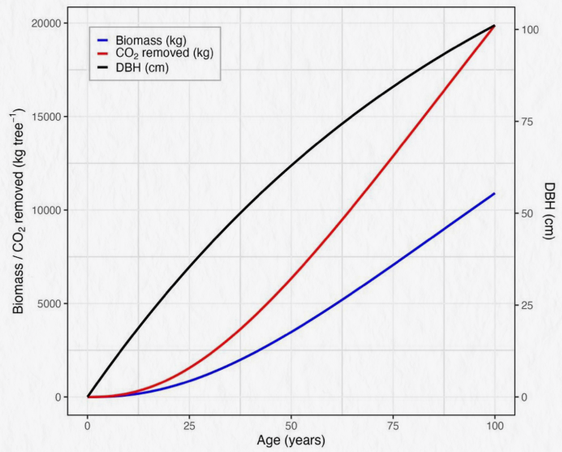


Fig. 4.4 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Albizia lebbeck *over time*

Albizia lebbeck (L.) Benth. (大葉合歡)

C. Design and Management Implications

Spacing and Soil Provision

Albizia lebbeck (大葉合歡) develops a broad, umbrella-shaped crown, with local Old and Valuable Tree (OVT) records showing heights up to 24 m and crown spreads of about 24 m in mature individuals (OVT Register). To allow for full canopy development, spacing of at least 10 m between trees is recommended. A minimum soil volume of 24 m^3 should be provided for trees since its mature crown is often greater than 8 m.

Site Selection and Tolerance

Albizia lebbeck (大葉合歡) is widely cultivated as a shade and street tree. It performs well in full sun and well-drained soils, and tolerates a broad range of soil pH. It is also a nitrogen-fixing species, which can help improve soil fertility (Kadiata and Mulongoy, 1995). However, compacted soil would suppress its growth (Asif et al., 2023). Also, given its wide crown development, it is preferably planted in parks and other open landscapes, but not in confined locations where root and canopy development would be restricted.

Lifecycle Management

Given its large mature size and dense crown, *Albizia lebbeck* (大葉合歡) should receive regular inspection and pruning to maintain crown balance and reduce wind load. The species has been occasionally recorded as a host of wood-decay fungi, including *Fuscoporia senex* (老褐孔菌) and *Ganoderma lucidum* (赤靈芝), mainly where wounds or basal cavities are present (GLTMS, 2020). Good site conditions and careful maintenance can effectively minimise these risks, allowing the species to perform for carbon sequestration purpose.

Ficus virens Aiton (大葉榕、黃葛樹)



Photo by Hong Kong Herbarium, AFCD

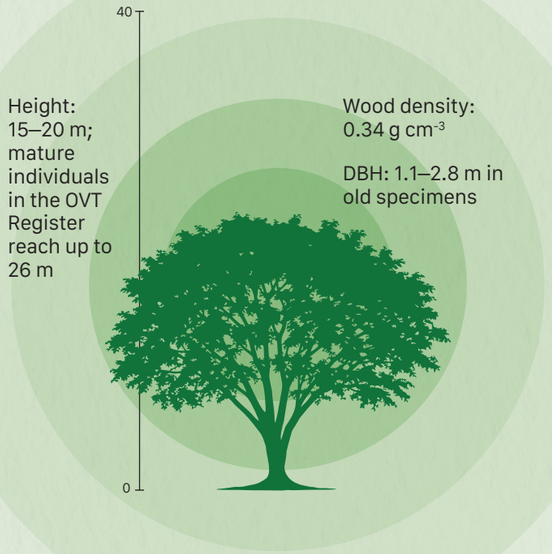
A. Basic Information

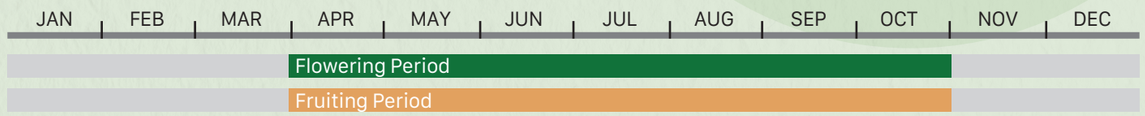
FAMILY Moraceae

ORIGIN Native to Hong Kong and South China

HABIT Semi-deciduous tree; with buttress roots or prop roots, aerial root not well developed.

FORM Broad-spreading crown





Growth Environment	• Prefers full sun, no strict soil requirement. • Also a common stone wall tree in Hong Kong.
Biodiversity Value	• The figs attract many birds.
Market Availability	Abundant in the local nursery.

Ficus virens Aiton (大葉榕、黃葛樹)

B. Carbon Performance Summary

Ficus virens (大葉榕) captures more than 23 kg CO_2/tree/year at about age 8, following a continuously accumulating pattern in which CO_2 uptake rises steadily as the tree matures. At age 100, annual removal surpasses 350 kg per tree and the cumulative removal reaches approximately 21.6 tonnes CO_2 per tree. These figures indicate strong long-term carbon sequestration potential when adequate space and management are provided

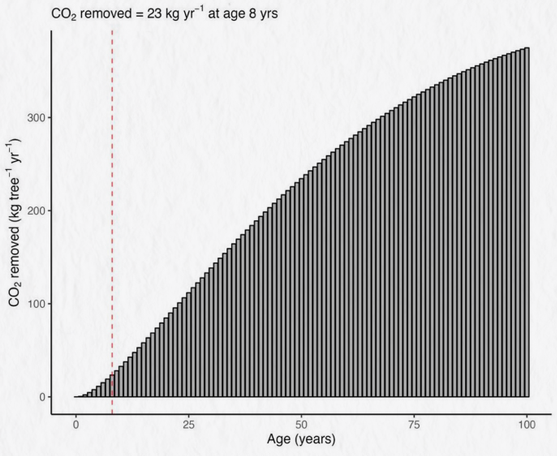


Fig. 4.5 - Annual CO_2 removed by Ficus virens *over 100 years*

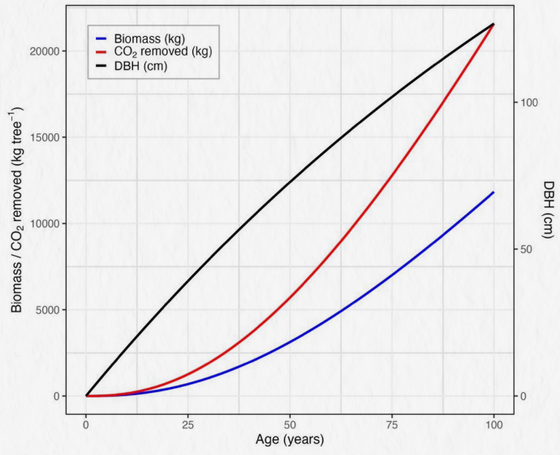


Fig. 4.6 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Ficus virens *over time*

C. Design and Management Implications

Spacing and Soil Provision

The OVT Register records mature *Ficus virens* (大葉榕) reaching heights up to 26 m and crown spreads of up to 38 m. To allow sufficient canopy and root development, at least 10 m spacing should be allowed. A minimum of 24 m^3 of soil volume should also be provided. It also develops an aggressive root system that could cause pavement uplift and damage to underground utilities. Consequently, it is recommended for locations with wide verges or open planting sites to accommodate its root spread, and it should be avoided in confined roadside pits to prevent conflict with hard landscape features. This spatial allowance would minimise conflicts with utilities and ensure long-term stability (GLTMS, 2025).

Site Selection and Tolerance

Ficus virens (大葉榕) demonstrates high tolerance to drought and roadside pollution. It has moderate tolerance to waterlogging, wind, pruning, and pest or disease, but performs poorly under soil compaction (GLTMS, 2025). It also shows high adaptability to different soil pH conditions, allowing flexibility across a range of urban soils. These traits make *Ficus virens* (大葉榕) well-suited to parks, large roadside space, and open landscapes, but it should be avoided in confined or heavily paved locations where root and canopy development would be restricted.

Lifecycle Management

Ficus virens (大葉榕) requires annual maintenance especially after maturity (GLTMS, 2025). The species typically matures at around age 11 and enters senescence from about age 81. Installation of root barriers or guides is recommended to control its vigorous rooting system. Ficus species may host wood-decay fungi such as *Ganoderma applanatum* and *Inonotus rickii* (GLTMS, 2020); regular inspection and prevention of mechanical injury can effectively reduce decay risk and ensure long-term stability.

In recent years, a leaf-feeding pest — *Phauda flammans* (朱紅毛斑蛾) — has caused defoliation in *Ficus* species across Hong Kong. While infestations do not usually threaten tree survival, they can cause canopy loss and aesthetic decline. When designing planting mixes, consideration should be given to avoiding excessive use of *Ficus* species in a single site, to reduce the risk of large-scale outbreaks and maintain overall landscape resilience.

Ficus virens Aiton (大葉榕、黃葛樹)

Phauda flammans (朱紅毛斑蛾) — a recent pest of *Ficus* in Hong Kong

Native range:
South and Southeast Asia; widely distributed in India, Myanmar, Thailand, southern China, and the Indo-Malayan region.

Status in Hong Kong:
Identified as a defoliating pest of *Ficus* species since 2020, affecting approximately 2,500 *Ficus* trees (Development Bureau, 2021).

Host species:
Ficus spp.

Symptoms and impact:
Larvae feed on the leaves and young petioles of *Ficus* trees, causing rapid defoliation of the tree crown. Affected trees are generally able to recover foliage once the infestation ceases (The Conservancy Association, 2021).

Recommended management:
- Wrap the tree trunk with bamboo/straw mats (or hessian bags) to catch active larvae.
- Clear pupae inside bark crevices, roots, topsoil and fallen leaves when larvae are forming cocoons.
- Spray soap water or chilli water on the leaves or trunk to remove larvae.
- Engage a professional pest control agent if necessary.

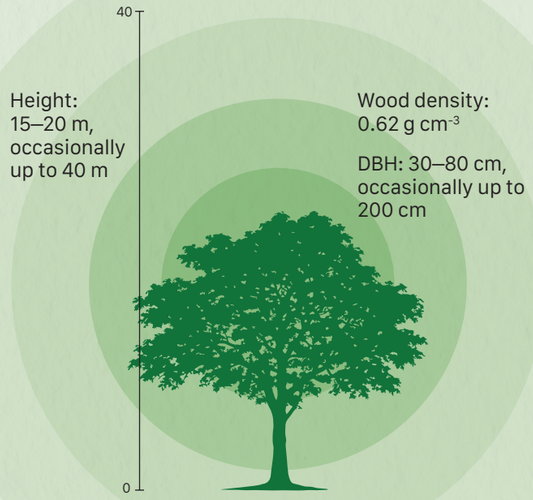
Bischofia javanica Blume (秋楓)

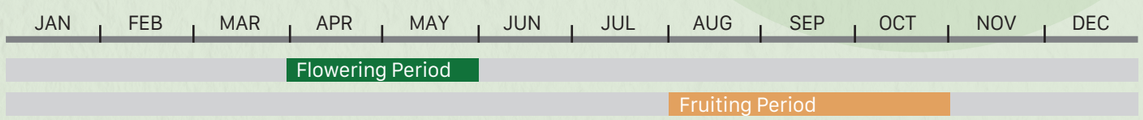


Photo by Hong Kong Herbarium, AFCD

A. Basic Information

FAMILY	Euphorbiaceae
ORIGIN	Native to Hong Kong
HABIT	Evergreen to semi-deciduous tree
FORM	Tree crown nearly round, dense and neat





Growth Environment	• Prefers full sun and moist environment. • Grows well in deep fertile sandy soil, common in Fung Shui Woods and lowland forests.
Biodiversity Value	Fruits are eaten by diverse types of birds and small mammals.
Market Availability	Abundant in the local nursery.

Bischofia javanica (Blume) (秋楓)

B. Carbon Performance Summary

Bischofia javanica (秋楓) begins to capture more than 23 kg CO_2/tree/year at around age 10, increasing steadily through subsequent decades but begins to slow down after age 50. By age 100, cumulative removal is estimated at approximately 12.2 tonnes CO_2 per tree. The persistent biomass gain makes this tree an effective long-term contributor to carbon storage in Hong Kong's urban environment.

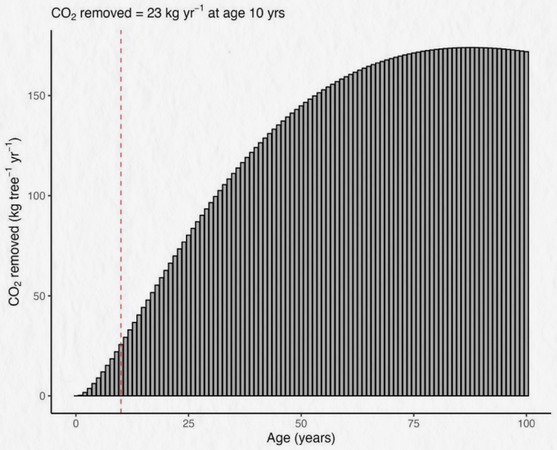


Fig. 4.7 - Annual CO_2 removed by Bischofia javanica *over 100 years*

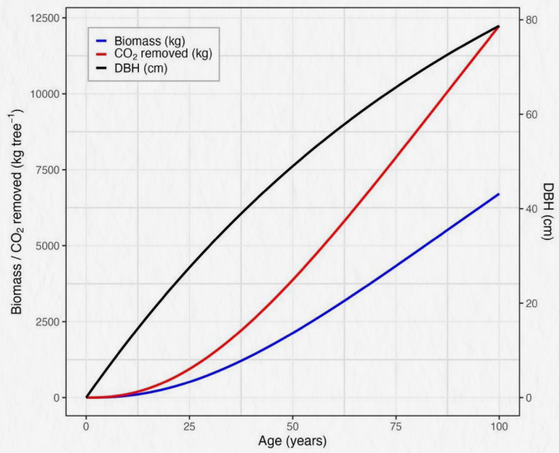


Fig. 4.8 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Bischofia javanica *over time*

C. Design and Management Implications

Spacing and Soil Provision

Mature *Bischofia javanica* (秋楓) is typically able to reach 20m in height with crown spread around 20 m (OVT Register); spacing should therefore be planned to accommodate this mature crown spread.

In order to support root development, it is recommended to provide ≥ 24 m^3 of soil volume per tree. In paved areas, GLTMS (2023a) recommends using soil corridors or vault systems to provide subsurface rooting space. However, due to its aggressive root system, *Bischofia javanica* (秋楓) may lift pavement or curbs if planted within 2 m of walkways or roads (Gilman et al., 2019).

Site Selection and Tolerance

Bischofia javanica (秋楓) shows high tolerance to heat, roadside pollution, and periodic waterlogging, but is less tolerant of soil compaction. The species performs best under full sun in moist, well-drained soils.

Lifecycle Management

Regular pruning is required to maintain crown balance and structural stability. Root rot has been reported in this species, including a documented case (Tree No. LCSD TP/18) listed in the OVT Register, highlighting the need for root-collar protection and early inspection for decay symptoms. Adequate rooting space and the avoidance of soil compaction are crucial to support long-term tree health and stability (Gilman et al., 2019; GLTMS, 2013).

Pterocarpus indicus Willd. (紫檀)



Photo by Hong Kong Herbarium, AFCD

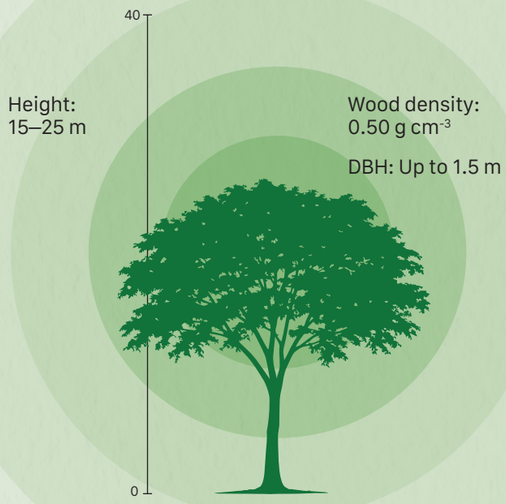
A. Basic Information

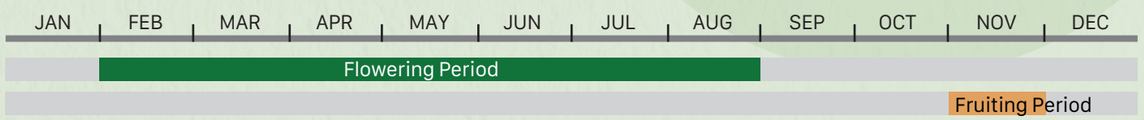
FAMILY Fabaceae

ORIGIN Exotic but native range includes South China

HABIT Semi-deciduous tree

FORM Large tree with broad crown; fragrant yellow flowers





Growth Environment	Prefers full sun or partial shade, naturally growing in open forests on slopes.
Biodiversity Value	Nectar sources for many insects.
Market Availability	Available in the local nursery.
Conservation value	• Endangered in the IUCN Red List (Barstow, 2018). • Critically Endangered in the China Red List 2020. • Protected under Cap. 586 Protection of Endangered Species of Animals and Plants Ordinance.
Other value	Nitrogen-fixing symbiosis.

B. Carbon Performance Summary

Pterocarpus indicus (紫檀) captures more than 23 kg CO_2/tree/year by about age 7, rising quickly through the first few decades; annual uptake begins to level off around ages 50–60. Cumulative removal nonetheless continues to increase, reaching about 18.5 tonnes CO_2 per tree by age 100. Notably, the species has a long lifespan when conditions allow, with an individual recorded at about 170 years old (OVT Register, Tree No. LCSD CW/141), enabling it to contribute to carbon sequestration over an extended period

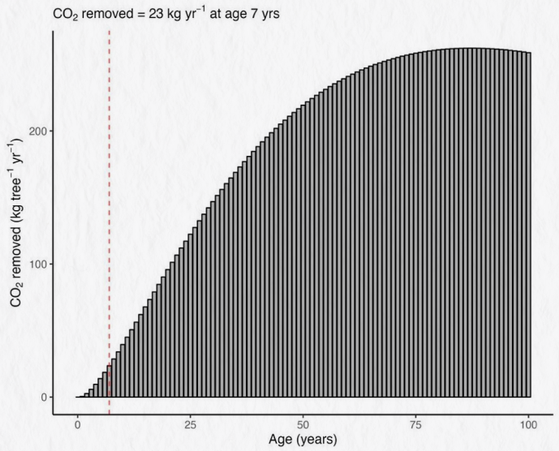


Fig. 4.9 - Annual CO_2 removed by Pterocarpus indicus *over 100 years*

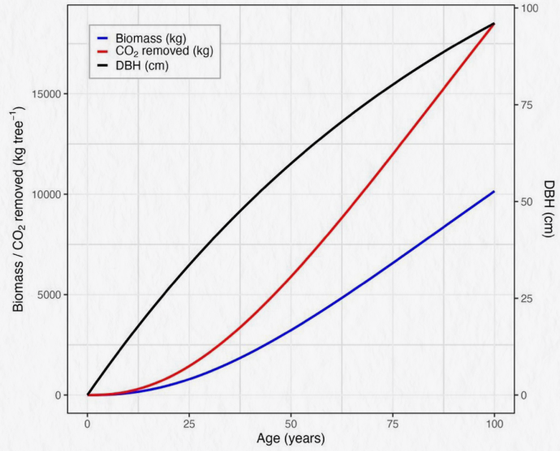


Fig. 4.10 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Pterocarpus indicus *over time*

Pterocarpus indicus Willd. (紫檀)

C. Design and Management Implications

Spacing and Soil Provision

Mature *Pterocarpus indicus* (紫檀) could reach 25 m in height with a crown spread of 29 m (OVT Register). Planting design should therefore allow sufficient lateral space to accommodate full crown development. A minimum soil volume of 24 m^3 per tree is recommended for large-canopy species to ensure adequate root growth. Because of its aggressive root system, installation of root barriers or guiding systems is recommended to reduce pavement conflict (GLTMS, 2025).

Site Selection and Tolerance

Pterocarpus indicus (紫檀) grows best in full sun or partial shade, in moist, well-drained soils. It is moderately tolerant to heat, drought, wind, waterlogging and soil compaction. It is suitable for parks, open landscapes, and wide roadside verges, but should be avoided in confined or heavily paved sites where root development would be restricted (GLTMS, 2025).

Lifecycle Management

The species shows moderate maintenance manageability and should be provided with root barriers or guiding systems to manage its vigorous root development. Fungal infection of roots and stems has been reported in young seedlings, indicating the need for good soil conditions and early health monitoring.

Celtis sinensis Pers. (朴樹)



Photo by GLTMS, DEVB

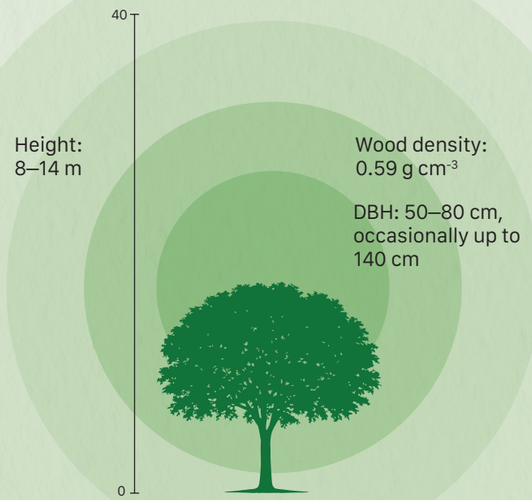
A. Basic Information

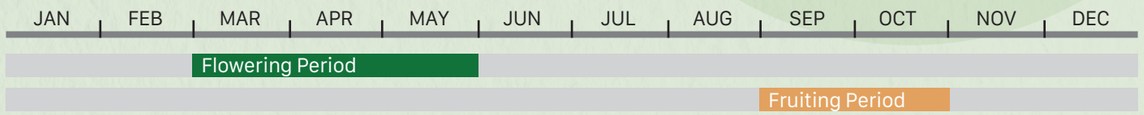
FAMILY Ulmaceae

ORIGIN Native to Hong Kong

HABIT Deciduous tree

FORM Umbrella-shaped tree crown





Growth Environment	• Widely and sparsely distributed in lowland or urban area. • Prefers full sun, slightly tolerant to shade and saline-alkaline soil; no strict requirement on soil.
Biodiversity Value	• Host plant of the butterfly *Hestina assimilis* (GLTMS, 2021a). • Fruits attractive to many frugivorous birds.
Market Availability	Abundant in the local nursery.

Celtis sinensis Pers. (朴樹)

B. Carbon Performance Summary

Celtis sinensis (朴樹) captures more than 23 kg CO_2/tree/year by age 12, with annual uptake increasing steadily in subsequent decades. Growth begins to stabilise around age 60, while cumulative removal continues to rise, reaching approximately 8.7 tonnes CO_2 per tree by age 100.

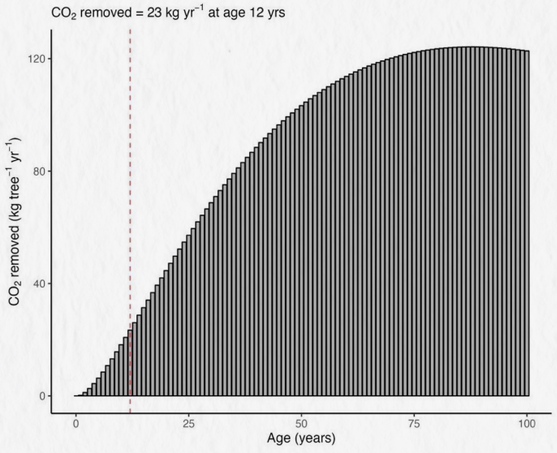


Fig. 4.11 - Annual CO_2 removed by Celtis sinensis *over 100 years*

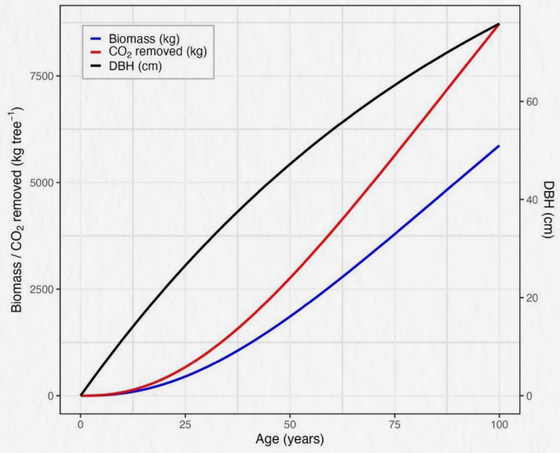


Fig. 4.12 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Celtis sinensis *over time*

C. Design and Management Implications

Spacing and Soil Provision

Mature *Celtis sinensis* (朴樹) in Hong Kong can reach about 14 m in height and 21 m in crown spread (OVT Register, Tree No. LCSD WCH/1). However, the species is common in secondary woodlands where individuals are generally smaller and occur at higher density. Planting design should therefore take account of the expected mature crown width and site context: wider spacing is appropriate only where it serves as a 'Pillar' species, whereas closer spacing is suitable for woodland or slope restoration. For large-crowned trees, a minimum soil volume of 24 m^3 per tree is recommended to support root development (GLTMS, 2023a).

Site Selection and Tolerance

Celtis sinensis (朴樹) occurs naturally on well-drained slopes, forest edges and low hills, indicating a preference for sunny and moderately fertile soils with good drainage. These characters make it well suited to parks, gentle slopes and open woodland plantings

Lifecycle Management

The species develops a broad branching structure with age and requires regular pruning to maintain structural balance and clearance in urban settings. Good soil aeration, avoidance of root-zone compaction are important practices to maintain its long-term health and stability.

Bombax ceiba L. (木棉)



Photo by GLTMS, DEVB

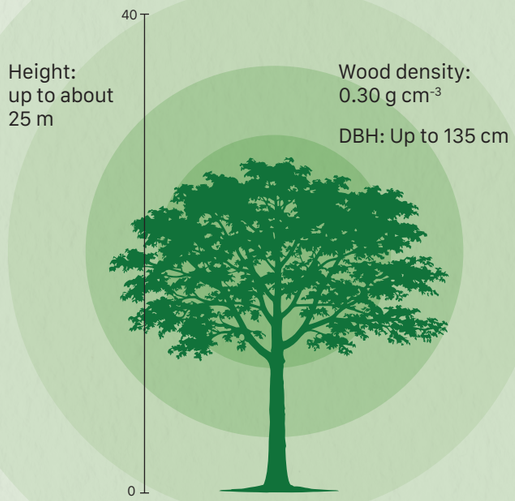
A. Basic Information

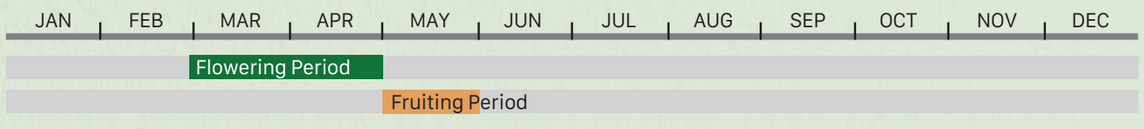
FAMILY Bombacaceae

ORIGIN Exotic in Hong Kong; native to Southern/Southwestern China and tropical Asia; widely planted locally

HABIT Deciduous tree

FORM Straight, single trunk; branches in clear tiers; sometimes with buttresses; young trunks typically spiny





Growth Environment	• Occurs on hot–dry river banks/savannas in native range (GLTMS, 2021c). • Widely cultivated in urban environments in Hong Kong.
Biodiversity Value	Major nectar source for urban birds and mammals.
Market Availability	Abundant in the local nursery.

B. Carbon Performance Summary

The model shows that the tree reaches about 31 cm in diameter at age 20 and about 99 cm at age 100. Its annual CO_2 removal rises above 23 kg per year from about age 9, reaches around 90 kg per year at age 30, and peaks near 130 kg per year around age 50 before slightly decreasing afterwards. The total amount of CO_2 removed continues to increase through the modelled timeframe, from about 1.4 tonnes at age 30 to about 10 tonnes at age 100, showing that the species keeps storing carbon even though annual CO_2 uptake becomes lower in old age.

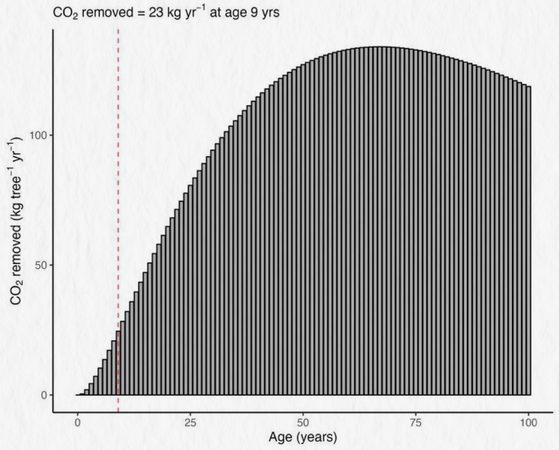


Fig. 4.13 - Annual CO_2 removed by Bombax ceiba *over 100 years*

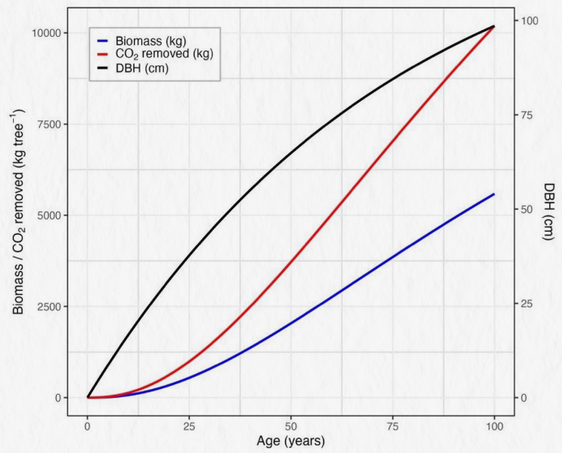


Fig. 4.14 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Bombax ceiba *over time*

Bombax ceiba L. (木棉)

C. Design and Management Implications

Spacing and Soil Provision

As a large-canopy tree reaching over 25 m in height and 23 m crown spread (OVT Register), *Bombax ceiba* (木棉) requires adequate soil volume and open space for crown and root development. Following the Guidelines on Soil Volume for Urban Trees (GLTMS, 2023a), a minimum of 24 m^3 of soil per tree is recommended for species of this size class. It should be planted with sufficient distance from nearby structures to allow for mature trunk diameter and buttress formation. Closer spacing may be considered only in temporary or early restoration settings.

Site Selection and Tolerance

Bombax ceiba (木棉) occurs naturally in lowland areas and open slopes in South China and is widely planted in Hong Kong as an ornamental and roadside tree. It grows in full sun on well-drained soils typical of local lowland environments.

Lifecycle Management

The species develops a straight trunk with clear branching tiers and may form buttresses with age. Early pruning during establishment helps to produce a stable framework and reduce subsequent structural issues. Flowering occurs in springs, followed by capsule fruits that release silky fibres. These fibres are spread by wind and may cause nuisance or respiratory discomfort to pedestrians and nearby residents; planting of this species should be carefully considered during site selection.

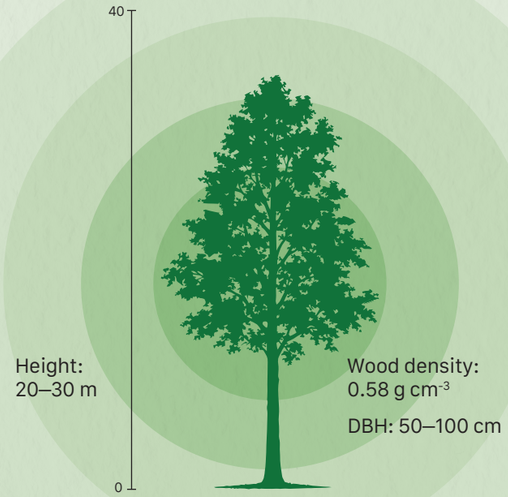
Liquidambar formosana Hance (楓香)

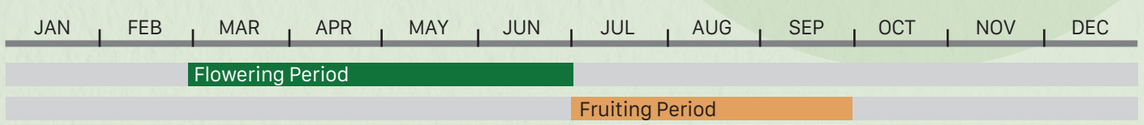


Photo by Hong Kong Herbarium, AFCD

A. Basic Information

FAMILY	Hamamelidaceae
ORIGIN	Native to Hong Kong
HABIT	Deciduous tree
FORM	Conical when young, becoming broadly spreading with age; trunk straight and upright





Growth Environment	• Prefers full sun and warm, humid climate; also tolerates drier inland sites. • Commonly planted in lowland forests and urban landscapes of Hong Kong.
Biodiversity Value	• Flowers are good source of pollen. • Fruiting trees also attract a range of granivorous birds such as the rare migrant and winter visitor Eurasian Siskin (Carey and Pang, 2023).
Market Availability	Abundant in the local nursery.

Liquidambar formosana Hance (楓香)

B. Carbon Performance Summary

Liquidambar formosana (楓香) shows a steady increase in carbon removal during its early and middle growth stages, followed by a stable phase. The model shows the tree reaching about 25 cm in diameter at age 30 and over 60 cm at age 100. Its annual CO_2 removal becomes higher than 23 kg per year from around age 16. Although the annual uptake becomes steady in late maturity, the total CO_2 removed continues to accumulate, from about 0.7 tonnes at age 30 to around 6.4 tonnes at age 100.

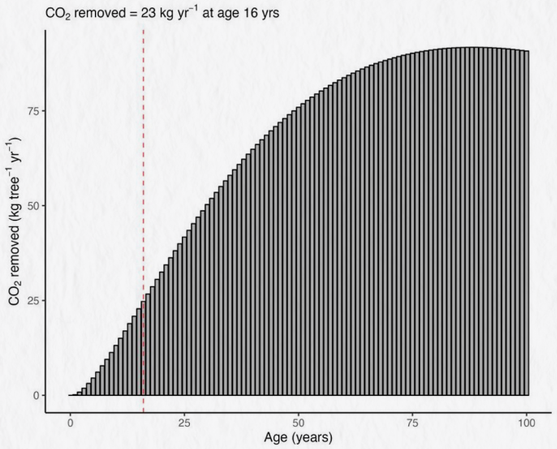


Fig. 4.15 - Annual CO_2 removed by Liquidambar formosana *over 100 years*

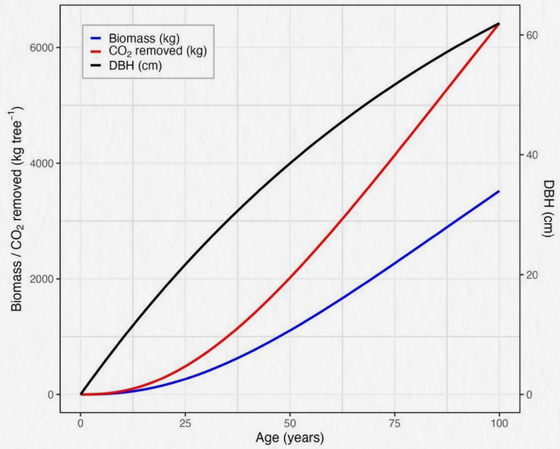


Fig. 4.16 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Liquidambar formosana *over time*

C. Design and Management Implications

Spacing and Soil Provision

This species typically reaches 10-20 m in height and up to about 30 m under favourable conditions. One of the largest recorded specimens in Hong Kong even reaches 26 m in height and 21 m in crown spread (OVT Register, Tree No. LCSD TP/14). It has an aggressive, spreading root system, and the installation of root barriers or guides is recommended in constrained urban sites. A minimum soil volume of 24 m^3 per tree is suitable for large-crown species of this form.

Site Selection and Tolerance

Liquidambar formosana (楓香) prefers full sun or partial shade and grows well under warm, humid conditions, but it can also adapt to moderately dry sites. It shows moderate tolerance to drought and wind and has high tolerance to roadside pollution, pests and diseases. The tree is deciduous, producing red to golden foliage in autumn and early winter, which enhances its ornamental values in urban landscapes.

Lifecycle Management

Liquidambar formosana (楓香) has moderate manageability and moderate pruning tolerance. Newly planted trees require routine maintenance during establishment, such as weeding and form correction. As trees mature, the maintenance demand becomes moderate, although periodic pruning is needed to manage crown spread. Structural pruning in the early years helps to develop a balanced crown and reduce future structural issues (GLTMS, 2023b). Seasonal litter from leaf fall and small fruits may occur but is manageable through regular maintenance.

Ficus elastica Roxb. ex Hornem. (印度橡樹、印度榕)

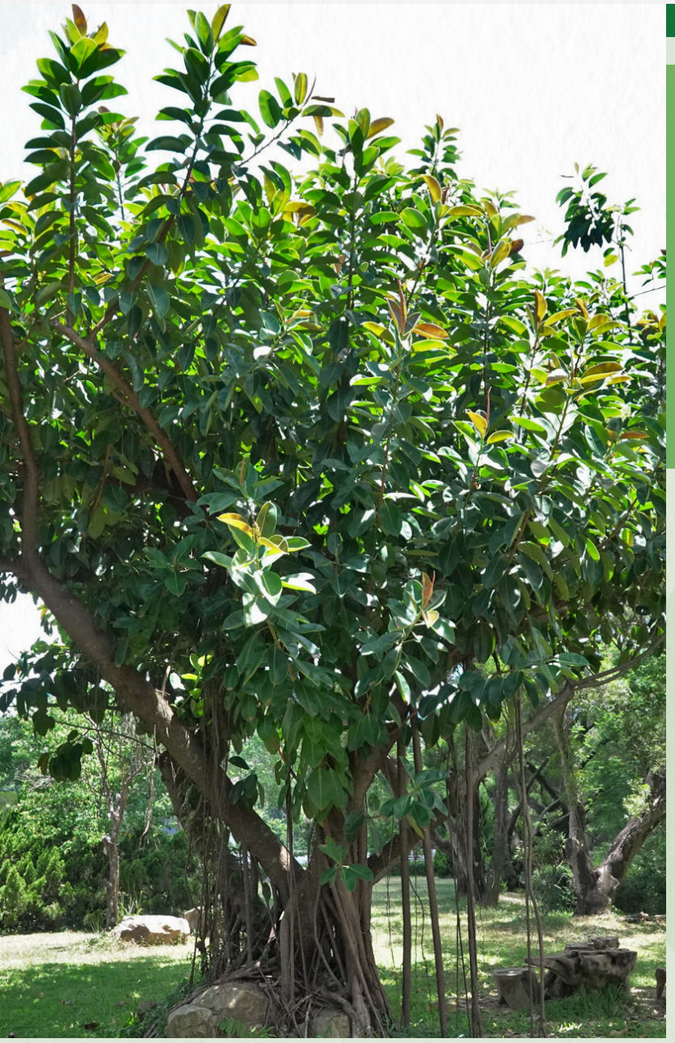


Photo by GLTMS, DEVB

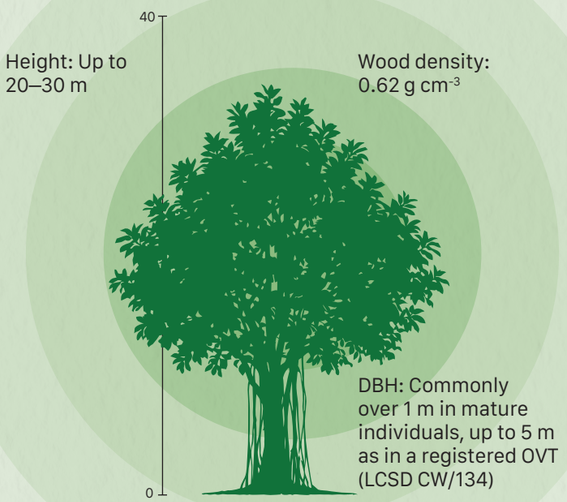
A. Basic Information

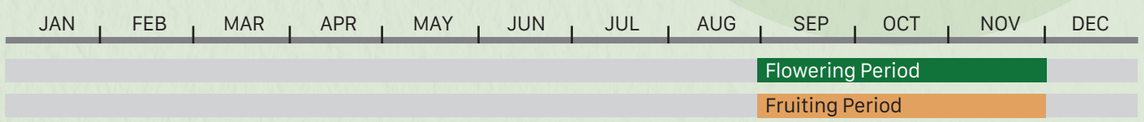
FAMILY Moraceae

ORIGIN Exotic but widely cultivated in Hong Kong; native to South and Southeast Asia

HABIT Evergreen tree

FORM Single trunk with spreading crown; produces aerial roots, growing into woody trunks once reach the ground





Growth Environment	• Prefers full sun to partial shade. • Grows well under urban conditions, showing good adaptability to both drought and shade, and tolerance to air pollution.
Biodiversity Value	• Fruits are consumed by birds (Corlett et al., 2006). • The massive tree crown provides favourable roosting sites for birds and habitats for insects.
Market Availability	Abundant in the local nursery.

B. Carbon Performance Summary

Ficus elastica (印度榕) maintains strong biomass accumulation throughout its lifespan. Its annual CO_2 removal exceeds 23 kg/year from around age 13 and continues to increase steadily thereafter, indicating sustained uptake capacity, without a clear plateau within the 100-year modelled period. A specimen (LCSD CW/134) on Lugard Road, Hong Kong Island, in the Register of Old and Valuable Trees has reached a trunk diameter of about 5 m, making it one of the largest trees in the database. It demonstrates the species' strong capacity for long-term biomass accumulation and carbon storage.

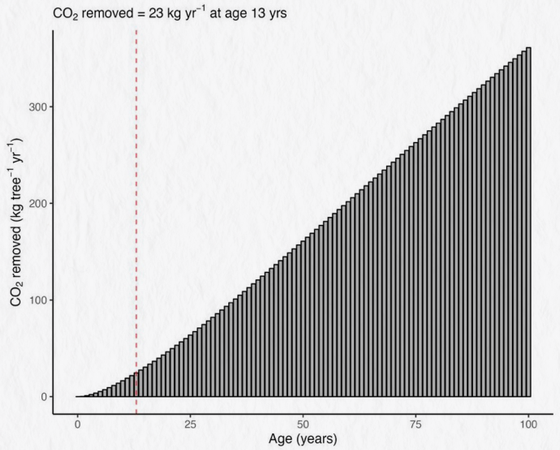


Fig. 4.17 - Annual CO_2 removed by Ficus elastica *over 100 years*

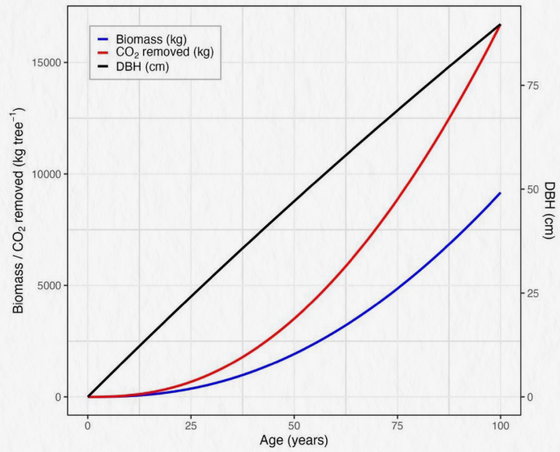


Fig. 4.18 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Ficus elastica *over time*

Ficus elastica Roxb. ex Hornem. (印度橡樹、印度榕)

C. Design and Management Implications

Spacing and Soil Provision

This large-canopy species can reach 32 m in height and 50 m in crown spread (OVT Register). It develops extensive aerial roots that form secondary trunks when they reach the ground. This *Ficus* species has vigorous root systems that can damage pavements and carriageways. Instead of roadside pit planting, it is suited to woodlands or wide verges where space allows full crown and root development. A minimum soil volume of 24 m^3 per tree is recommended for healthy establishment.

Site Selection and Tolerance

Ficus elastica (印度榕) grows best in warm, humid conditions with full sun, and tolerates drought, shade and air pollution. It is widely cultivated in Hong Kong, commonly seen near villages and in urban landscapes, showing high adaptability to lowland and built environments

Lifecycle Management

Ficus elastica (印度榕) establishes quickly and tolerates pruning. Early structural pruning during establishment helps develop a stable framework and reduce future structural issues. Mature trees should be inspected periodically for heavy limbs and aerial-root growth near structures. Regular pest monitoring is recommended, as *Phauda flammans* has been reported on *Ficus* trees locally (Development Bureau, 2021).

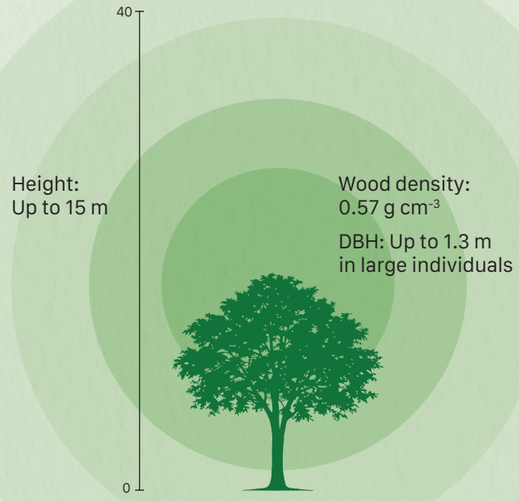
Peltophorum pterocarpum (DC.) Baker ex K. Heyne (盾柱木、雙翼豆)

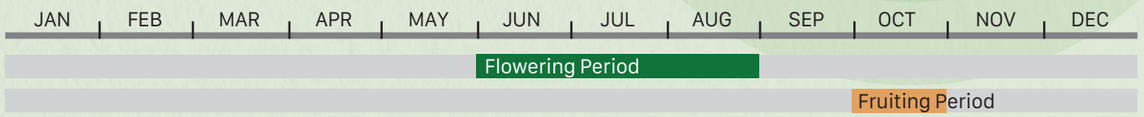


Photo by GLTMS, DEVB

A. Basic Information

FAMILY	Fabaceae
ORIGIN	Exotic but widely cultivated in Hong Kong; native to Southeast Asia and Northern Australia
HABIT	Deciduous tree
FORM	Umbrella-shaped tree corwn with open density





Growth Environment	Fast growing and adapted to warm and humid environments but grows poorly in cold climates or in dry, shallow soils.
Market Availability	Abundant in the local nursery.
Biodiversity Value	Nectar flowers for wildlife (e.g. *Xylocopa* Large Carpenter Bees: Raju & Rao, 2006).
Other Value	Nitrogen-fixing symbiosis.

Peltophorum pterocarpum (DC.) Baker ex K. Heyne (盾柱木、雙翼豆)

B. Carbon Performance Summary

Peltophorum pterocarpum (盾柱木、雙翼豆) shows steady biomass accumulation and carbon removal through its lifespan. Annual CO_2 removal exceeds 23 kg/year from around age 9 and continues to increase, reaching about 100 kg/year by age 30 before levelling near 180 kg/year in maturity. Total CO_2 removed rises consistently throughout the 100-year period, reaching over 12 tonnes CO_2 per tree, indicating strong long-term storage potential.

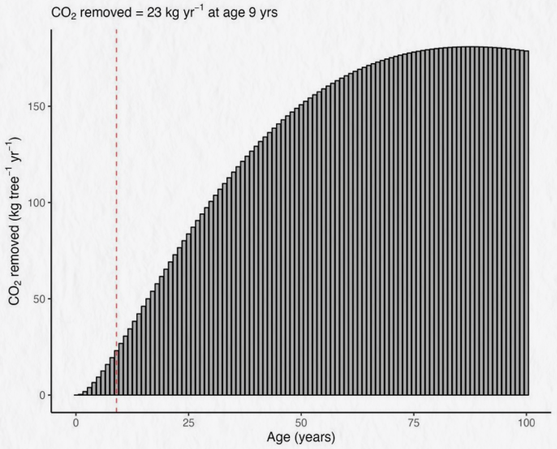


Fig. 4.19 - Annual CO_2 removed by Peltophorum pterocarpum *over 100 years*

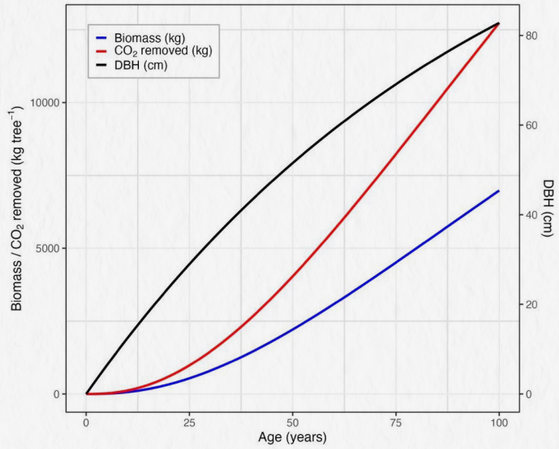


Fig. 4.20 - Changes in DBH (cm), total biomass (kg), and CO_2 removed (kg/tree) by Peltophorum pterocarpum *over time*

C. Design and Management Implications

Spacing and Soil Provision

Peltophorum pterocarpum (盾柱木、雙翼豆) develops a broad crown and extensive roots that require sufficient underground and overhead space. A minimum soil volume of 24 m^3 per tree is recommended to support its growth. It is preferred to be planted away from narrow pavements or confined tree pits to prevent root constraint and allow stable canopy development.

Site Selection and Tolerance

Peltophorum pterocarpum (盾柱木、雙翼豆) is an exotic species widely cultivated in Hong Kong as a street and ornamental tree. It is fast-growing and adapts well to humid conditions. However, it is sensitive to cold and does not perform well on dry soils. This species is also susceptible to root plate instability and branch failure during typhoons. It requires a wide planting area to accommodate its extensive root system. The branches could be brittle under strong wind and should be avoided in exposed, high-wind locations to minimise risk.

Lifecycle Management

No known pest or structural issues have been reported for this species in Hong Kong. Routine maintenance should follow the general guidance issued by the GLTMS, including periodic inspection and pruning appropriate for medium- to large-canopy trees.

5

Recommended Planting Design Considerations

Chapter 5
Recommended Planting Design Considerations

This chapter discusses planting design considerations in the local environmental context. Planting fulfils various long-term functions including carbon storage, ecological support, microclimate improvement, soil stabilisation and visual amenity. These outcomes depend not only on individual species choices but on how planting is implemented as a whole — its diversity, structure, rooting environment and maintenance conditions.

5.1 Structural and Species Diversity

5.1.1 Balanced Species Composition

A resilient planting system requires a balanced species composition. One widely used approach is the 10–20–30 rule, which is a general guideline for avoiding over-use of particular taxa in the planting mix. It means that:

- no more than about 10% of the planting should be from any one species;
- no more than about 20% should be from any one genus; and
- no more than about 30% should be from any one family.

This reduces the risk that a single pest, disease or storm event will damage a large part of the planting.

5.1.2 Complementary Vegetation Community Mix

Structural diversity is equally important. Vegetation should be organised in complementary layers — trees, shrubs and groundcovers — forming an integrated plant community, often described as a Complementary Vegetation Community Mix. A multi-layer structure can improve landscape performance by:

- reducing bare soil and suppressing weeds;
- reducing maintenance needs;
- improving soil quality; and
- providing a range of microhabitats that support urban wildlife.

Where large canopy trees require sufficient spacing, these sub-canopy and understorey layers are important for maintaining soil condition, moderating microclimate and visually connecting the space between tree crowns.

5.2 How Diversity Enhances Carbon Storage

Diversity is also closely linked to carbon accumulation. Research in subtropical forests in China showed that species-rich tree communities store more biomass than species-poor ones (Liu et al., 2018). The ecosystem carbon increased by approximately 6.4% for each additional tree species. Several ecological processes help explain this pattern:

1. **Complementary Resource Use**
   Different species use light, water and nutrients in different ways. This reduces competition and increases the overall efficiency of resource capture.
2. **More Complex Canopy Structure**
   Mixed-species forest often form multi-layered canopies, allowing better use of vertical space and improving total photosynthetic capacity.
3. **Increased Resilience**
   Species vary in their responses to environmental stress such as pest or drought. Higher diversity spreads risk, making biomass gain more stable over time.

Although urban landscapes are more constrained than natural forests, these principles apply in urban planting: diverse planting mix tends to maintain growth more consistently, supporting long-term carbon storage.

Hong Kong's secondary broadleaf forests commonly hold around 20–30 native tree species per hectare. In the 20-ha ForestGEO plot at Tai Po Kau, species–area analysis indicates that total woody species richness (including small trees and shrubs ≥1 cm DBH) can reach an average of about 106 species per hectare (Zhang et al., 2024). When planning large-scale planting, particularly in NDAs, nursery stock availability and maintenance capacity must be taken into account. Incorporating approximately 15–20 tree species per hectare is generally achievable and provides a level of diversity that aligns with the structure of natural forests.

5.3 Provide Year-Round Resources

Urban biodiversity depends not only on plant species richness but also on the timing of food availability. The planting mix should therefore include species that flower and fruit at different times, so that nectar, pollen, fruits and seeds are available across most of the year.

Native species are particularly suitable because their flowering and fruiting pattern, and the type of resources they provide (e.g. berry-fruits), match the needs of the local fauna. For example, many native trees fruit during the dry season when wintering frugivorous birds are present in Hong Kong. Using species with different flowering and fruiting periods creates a more stable and seasonally diverse food supply for wildlife.

5.4 Pillar Trees

5.4.1 Soil Volume and Rooting Space

Large canopy trees can act as pillar trees because they contribute the majority of long-term carbon storage. A sufficient amount of soil is essential for maximising growth and reaching the full size of these trees. (GLTMS, 2023a):

- small trees need about 6 m^3 of soil;
- medium trees need about 13 m^3;
- large canopy trees need 24 m^3 or more.

Adequate soil volume should be provided in the form of continuous planting area with 1 m depth available for root development, and should be free from obstructions such as compacted layers or underground utilities. If individual tree pits cannot provide enough soil, they can be connected using shared planting beds, structural soil or soil-cell systems beneath pavements.

To realise their full carbon potential, trees should be allowed to reach maturity, as carbon storage increases exponentially with size. Accordingly, soil volume requirements should be regarded as essential engineering parameters rather than discretionary landscaping guidelines. The projected long-term carbon benefits warrant investment in space allocation or potential utility diversion, ensuring that the infrastructure supports a functional carbon sink rather than a transient green feature.

5.4.2 Right Tree in the Right Place

Not all planted trees will survive to maturity, and early losses can significantly influence long-term carbon outcomes. Survival rate depends on soil quality, rooting space, exposure, seedling quality and the level of care during establishment. Matching species to site conditions — the principle often referred to as "Right Tree in the Right Place" — is one of the most effective ways to reduce early mortality. Pillar trees, in particular, should be placed only where soil and rooting conditions can support their full development, while more restricted areas are better suited to smaller trees or shrubs. During the establishment period, replacement planting may be required to maintain the intended structure and ensure that long-term carbon and ecological functions can be achieved.

5.4.3 Balancing Early and Long-Term Carbon Needs

Different species sequester carbon at different rates and at different stages of their life. Fast-growing species often remove carbon quickly during their first 10–20 years but then level off. In contrast, pillar trees grow more slowly at first but store much larger amounts of carbon later. A practical planting mix can include both types, so that early carbon gains are achieved while the slower, long-lived species mature. As pillar trees develop, the role of the fast-growing species can gradually be reduced or replaced depending on site objectives.

5.4.4 Understorey Integration

The wide spacing required by pillar trees (often around 10 m) does not mean leaving open ground between them. These areas should be filled with small trees, shrubs or groundcovers. Understorey planting reduces soil erosion, maintains soil moisture and provides additional ecological value.

5.5 Soil Evaluation

A pre-planting soil assessment should be carried out to identify conditions that may limit tree establishment and long-term growth. Assessment should cover soil texture, structure, drainage, compaction, pH and available nutrients; laboratory soil tests should be conducted where site conditions are uncertain or where a history of construction, filling or contamination is suspected. A follow-up assessment should be carried out if site conditions change due to subsequent construction or utility works. Areas intended for pillar trees should receive priority, as these species require stable, long-term rooting environments.

Where deficiencies are identified, soil improvement works should be carried out prior to planting. This may include decompaction, incorporation of organic matter, pH adjustment or replacement of unsuitable fill with appropriate planting medium.

Construction activity commonly degrades soil microbial communities that support nutrient uptake and tree establishment. Incorporating leaf litter and surface soil sourced from nearby natural forests into planting areas is a practical approach of reintroducing soil biota. Mulching with organic material following planting can further support the recovery of soil microbial activity.



5.6 Advance Tree Planting

Advance tree planting refers to the *ex-situ* preparation of tree stocks, where trees are grown in nurseries to an appropriate planting size before being transplanted to their final locations. This approach allows tree growth to start earlier, thereby shortening the time required for trees to contribute to carbon removal targets after transplantation.

From a carbon perspective, advance planting enables trees to enter the landscape after the early seedling stage under nursery conditions, reducing seedling losses and shortening the time required to meet carbon removal targets. When properly managed, advance planting can also improve post-planting survival, as larger and well-established nursery stock generally exhibits higher tolerance to environmental stress during the establishment phase.

For larger planting stock, careful nursery management is essential. For example, any unnecessary or excessive pruning should be avoided, as it may delay recovery and potentially cause other health issues, compromise post-transplantation performance. Proper root ball management should be implemented to prevent girdled roots or root-binding from occurring in containers.

Planting stock size should be selected with regard to planting species, scale, site conditions and project objectives. Larger planting stock is generally associated with higher transportation, handling, planting and establishment costs. In addition, where planting is required at a large scale, the availability of sufficient nursery stock of larger tree sizes may be constrained. Advance planting strategies should therefore balance planting stock size, logistical considerations and nursery supply capacity, while focusing on optimising growth duration and survival performance to facilitate earlier contributions to long-term carbon removal.

Where the project programme allows, landscape areas such as parks and open spaces should be implemented in the early phases of development to allow planting to be established prior to project completion. This approach complements *ex-situ* nursery preparation, shortens the interval between site formation and effective carbon sequestration, and ensures that greening is not deferred to the final stage of the project.



6

Recommendations for Future Studies

Chapter 6
Recommendations for Future Studies

The carbon estimates in this study rely on species growth parameters and allometric equations. Improving the accuracy of each parameter used will improve future modelling and support better planting design.

6.1 Long-Term Growth Monitoring

Reliable growth modelling depends on repeated measurements, yet long-term DBH and height records remain limited for many Hong Kong tree species.

Recommendations:

- **Database Establishment**
  Establish a database that consistently tracks DBH and height of the same individuals over time. Such repeated measurements allow growth rates to be derived directly.
- **Coverage across Multiple Size Classes**
  Monitoring should include small, medium and large individuals of each species. This helps capture early, mid-stage and late-stage growth pattern, all of which are essential for fitting growth curves and estimating long-term carbon storage.
- **Monitoring across Different Site Types**
  Growth rates differ substantially between site settings due to differences in rooting volume, exposure and microclimate. Tracking individuals across these site types would clarify how environmental setting influences growth and whether separate models are needed.
- **Multi-Year Monitoring Programme**
  A 5-year cycle would improve growth parameter estimation, while tracking trees over decades is ideal for long-term carbon modelling.

6.2 Local Allometric Information

This study adopts widely applied allometric equations, but local tree form and biomass may deviate from global estimations under Hong Kong conditions.

Recommendations:

- **More Empirical Biomass Measurements**
  Direct or opportunistic destructive sampling — such as collecting data from fallen trees — would provide valuable calibration for wood density and biomass calculation.
- **Wider Species Coverage**
  Current data are limited to a small number of species. Expanding measurements to more native and commonly planted species would improve the applicability of allometric models.
- **Local Verification of Global Equations**
  Comparing measured biomass with predictions from Chave et al. equations would help determine whether adjustments are required.

- **Development of Hong Kong-specific Allometric Models**
  If consistent deviations are found, local models — whether species-specific or functional-group-specific — could reduce uncertainty and improve future carbon assessments.

6.3 Species Survival and Establishment Performance

Long-term carbon accumulation is greatly influenced by early establishment success. Here are some recommendations:

- **Species Tolerance to Planting Shock**
  Some species experience higher mortality immediately after planting due to root disturbance and environmental transition. Understanding this informs species selection.
- **Exposure, Drought and Microclimate Sensitivity**
  Open, newly developed sites can be hot, dry and windy. Species differ widely in their tolerance to these conditions, which affects their establishment success.
- **Species-Level Survival Data**
  Collecting data on survival rates across species and site types would improve planting mix selection and reduce both replacement frequency and maintenance costs.

6.4 Expansion of Database via Field Test

To enhance the robustness and applicability of the current database, it is recommended that the scale of data collection should be expanded through more extensive field tests. Efforts should be made to capitalise on opportunities arising from government projects. Specifically, trees that are removed or pruned during these projects, instead of being discarded, can be utilised for research purposes. This will enable increased data collection without causing unnecessary harm to the environment.

Furthermore, tree sample collection should include a greater diversity of species to enrich the database. At present, the database primarily comprises common roadside tree species, which limits its comprehensiveness. Including a broader variety of tree species, particularly native and less-studied ones, would improve the accuracy and generalisability of biomass and carbon storage estimations.

In addition, consideration should be given to including both huge and very small trees. While most of the trees available for pruning are often older or unhealthy, sampling larger trees with high biomass or younger, fast-growing trees would provide valuable insights. However, as this is an environmentally conscious project, it is essential to emphasise that tree preservation remains a priority. Trees should only be used for research when pruning or removal is unavoidable.

7

Summary

Chapter 7
Summary

This booklet presents a data-driven overview of how different tree species contribute to long-term carbon storage in Hong Kong. Selected species profiles are provided to illustrate their long-term carbon removal potential. These examples are not intended to restrict choice-appropriate selection depends on site conditions and project objectives.

It is noted that, most trees sequester substantial amounts of carbon only after reaching a large size and maturity. Smaller trees store relatively little biomass, while a single large tree can store hundreds times more than small trees of the same species. Most carbon accumulation occurs in the later stages of growth, and reaching maturity takes considerable time.

All figures and models in this booklet represent reference estimates based on available data. Actual carbon storage will vary with species performance and site conditions.

Carbon storage is only one consideration in NDAs' landscape design. Other functions, such as ecological value and visual amenity, remain as essential components of a balanced and resilient planting approach.

Appendix

Appendix

A1. Guidelines for Field Measurement and Laboratory Testing

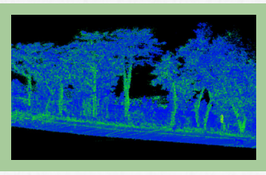
This appendix set out some guidelines for estimating the biomass, carbon content and thus carbon storage of an individual tree by field measurements and laboratory testing.

1. Field Measurements and Samples Collection

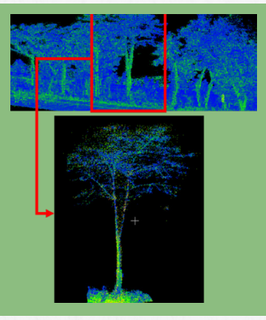
LiDAR Scanning for Tree Volume Estimation

The target tree should be scanned using a backpack mobile laser scanning system equipped with dual LiDAR sensors (one horizontal for trunk capture, one vertical for canopy) in the field. The operator should walk slowly in a full 360° spiral around each tree to generate high-density 3D point clouds. Raw point clouds should then be processed as follows to establish the 3D tree model:

Step 1
Geo-reference of LiDAR Raw Data
Geo-referencing the LiDAR model to obtain accurate geo-location of the target tree

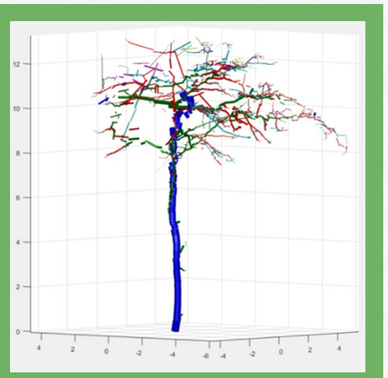


Step 2
Individual Tree Segmentation
Segmenting out the target tree and filtering out the outliers, such as shrubs and grasses



Step 3
Tree Metrics Extraction
Converting the point cloud data to 3D tree model and measuring the tree metrics from the model to estimate the total tree volume:

- **Tree Height -** Subtract the minimum from the maximum z-value in point cloud data
- **DBH -** Average maximum horizontal spread at 1.3 to 1.5 meters in z-values
- **Crown Length -** Maximum spread across 2-meter vertical layers in point cloud
- **Trunk Volume -** The volume of the tree trunk from the tree model
- **Branch Volume -** The volume of the tree branches from the tree model



Samples Collection for Laboratory Testing

In the field, tree samples should be collected, using destructive sampling, from the trees already identified for removal under government projects. The trees should be felled by trained professionals, ensuring safety and minimal damage to the surrounding areas. To ensure comprehensive coverage of the biomass, samples should be collected from various parts of the tree, including:

Sample	Description
Trunk	Circular slices approximately 2–5 cm thick, with 2–3 slices taken from different sections
Branch	Sections measuring 10–40 cm in length, with 3–5 branches collected per tree
Leaf	20 – 50 leaves were sampled from different parts of the tree canopy

All samples should be carefully labelled with unique tree ID, collection date, and species. The samples should also be sealed in polystyrene zipper bags to prevent contamination and water loss, preserving their integrity for subsequent laboratory testing and analysis.

2. Laboratory Testing and Data Analysis

Tree Samples Processing for Calculating Wood Density and Above-Ground Biomass (AGB)

After sample collection, the fresh weight of the wood and leaf samples should be measured and recorded. The volume of the wood samples should be calculated based on their dimensions, while the area of the leaf samples should be determined. The samples should then be oven-dried at 50°C until reaching a constant weight. With both dry weight and volume of the samples measured, the wood density and thus AGB can then be determined based on the LiDAR-derived total tree volume (excluding BGB) using the formula below:

$$\text{AGB (kg)} = (\text{Sample Dry Weight} / \text{Sample Volume}) \times \text{Tree Volume}$$

Chemical Composition and Carbon Content Analysis

Chemical composition analysis should be conducted to quantify the cellulose, hemicellulose, and lignin contents of biomass samples with the use of high-performance liquid chromatography (HPLC). The total carbon content (fcm) in a biomass sample can then be calculated by the following formula:

$$f\,cm = k_{cl} \times f_{cl} + k_h \times f_h + k_l \times f_l$$

where f_{cl}, f_h, and f_l represent the mass content of cellulose, hemicellulose and lignin, respectively; and k_{cl}, k_h, and k_l represent the theoretical carbon contents of these corresponding building-block chemicals, with the value set to 0.4444, 0.4545 and 0.6667, respectively (Chan et al., 2018).

The detailed procedures of the chemical composition analysis are as follows:

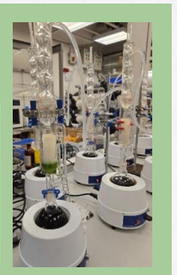
Step 1
Sample Drying
Using oven to dry samples until reaching a constant weight, ensuring no water content



Step 2
Sample Preparation

a. Fragmentizing and grinding samples to powder
b. Placing ground samples into a Soxhlet extraction system to remove extractives (e.g. pigments) soluble in a 2:1 mixture of n-hexane to absolute ethanol for at least 48 hours[3]





Step 3
Sample Digestion, Neutralisation, and Filtration[4]

a. Adding 72% (w/w) sulphuric acid to each washed sample and mixing constantly for 1 hour to digest the biomass via hydrolysis
b. Diluting the reaction mixture to 4% (w/w) and autoclaved at 121°C for 60 minutes for further hydrolysis
c. Neutralizing the hydrolysate by adding barium carbonate powder in excess
d. Centrifuging the tube and transferring 1mL of the supernatant into HPLC vials via a 0.22 µm filter

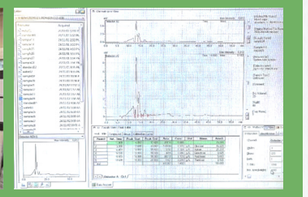




Step 4
Data Analysis

a. Determining the hydrolysate composition by an HPLC[5]:
   i. Loading 20 µL of aliquot from the vial with flow rate set to 0.6 mL/min
   ii. Monitoring elution of the samples by a refractive index detector (RID)
   iii. Interpreting the cellulose and hemicellulose content of the biomass samples from the concentration of simple sugars in the aliquot derived from the chromatogram
b. Filtering, oven-drying at 105°C and heating to 575°C, using a muffle furnace, the acid-insoluble residues from the products of hydrolysis to determine the mass of acid-insoluble lignin by comparing the weight of contents in the crucible before and after each step







3. *In Step 2b, substances which may interfere with the signals produced from HPLC system are removed to ensure the accuracy of the chemical analysis.*
4. *Polymeric carbohydrates are broken down into monomeric sugars in Steps 3a and 3b while undissolved particulates and aggregates that may disrupt HPLC operations are removed in Steps 3c and 3d.*
5. *Accurate calibration and identification of sugar peaks are essential for reliable quantification.*

Estimation of Carbon Storage in a Tree

With AGB and total carbon content of tree samples measured, the total carbon stored in a tree can then be determined by the following formula:

$$CO_2 \text{ stored} = 44/12 \times f_{cm} \times \text{Tree Volume} \times \rho \times 1.265$$

where ρ =wood density = sample dry weight/sample volume;
f_{cm} = measured carbon content %

This methodology integrates field measurement techniques, such as LiDAR scanning and sample collection, with comprehensive lab tests and data analysis processes, including point cloud analysis, sample processing, and chemical composition analysis. It offers a reproducible framework for estimating AGB and carbon storage of trees in Hong Kong.

A2. Tree Data Tables and Graphs

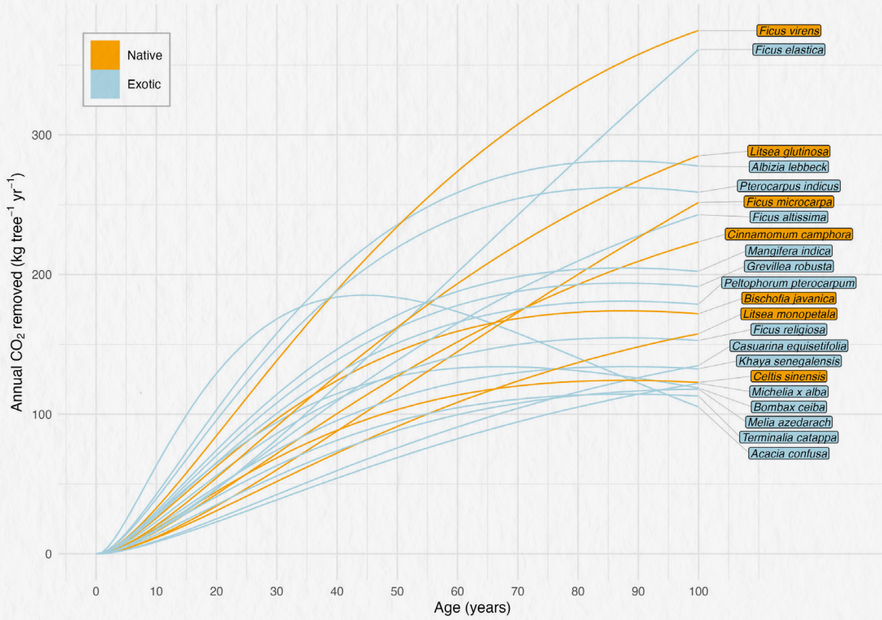


Chart A2-1. Annual CO_2 Removal of Tree Species with annual CO_2 removal reaching or exceeding 100 kg/tree/year at age 100

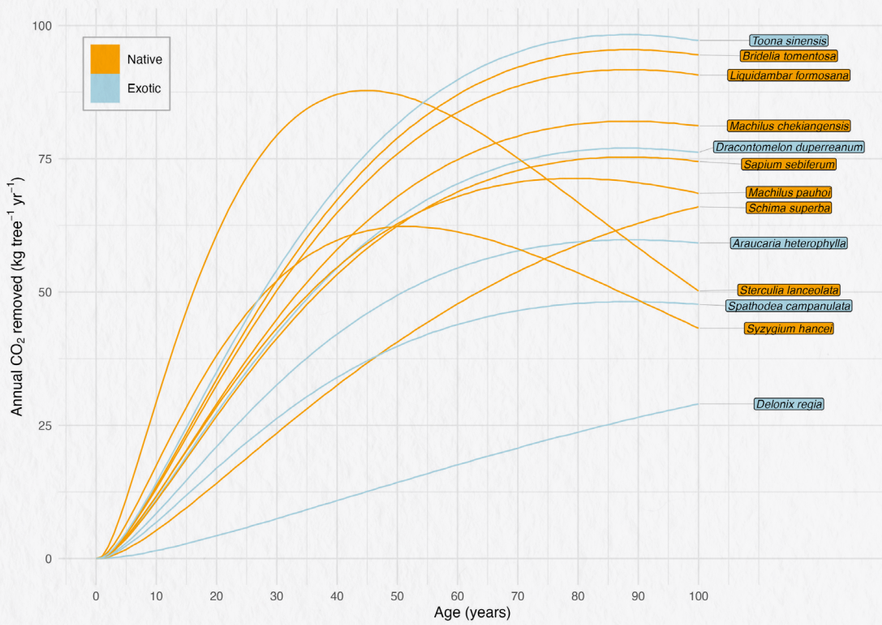


Chart A2-2. Annual CO_2 Removal of Tree Species with annual CO_2 removal ranging between 23–99 kg CO_2/tree/year at age 100

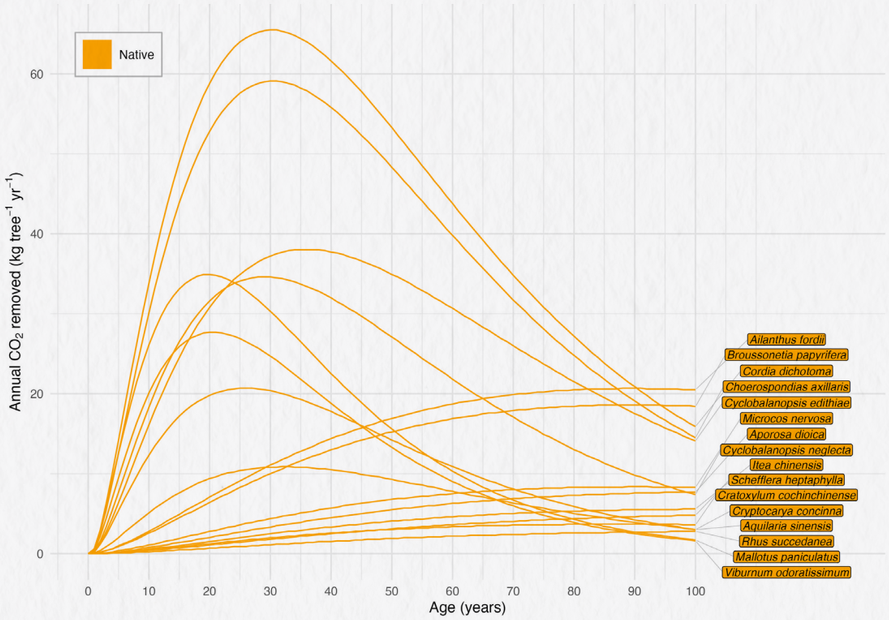


Chart A2-3. Annual CO_2 Removal of Tree Species with annual CO_2 removal remaining below 23 kg CO_2/tree/year at age 100

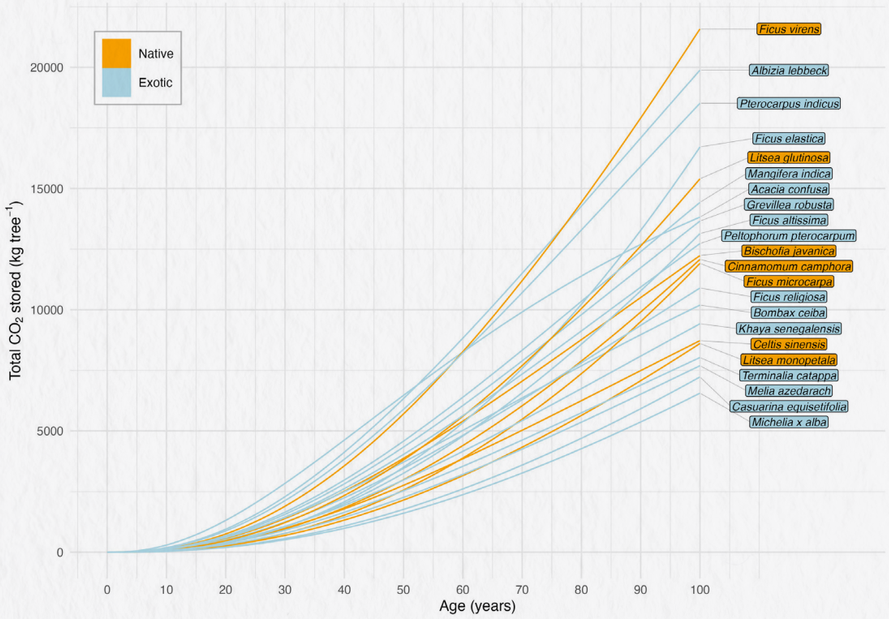


Chart A2-4. Total CO_2 Stored in Tree Species with annual CO_2 reaching or exceeding 100 kg/tree/year at age 100

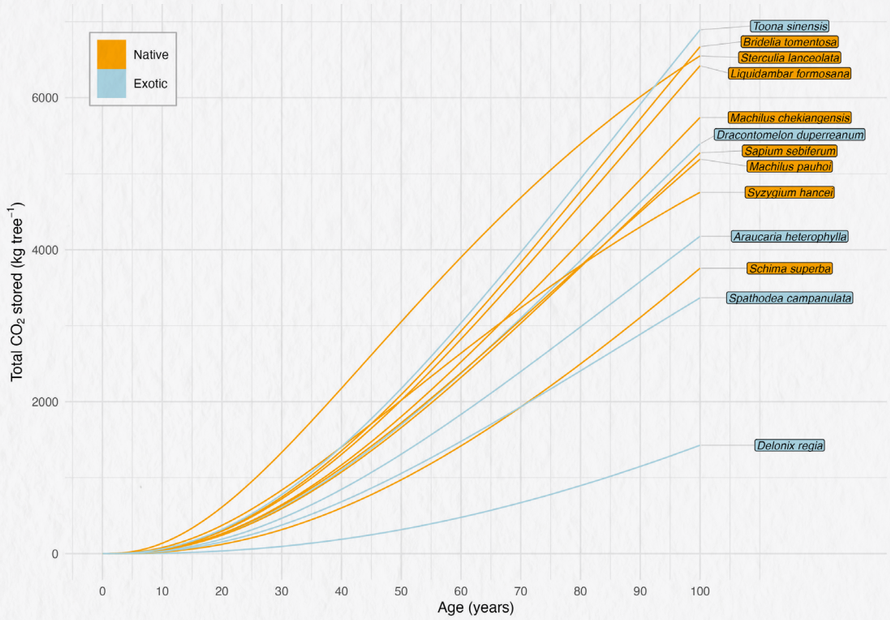


Chart A2-5. Total CO_2 Stored in Tree Species with annual CO_2 removal ranging between 23–99 kg CO_2/tree/year at age 100

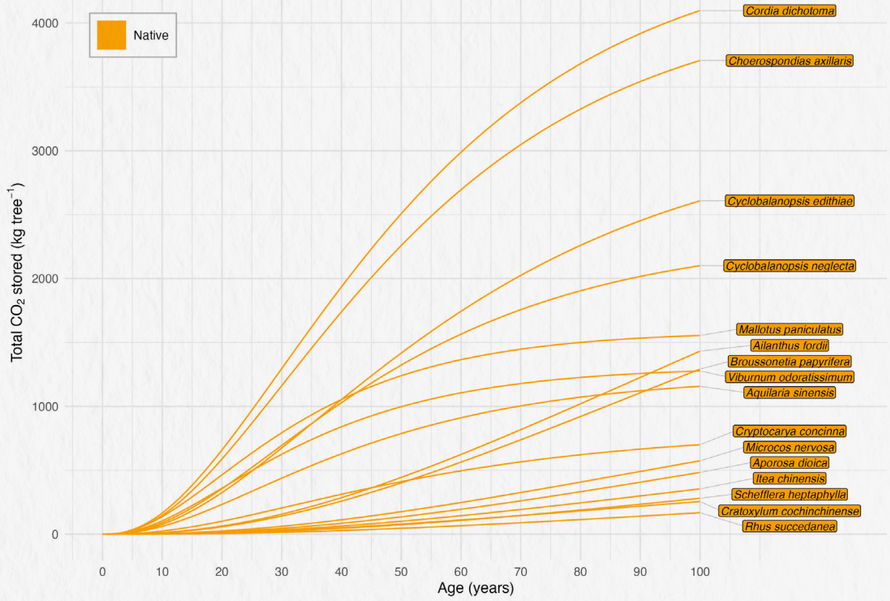


Chart A2-6. Total CO_2 Stored in Tree Species with annual CO_2 removal remaining below 23 kg CO_2/tree/year at age 100

Detailed data is available here.

Table A2-1. Summary of the Basic Ecological Information and Carbon Capture Performance of the 51 Tree Species Modelled.

Scientific Name	Chinese Name	Family	Origin	Tree size class	Wood Density (g/cm^3)#
*Acacia confusa^*	台灣相思	Mimosaceae	Exotic	Canopy	0.72[a]
Ailanthus fordii	常綠臭椿	Simaroubaceae	Native	Canopy	0.41[c]
Albizia lebbeck	大葉合歡	Mimosaceae	Exotic	Canopy	0.55[c]
*Aporosa dioica**	銀柴	Euphorbiaceae	Native	Subcanopy	0.65[a]
Aquilaria sinensis	土沉香	Thymelaeaceae	Native	Subcanopy	0.37[c]
Araucaria heterophylla	異葉南洋杉	Araucariaceae	Exotic	Canopy	0.50[c]
Bischofia javanica	秋楓	Euphorbiaceae	Native	Canopy	0.62[a]
Bombax ceiba	木棉	Bombacaceae	Exotic	Canopy	0.30[a]
*Bridelia tomentosa**	土蜜樹	Euphorbiaceae	Native	Understorey	0.75[a]
Broussonetia papyrifera	構樹	Moraceae	Native	Understorey	0.29[b]
Casuarina equisetifolia	木麻黃	Casuarinaceae	Exotic	Canopy	0.67[b]
Celtis sinensis	朴樹	Ulmaceae	Native	Canopy	0.59[a]
*Choerospondias axillaris**	南酸棗	Anacardiaceae	Native	Canopy	0.64[a]
Cinnamomum camphora	樟樹	Lauraceae	Native	Canopy	0.49[c]
*Cordia dichotoma**	破布木	Boraginaceae	Native	Canopy	0.45[b]
*Cratoxylum cochinchinense**	黃牛木	Clusiaceae	Native	Subcanopy	0.72[a]
Cryptocarya concinna	黃果厚殼桂	Lauraceae	Native	Canopy	0.68[a]
Cyclobalanopsis edithiae	華南青岡	Fagaceae	Native	Canopy	0.85[a]
Cyclobalanopsis neglecta	竹葉青岡	Fagaceae	Native	Canopy	0.86[a]
Delonix regia	鳳凰木	Caesalpiniaceae	Exotic	Canopy	0.58[c]

Scientific Name	Chinese Name	Family	Origin	Tree size class	Wood Density (g/cm^3)
*Dracontomelon duperreanum**	人面子	Anacardiaceae	Exotic	Canopy	0.45[c]
*Ficus altissima**	高山榕	Moraceae	Exotic	Canopy	0.47[c]
Ficus elastica	印度橡樹	Moraceae	Exotic	Canopy	0.62[b]
Ficus microcarpa	細葉榕	Moraceae	Native	Canopy	0.49[a]
*Ficus religiosa**	菩提樹	Moraceae	Exotic	Canopy	0.44[c]
*Ficus virens**	大葉榕	Moraceae	Native	Canopy	0.34[c]
Grevillea robusta	銀樺	Proteaceae	Exotic	Subcanopy	0.52[b]
Itea chinensis	鼠刺	Grossulariaceae	Native	Subcanopy	0.56[b]
*Khaya senegalensis**	非洲楝	Meliaceae	Exotic	Canopy	0.52[c]
*Liquidambar formosana**	楓香	Hamamelidaceae	Native	Canopy	0.58[a]
*Litsea glutinosa**	潺槁樹	Lauraceae	Native	Subcanopy	0.66[a]
*Litsea monopetala**	假柿木薑子	Lauraceae	Native	Canopy	0.46[a]
*Machilus chekiangensis**	浙江潤楠	Lauraceae	Native	Canopy	0.55[a]
Machilus pauhoi	刨花潤楠	Lauraceae	Native	Canopy	0.53[a]
Mallotus paniculatus	白楸	Euphorbiaceae	Native	Subcanopy	0.58[a]
Mangifera indica	杧果	Anacardiaceae	Exotic	Canopy	0.55[b]
*Melia azedarach**	苦楝	Meliaceae	Exotic	Canopy	0.54[b]
Michelia x alba	白蘭	Magnoliaceae	Exotic	Canopy	0.49[b]
*Microcos nervosa**	布渣葉	Tiliaceae	Native	Understorey	0.50[c]
Peltophorum pterocarpum	盾柱木、雙翼豆	Caesalpiniaceae	Exotic	Canopy	0.57[b]
*Pterocarpus indicus**	紫檀	Fabaceae	Exotic	Canopy	0.58[b]

Scientific Name	Chinese Name	Family	Origin	Tree size class	Wood Density (g/cm³)
Rhus succedanea	野漆樹	Anacardiaceae	Native	Subcanopy	0.64[(a)]
*Sapium sebiferum**	烏桕	Euphorbiaceae	Native	Canopy	0.46[(a)]
Schefflera heptaphylla	鴨腳木	Araliaceae	Native	Canopy	0.46[(a)]
*Schima superba**	木荷	Theaceae	Native	Canopy	0.60[(a)]
Spathodea campanulata	火焰樹	Bignoniaceae	Exotic	Subcanopy	0.37[(b)]
Sterculia lanceolata	假蘋婆	Sterculiaceae	Native	Subcanopy	0.65[(a)]
*Syzygium hancei**	韓氏蒲桃	Myrtaceae	Native	Canopy	0.69[(a)]
Terminalia catappa	欖仁樹	Combretaceae	Exotic	Canopy	0.48[(b)]
Toona sinensis	香椿	Meliaceae	Exotic	Canopy	0.49[(b)]
Viburnum odoratissimum	珊瑚樹	Caprifoliaceae	Native	Subcanopy	0.54[(a)]

 # Sources of wood density values:

(a) Local specimen measurement

(b) Chao et al. (2022)

(c) Global Wood Density Database v.2 (Fischer et al., 2026)

^ A species with a rapid growth rate but a comparatively short lifespan, around 50 to 60 years (ref: https://www.greening.gov.hk/en/community-outreach/qrcode-tree-labels/index_id_3.html)

**Suitable Tree Species for each Street Typology*

Table A2-2. Summary of the Sampled Trees for Field Measurements and Laboratory Testing

S/N	Site	Tree Species	Volume (l)	DBH (m)	Sample collection		Overall Carbon Content
					No. of Trunk samples	No. of Branch samples*	
1	Tung Chung Road	*Celtis sinensis*	600	0.21	3	5	41%
2	Tung Chung Road	*Microcos nervosa*	981	0.23	3	5	45%
3	Tung Chung Road	*Celtis sinensis*	542	0.19	3	5	39%
4	Tung Chung Road	*Microcos nervosa*	335	0.20	3	2	47%
5	Mui Wo	*Casuarina equisetifolia*	2,134	0.51	2	3	47%
6	Mui Wo	*Casuarina equisetifolia*	1,476	0.40	3	5	47%
7	Mui Wo	*Livistona chinensis*	168	0.29	3	0	47%
8	Mui Wo	*Callistemon viminalis*	341	0.23	2	1	49%
9	Mui Wo	*Callistemon viminalis*	272	0.21	3	4	49%
10	Mui Wo	*Araucaria columnaris*	1,377	0.33	2	0	49%
11	Mui Wo	*Roystonea regia*	712	0.22	1	2	44%
12	Sheung Shui	*Leucaena leucocephala*	692	0.13	3	5	47%
13	Sheung Shui	*Bombax ceiba*	954	0.31	3	5	43%
14	Sheung Shui	*Ficus microcarpa*	1,393	0.40	3	5	46%
15	Sheung Shui	*Sapium sebiferum*	104	0.12	3	5	46%
16	Sheung Shui	*Acacia auriculiformis*	516	0.20	3	0	51%
17	Sheung Shui	*Sapium sebiferum*	228	0.26	3	5	47%
18	Sheung Shui	*Bombax ceiba*	384	0.22	1	2	43%
19	Pak Kung Au	*Schima superba*	368	0.13	2	0	40%
20	Pak Kung Au	*Ficus microcarpa*	488	0.13	2	0	42%
21	Pak Kung Au	*Aquilaria sinensis*	483	0.12	2	0	38%
22	Pak Kung Au	*Machilus chekiangensis*	56	0.09	2	0	40%
23	Mui Wo	*Roystonea regia*	515	0.34	3	0	43%
24	Mui Wo	*Livistona chinensis*	155	0.17	3	0	41%
25	Mui Wo	*Roystonea regia*	200	0.18	3	0	42%

** Branch samples for some trees were unavailable.*

A3. Reference List

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