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Problems and Management of *Acacia*-Dominated Urban Forests on Man-Made Slopes in a Subtropical, High-Density City

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Abstract: *Acacia* spp. are exotic tree species that have been widely planted on man-made slopes in Hong Kong since the 1960s. However, as they become mature and senescent, they may become a concern and cause various problems, including soil constraints for plant growth, decreasing provision of intended ecosystem services, declining syndromes, arrested succession, and high risk of failure. In this perspective paper, we present and discuss these problems using practical examples of *Acacia*-dominated urban forests on man-made roadside slopes in Hong Kong, based on a cross-disciplinary survey and a literature review. To conclude, we suggest that selective cutting, specific silvicultural operations of *Acacia* plantations, and the management of plantation edge and soils can be exercised, along with the planting of native species, to potentially alleviate these problems associated with mature *Acacia* plantations, by promoting the establishment of native forests, enhancing biodiversity, expediting succession, and providing better ecosystem services.

Keywords: *Acacia* plantations; ecosystem services; exotic trees; forest management; tree senescence; urban forest

1. Introduction

Acacia species (Fabaceae), including *A. confusa*, *A. mangium* and *A. auriculiformis*, have been extensively planted in Hong Kong, China since the 1960s. They were used as pioneer tree species for large-scale reforestation of hillside, man-made slopes and other natural terrains [1]. They were also used to restore degraded lands such as phased-out quarries and restored landfills [1–3]. Among the three *Acacia* species, *A. confusa* had been the most common choice in the urban forests with an occurrence of 7.9%, while *A. mangium* and *A. auriculiformis* comprising another 1.5% [4].

As a species native to Taiwan and the Philippines, *Acacia confusa* (Taiwan *Acacia*) has been widely applied and planted in places outside its native range since it grows very well on dry, infertile or rough lands. This pioneer species can quickly establish vegetation cover, prevent soil erosion, stabilize slopes, and prevent landslides [5–8]. Additionally, its root nodules contain symbiotic bacteria called *Rhizobium* spp., which can convert atmospheric nitrogen gas into ammonium or organic nitrogen to supply the nutrient need of the host plants [1,9]. This means that they are tolerant to nutrient-deficient environments,

rendering it one of the best candidates for landscape treatment on engineered slopes in the past.

Hong Kong has a hilly terrain with little flat land, with about 63% and 30% of the land being steeper than 15° and 30°, respectively [10]. Due to the intense urban development, at least 60,000 man-made slopes have been formed on hillsides in close proximity to buildings, roads and other facilities. These man-made slopes may be susceptible to landslide during rainy seasons and typhoon events, and could be hazardous to people if not properly managed. To make slopes look as natural as possible and reduce the risk of landslide, shrubs and trees are planted on man-made slopes which are gentler than 55°. Currently, there are at least 95,909 *A. confusa* trees distributed on areas adjacent to high pedestrian and vehicular flows in Hong Kong [11]. However, as *A. confusa* has an average life span of about 50 to 60 years, many trees are now reaching the stage of senescence and approaching the end of their life. Senescence problems, such as trunk decay, crown dieback and fungal diseases are becoming more common in ageing *Acacia* trees [5,12]. In particular, the prevalence of butt and root rot disease, caused by fungal species *Ganoderma tropicum* and *Amauroderma elmerianum*, has attracted much attention of different government departments, and it has been agreed that close monitoring has to be conducted to avoid potential risks to vehicles and pedestrians [13].

Without proper management, ageing *Acacia* trees on *Acacia*-dominated slopes may impose greater fall risks, endangering pedestrians and roadside vehicles. *Acacia confusa* planted on the inclined surface of disturbed slopes and small pits may suffer from growth stress and limited space [14]. *Acacia* trees on roadside slopes may also have leaning structures that increase their likelihood of failure [15]. When they fall, their trunks and branches may obstruct traffic, damage vehicles, and injure pedestrians. In view of these potential hazards, the Hong Kong Government has published two technical guidelines on landscape treatment of slopes and the requirements of pit planting [16,17]. From 2012 to 2017, the core tree management departments in Hong Kong removed around 13,000 *A. confusa* beset with health or structural problems or severe damage caused by inclement weather during routine tree maintenance program on roadside slopes, in public housing estates, parks, as well as recreational facilities and venues. In view of this, the Highways Department of Hong Kong, the government department responsible for planning, design, construction and maintenance of the public road system, has initiated a program entitled “Enhancement of Vegetated Slopes Programme” to replace senescent trees and trees with structural or health problems since mid-2016. For instance, *Liquidambar formosana* has become a popular choice in recent years to replace problematic trees due to its high aesthetic values, long life expectancy, high wind tolerance, and strong resistance to pests and diseases [4].

In addition to the problems stated above, the mature *Acacia* may also have reduced ecosystem services compared to young, growing forests. Forests typically provide a large array of ecosystem services, including supporting, provisioning, regulating and cultural services. One regulating service is the regulation of climate and air quality, which are significant concerns in most megacities such as Hong Kong. For instance, many urban trees are known to remove surface ozone, a harmful air pollutant, from the atmosphere via leaf uptake [18]. However, as a forest matures and trees become senescent, some of these services may decline; the status of such services provided by a given mature forest should be evaluated before a tree replacement program takes place.

The objectives of this perspective paper are to (1) discuss the major problems of *Acacia*-dominated urban forests on man-made roadside slopes in Hong Kong based on a cross-disciplinary survey and literature review, (2) suggest some potential management strategies to alleviate these problems, which would enhance and promote various values and ecosystem services of urban forests on man-made slopes in a subtropical, high-density city.

2. Methods

We illustrated the various problems of *Acacia*-dominated slopes by combining the results of a targeted literature review of peer-reviewed scientific articles, research reports and local research theses published in the last 25 years and a cross-disciplinary survey of *Acacia*-dominated slopes at Tai Tong, Hong Kong (China). We studied four sites that are located adjacent to the roadside with high pedestrian and traffic flows particularly during the daytime. These sites were selected since they represented some *Acacia*-dominated slopes that were covered under the Government's "Enhancement of Vegetated Slopes Programme" in which the senesced *A. confusa* trees would be felled and replaced with the planting of other native species. The study area is located in close proximity (around 100 m or less) to natural regenerated forests and plantations the Tai Lam Country Park, which is a legally protected area in Hong Kong for nature conservation, recreational and educational purposes. The size of the four sites ranges from 959.5 m² to 3248 m² and with a total of 262 numbers of *A. confusa* trees at the beginning of the survey. We conducted the following measurements: monitoring of soil conditions, measurement of canopy ecophysiological parameters for evaluating climate and air quality regulating services, and assessment of tree health.

To monitor the soil conditions, surface (0–10 cm) soil samples were collected with a soil auger seasonally in 5 replicate locations at each of the four sites in Tai Tong from July 2018 to April 2020. The samples were immediately brought back to the laboratory and stored at 4 °C in a refrigerator until further analysis of their physicochemical properties. Soil pH was measured by the glass electrode method using an Orion Expandable Ion Analyzer after shaking the soil slurry with a soil to water ratio of 1:2.5 (*w/v*). Soil bulk density was determined by collecting a fixed volume of top soils with aluminum cores, drying in the oven at 105 °C for 48 h, and measuring the total weight of the oven-dry soils. Soil ammonium and nitrate concentrations were determined by extracting the soil samples with potassium chloride for 1 h and analyzing the extracts for ammonium and nitrate concentrations spectrophotometrically by flow injection analyzer. Available phosphorus concentration was determined by extracting soil samples with ammonium lactate solution and analyzing the extracts for phosphate concentration by flow injection analyzer. Soil organic matter was determined by the loss on ignition method by combusting the soil samples at 550 °C for 4 h. Total Kjeldahl nitrogen in soils was determined by the Kjeldahl oxidation method. The concentrations of extractable cations (Na, Mg, K, Ca) were determined by atomic absorption spectroscopy after extracting the soils with ammonium acetate solution for one hour.

To evaluate climate and air quality regulating services, we first measured important climate- and air quality-relevant ecophysiological parameters at the four sites over six seasons from spring 2019 to summer 2020, combined with reference data representing typical "conventional" values for the corresponding vegetation types from Kattge et al. [19]. Specifically, we collected two variables, namely, species-specific maximum carboxylation rates at 25 °C ($V_{\text{cmax}25}$) using the LICOR-6800 photosynthesis system and following the established protocol of Bellasio et al. [20], and leaf area index (LAI) using the LICOR-2200C LAI meter, of three plant species: *A. confusa* (old, exotic plantation), *Liquidambar formosana* (replanted native) and *Trema orientalis* (native). The latter two species were chosen because *L. formosana* is the most prevalent native tree used in the replanting program, and *T. orientalis* is a common native shrub found in the study sites. We then used a numerical ecosystem model, the Terrestrial Ecosystem Model in R (TEMIR; <https://github.com/amospktai/TEMIR>; last assessed on 5 January 2021), to simulate the gross primary production (GPP) and dry-depositional uptake of surface ozone of the three species using various combinations of measured vs. conventional values of $V_{\text{cmax}25}$ and LAI (see Supplementary Materials for model details).

To assess tree health, individual tree data including height, diameter at breast height (DBH), percentage of dieback, general health (good, fair or poor), presence or absence of

dead branches, were recorded or measured with all *A. confusa* trees at the four sites from August 2018 to October 2020 on a bimonthly basis.

3. Results and Discussion

3.1. Soil Constraints for Plant Growth

Numerous studies have examined the influence of *Acacia* vegetation on various properties of soils in a number of geographical regions. It has been suggested that an increase in *Acacia* biomass could alter soil nutrient availability through the nitrogen-fixing behavior of *Acacia* trees, modify soil moisture regime through the shading effects of *Acacia* trees and litter layer, as well as exert impacts on soil microbial communities through changes in the physio-chemical environment [21]. Yelenik et al. [22] found that *Acacia saligna* increased soil ammonium and nitrate availability as well as total soil nitrogen pool when compared to non-nitrogen-fixing native species. In the European sand dunes, the invasion by *Acacia longifolia* was shown to significantly alter the catabolic diversity of decomposer community in soils, which could further affect litter breakdown and nutrient cycling rates [23]. It has been shown that the litter of *Acacia longifolia* had relatively slow decomposition rate, in spite of a high nitrogen content and low carbon to nitrogen ratio, which would contribute to the accumulation of nitrogen-rich litter on the soil surface [24].

Table 1 shows the basic physio-chemical properties of soils on *Acacia*-dominated slopes in Hong Kong. The soils on these slopes are generally acidic with a mean pH of 5.22, which are typical for soils developed in this subtropical region with high annual precipitation (>2400 mm) and intense leaching. The soils have a mean bulk density of 1.02 g/cm³, which is within the range of uncompact soils and indicative of a suitable environment for root penetration [25]. The mean soil ammonium and nitrate concentrations are 25.9 and 9.1 mg/kg, respectively, which together are considered to be rather low (< 40 mg/kg) for supporting plant growth [25]. The mean available phosphorus concentration is 9.1 mg/kg, which falls within the medium range (2–40 mg/kg) that could have probable fertilizer response [25]. The soil organic matter and total Kjeldahl nitrogen concentrations are 7.22% and 0.27%, respectively, which are around the threshold values that distinguishes between low and medium levels [25]. The mean exchangeable sodium, potassium, magnesium, and calcium concentrations are 13.5, 81.6, 47.8, and 646 mg/kg, respectively, which are all considered to be low [25], which reflects the low cation exchange capacity of the acidic and highly leached soil in this climatic region.

Table 1. The physio-chemical properties of soils on *Acacia*-dominated slopes (mean $\pm$ 1 standard error, N = 40).

pH	Bulk Density (g/cm ³)	Ammonium Nitrogen (mg N/kg)	Nitrate Nitrogen (mg N/kg)	Available Phosphorus (mg/kg)	Soil Organic Matter (%)	Total Kjeldahl Nitrogen (%)	Exchangeable Cations (mg/kg)			
							Na	K	Mg	Ca
5.22 (0.32)	1.02 (0.02)	13.04 (2.42)	25.87 (3.41)	9.13 (0.99)	7.22 (0.16)	0.27 (0.01)	13.5 (1.5)	81.6 (6.3)	47.8 (3.9)	646 (66)

3.2. Declining Ecosystem Services of *Acacia*

We evaluated the ecosystem services provided by the *Acacia* plantations as well as some neighboring species in terms of mitigating climate change and air pollution, which are significant concerns in Hong Kong. Measured values of $V_{\text{cmax}25}$ and LAI, together with their conventional values from literature, are tabulated in Table 2. The replanted *L. formosana* has a normal LAI but a roughly doubled $V_{\text{cmax}25}$ compared with typical tropical broadleaf deciduous trees, while the other two species, *A. confusa* in the old roadside plantations and the native *T. orientalis*, have smaller LAI (almost halved) but comparable $V_{\text{cmax}25}$ compared with typical tropical broadleaf evergreen trees and temperate broadleaf deciduous shrubs, respectively. The comparison reveals generally better physiological conditions of the replanted species than the mature *A. confusa* and mature native *T. orientalis*.

As we examined the aggregate measured LAI at the four sites (three with replanting, one as control) over the six seasons (Figure S1), we found that LAI of the forest canopies generally follows a seasonal cycle with peak LAI in autumn and lowest LAI in spring. It is particularly noteworthy that all the sites with replanting at various time points experienced an accelerated growth in LAI in the growing season in 2020 that was faster in comparison to the control site.

Table 2. Maximum carboxylation rate at 25 °C (V_{cmax25}) and leaf area index (LAI) data obtained from measurements using LICOR-6800 and LICOR-2200C in Tai Tong, Hong Kong and literature. Uncertainties are represented by ± 1 standard deviation. Conventional values for corresponding plant function types (PFTs) of the respective species are given by Kattge, Knorr, Raddatz and Wirth [16] and Oleson et al. [26]. The LICOR-6800 photosynthesis system measures real-time foliage physiological parameters and photosynthesis rate by an infrared gas analyzer and quantifies important parameters of light reaction, chlorophyll and gaseous exchange by a fluorometer. The LAI meter LICOR-2200C has an optical sensor that measures foliage density by considering the proportion of sunlight blocked by the plant canopy.

Species	Corresponding Plant Functional Type (PFT)	Measured V_{cmax25} ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Conventional V_{cmax25} ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	Mean Measured LAI ($\text{m}^2 \text{m}^{-2}$)	Conventional LAI ($\text{m}^2 \text{m}^{-2}$)
<i>Acacia confusa</i>	Tropical broadleaf evergreen tree	32 ± 13	29.0 ± 7.7	2.7 ± 0.6	5.8
<i>Liquidambar formosana</i>	Tropical broadleaf deciduous tree	62 ± 16	29.0 ± 7.7	2.7 ± 0.7	2.8
<i>Trema orientalis</i>	Temperate broadleaf deciduous shrub	67 ± 15	54.0 ± 14.5	2.3 ± 0.7	5.2

Based on the measured values of V_{cmax25} and LAI, the annual GPP and ozone uptake (F_{O_3}) of *A. confusa* were estimated to be about 1600 g C m^{-2} and $3.1 \text{ g O}_3 \text{ m}^{-2}$, respectively (Table 3). By comparison, the replanted species found in the same forest, *L. formosana*, has a significantly larger productivity (2300 g C m^{-2}) but slightly smaller ozone uptake ($2.5 \text{ g O}_3 \text{ m}^{-2}$) when compared to *A. confusa*. A native shrub species, *T. orientalis*, has a larger productivity (2100 g C m^{-2}) and larger ozone uptake ($3.5 \text{ g O}_3 \text{ m}^{-2}$) when compared to *A. confusa*. However, when comparing the results from the measurements with those using conventional LAI and V_{cmax25} values, we found that the replanted *L. formosana* has a normal LAI but an almost doubled V_{cmax25} compared with the conventional value, while both the original species *A. confusa* and *T. orientalis* have an LAI that is about half of the conventional value and a normal V_{cmax25} . The comparison reveals better health conditions and more active growth of the replanted species than the original species. The subpar performance of the original species is mostly due to the much lower measured LAI than the conventional LAI, which can be explained by the maturity and senescence of the old plants.

Climate change itself may have adverse impacts on forests and further constrain the ability of trees to provide ecosystem services [27]. Such impacts are complex, however, and strongly depend on the tree species, climate zone, and the complicating effect of urbanization. A recent global study [28] suggested that global warming and the accompanying CO_2 fertilization have accelerated urban tree growth worldwide since the 1960s, but accelerated growth might also have led to more rapid ageing and shortened lifetime, necessitating earlier replacement and replanting. While this might in part explain the poor provision of ecosystem services by the mature *Acacia* plantations, a localized study on the long-term impacts of climate change on Hong Kong urban trees is still lacking and much needed.

Table 3. Simulated annual gross primary production (GPP), ozone dry deposition flux (F_{O_3}), and dry deposition velocity (v_d) of the three species in Tai Tong in the simulated years. The meter square in the unit refers to land area. Setups include: a ‘Measurement’ setup using the measured V_{cmax25} and LAI data; one using conventional V_{cmax25} and measured LAI (ConV_{cmax}_MeaLAI); one using conventional V_{cmax25} and conventional LAI (ConV_{cmax}_ConLAI). Monthly time series of simulated results are presented in Figures S2–S10 in the Supplementary Materials.

Species	Setups	Annual GPP (g C m ⁻²)	Annual F_{O_3} (g O ₃ m ⁻²)	Mean v_d (10 ⁻³ m s ⁻¹)
<i>Acacia confusa</i>	Measurement	1595	3.125	3.52
	ConV _{cmax} _MeaLAI	1555	3.130	3.35
	ConV _{cmax} _ConLAI	2108	4.417	4.98
<i>Liquidambar formosana</i>	Measurement	2316	2.507	2.79
	ConV _{cmax} _MeaLAI	1531	2.201	2.47
	ConV _{cmax} _ConLAI	1554	2.225	2.50
<i>Trema orientalis</i>	Measurement	2129	3.516	3.95
	ConV _{cmax} _MeaLAI	2216	3.637	4.08
	ConV _{cmax} _ConLAI	2949	4.139	4.62

3.3. Declining Syndromes in Ageing Plantations

We monitored the health conditions of each *A. confusa* tree within the four sites between August 2018 and October 2020 for 12 times to see the changes within two years. The total number of *A. confusa* trees in the four slopes was originally at 262 to later 172, due to the phased selective removal of *Acacia* trees and tree collapse under typhoons. At the end of the survey, 35.29% of existing *A. confusa* were higher than 10 m, 30.59% were larger than 300 mm DBH, 30% were of 50% or more branch dieback, 60% were of poor health, and 88.24% possessed dead branches (Tables 4 and 5). The conditions of existing *A. confusa* trees in these slopes were found to be very poor, with widespread symptoms and defects such as sparse foliage, dieback, trunk crack, poor tree form, and heavy leaning, etc. In addition, fungal infection by *Ganoderma tropicum*, *Pyrrhoderma adamantinum*, and *Amauroderma rugosum* were observed on few trees with serious symptoms. The signs and symptoms indicated that most of the trees are declining and manifesting stress response. The health conditions were apparently deteriorating over the two years, which diminish the trees’ ability to respond to structural issues. Ageing plantations of this kind, due to the high proximity to people and properties, should be properly maintained and managed.

Table 4. Mean height, DBH, and dieback percentage of *A. confusa* in the study sites in Aug 2018 and Oct 2020. Values in parenthesis represent standard error of mean.

Site	Slope No.	No. of <i>Acacia confusa</i>	21 August 2018			No. of <i>Acacia confusa</i>	23 October 2020		
			Mean Height (m)	Mean DBH (mm)	Mean Dieback (%)		Mean Height (m)	Mean DBH (mm)	Mean Dieback (%)
1	6NW-D/C161	63	9.32 (0.25)	290.2 (10.89)	23.12 (2.23)	37	9.76 (0.33)	331.86 (16.13)	29.59 (3.03)
2	6NW-D/C158	33	10.94 (0.25)	260.34 (20.49)	26.09 (2.61)	15	10.6 (0.46)	248.67 (23.62)	38.53 (7.28)
3	6NW-D/C74	99	8.43 (0.19)	227.01 (9.71)	40.73 (2.21)	57	8.69 (0.2)	227.89 (11.24)	43.33 (2.47)
4	6NW-D/C78	67	7.99 (0.22)	251.96 (11.86)	25.67 (2.39)	61	8.03 (0.23)	258.56 (12.63)	31.8 (2.67)
Total		262	8.83 (0.13)	252.17 (6.18)	30.82 (1.3)	170	8.86 (0.15)	263.36 (7.69)	35.78 (1.61)

Table 5. Characteristics of *A. confusa* in the study sites in Aug 2018 and Oct 2020.

Site	Slope No.	21 August 2018						23 October 2020					
		No. of <i>Acacia confusa</i>	Height ≥10 m	DBH ≥300 mm	Dieback ≥ 50%	Poor Health	Possess Dead Branch	No. of <i>Acacia confusa</i>	Height ≥10 m	DBH ≥300 mm	Dieback ≥50%	Poor Health	Possess Dead Branch
1	6NW-D/C161	63	32 50.80%	29 46.00%	6 9.50%	26 41.30%	49 77.70%	37	20 54.05%	23 62.16%	5 17.95%	21 56.76%	36 97.30%
2	6NW-D/C158	33	28 84.80%	10 30.30%	5 15.20%	10 30.30%	22 66.70%	15	10 66.67%	3 20.00%	5 33.33%	9 60.00%	13 86.67%
3	6NW-D/C74	99	24 24.20%	18 18.20%	34 34.30%	69 69.70%	83 83.80%	57	15 26.32%	10 17.54%	27 47.37%	40 70.18%	52 91.23%
4	6NW-D/C78	67	17 25.40%	16 23.90%	10 14.90%	31 46.30%	46 68.70%	61	15 24.59%	16 26.23%	14 22.95%	32 52.46%	49 80.33%
Total		262	101 38.50%	73 27.90%	55 21.00%	136 51.90%	200 76.30%	170	60 35.29%	52 30.59%	51 30.00%	102 60.00%	150 88.24%

3.4. Arrested Ecological Succession

After decades, the *Acacia*-dominated man-made slopes now appear to fail to establish a right mix of species, resulting in low biodiversity. *Acacia* plantations in Hong Kong have a relatively simple structure with poor understorey [5,15] compared with naturally regenerated subtropical forests [29–31]. *A. confusa* is known to excrete toxic biochemicals into the soil following the decomposition of leaves. The allelochemicals released into the soil act to inhibit or suppress the growth of other plants [32]. This characteristic has limited the growth and natural propagation of native species [5,6,12]. With poor understorey and limited native species recruitment, succession may be arrested in *Acacia*-dominated locations [33]. *Acacia* plantations can form a closed canopy within three years of planting while light-demanding grass will die off with insufficient sunlight [33]. Even shade-tolerant dicot species may not survive in the understorey of *Acacia*-dominated locations because of allelopathic nature of leaf litter [29,32,34]. Studies also pointed out that even after ten years, the planted *Acacia* spp. remained dominant on restored lands [7,35,36]. Thus, without invasion of grass and colonization of other native species, succession is halted or arrested.

The ages of a plantation, however, may increase together with habitat complexity and establishment of native species [31,37], the presence of various vertical strata, understorey vegetations and microhabitats that enhances the diversity of animals such as forest birds [32], beetles [38], butterflies [39], and spiders [40,41]. Combinations of various vertical strata and microhabitats increase the partitioning of feeding niches of forest birds [42], although the seeds of the exotic *Acacia* spp. are not attractive to local frugivorous birds [5].

In a study on comparing the woody species regeneration in exotic monoculture plantations and secondary forests of similar ages in Hong Kong, *A. confusa* plantations apparently had much lower species diversity while the regeneration stem density was amongst the lowest when compared with the plantations of other exotic species, including the monocultures of *Losphostemon confertus* and *Melaleuca quinquenervia*, the plantations with a mixture of exotic species, and natural secondary forests [6]. Without proper intervention, such as post-planting management [31,34,43] and planting of native species with attractive fruits [6], exotic plantations cannot fully transform into secondary forests supporting higher diversity of native plants and animals [29,44].

4. Suggestions

To better manage mature *Acacia* plantations in Hong Kong, post-planting management, such as selective cutting, specific silvicultural operations of *Acacia* plantations and management of plantation edge, are required to facilitate establishment of native species, expedite succession, as well as address safety concerns. Native species should also be subsequently planted as they are more attractive to local animals and seed dispersers, which can enrich the ecological value and biodiversity of the sites [6,29].

4.1. Selective Cutting of *Acacia* Trees and Replanting Plans

Selective cutting, or selection felling, is the practice of selecting scattered single tree or groups of trees to be harvested or removed. This is usually a regular practice in silvicultural systems [45,46]. Generally, selective cutting involves trees that have attained a certain diameter or any criteria for opportunistically capitalizing on the volume and value a landowner can extract from a forest [47]. Such practice does not necessarily encourage natural regeneration and may result in serious deterioration of the forest [45,47]. In case of selective cutting of *Acacia* on artificially engineered slopes in Hong Kong, where no commercial value is involved, the selection criteria would be to prioritize removal of high-risk trees, minimize inherent effects to slope stability and enhance natural and assisted regeneration of forest with increasing biodiversity and ecosystem services. Important factors should include (a) a correct proportion of cutting should be proposed and the total health and risks of remaining trees after cutting are not to be deteriorating, (b) slope stability and safety are evaluated before and after selective cutting, (c) careful planning of “intentional” gaps (rather than random gaps) to allow later natural recruitment or assisted rehabilitation and that the created gaps are freed from suppression in sunlight, space and phytotoxic chemicals from the remaining *Acacia* and (d) potential effects of typhoon strike on the remaining, newly exposed *Acacia* should be carefully predicted [33,45].

Selective cutting artificially creates gaps in the existing plantation and, as a result, allowing more sunlight to reach the forest floor. This opens up the closed canopy and provides rooms for understorey growth [5,47]. Subsequently, this can encourage the regeneration of some light-demanding species [12,33]. The opened gaps should properly be replanted with a suitable mixture of native species to diversify vertical and horizontal structure or stratification for utilization of different bird and insect types. The right choice of replanting species should aim at selecting a mixture of trees, shrubs and ground vegetation that are of native origin, possess high reproductive potentials and ecological values, require low maintenance, and are generally tolerant to breakage, drought, heat, extreme climate events, poor soil, shade, spatial competition, and wind.

Careful cutting using light equipment such as chainsaw (but not heavy machines) is recommended to avoid damage to soil stability [12]. After felling, recycling of *Acacia* timber should also be considered to reduce burden of local landfills and minimize wastage. As *Acacia* timber has a hard texture and high wood density, they can be reused as materials for art, furniture, construction, or even chipping to become wood chips for mushroom cultivation (e.g., growing *Ganoderma* for medicinal use) [15].

4.2. Specific Silvicultural Operations of Existing and Remaining Stands

Other additional silvicultural operations should aim at prioritizing risk, improving the crown structure and tree health following damage from storms, and diversifying vertical structure in existing and remaining plantations. These operations may include crown cleaning, respacing, thinning, formative pruning, retrenchment pruning and other constructive ideas [48]. The purposes of different pruning practices are not only to provide preventative and responsive maintenance needs but also on the benefits of a range of vertical and horizontal structures and elements for later utilization of other plants, birds and insects at different dimensions in the ecological perspective. For example, in large areas of young Douglas fir plantations in the US Pacific Northwest [49], regimes aiming to increase structural diversity by leaving trees with large limbs, creating multi-layered canopies and dense unthinned areas may form habitat for the northern spotted owl (*Strix occidentalis*). In our study sites, two species of owls, including the Collared Scops Owl (*Otus lettia*) and Barred Owlet (*Glaucidium cuculoides*) were recorded during our ecological survey, suggesting these nocturnal birds of prey utilize the areas around. Sometimes, retention of older trees in the plantation, where potential risk for human safety is low, will increase opportunities for utilization and visitation of birds and insects, thus increasing the overall biodiversity in the long run. From the perspective of plants, silvicultural operations provide gaps for understorey growth and encourage establishment of natural or newly

planted species. This would benefit the successional development of plant diversity inside man-made slopes.

4.3. Management of Plantation Edge

The management of plantation edge on artificially engineered slopes is also very important. The habitat utilization by birds and insects on plantation edge is apparently different from the interior due to differences in microclimates, pedestrian and traffic disturbance, amount of sunlight, humidity and pollutants. Stand margins should therefore add greatly to the diversity of habitats by creating diffuse and irregular buffer zones using different types of trees, shrubs and ground vegetation, rather than sharp and constrained by the adjacent land use [48].

4.4. Management of Soils for the Growth of Replanted Vegetation

The impacts of removing *Acacia* trees on soil properties have been examined in some previous studies. Marchante et al. [50] found that 4.5 years after the removal of *Acacia longifolia* trees that had persisted for more than 20 years and the litter layer, the soil carbon and nitrogen pools were still higher than the native areas, though decreasing trends of soil carbon and nitrogen pools as well as microbial biomass and activity were observed. In a study in South Africa, soil legacy effects were found to persist up to 10 years after clearing of *Acacia saligna* trees, with the soils having significantly higher pH and nitrate concentrations than the native ecosystems without *Acacia* invasion [51]. In another study in South Africa, soil nutrient levels were significantly lower in locations with *Acacia* removal than those without, while nutrient recovery was observed in locations that were cleared 15 years ago than those that were more recently cleared 6 years ago [52]. Meanwhile, Nsikani et al. [53] found that the legacy of altered soil chemical properties after the removal of *Acacia saligna* had no significant impacts on the germination and growth of a native shrub. In the case of Hong Kong, the low mineral nitrogen and available phosphorus concentrations in the top soils of *Acacia*-dominated slopes suggest that fertilization should be carried out especially at the initial stage of replanting to ameliorate soil nutrient deficiency and improve the establishment and growth of replanted seedlings. Moreover, the felling of *Acacia* trees should be done around winter time to minimize the potential erosion caused by rainfall impacts on surface soils in the rainy season in this subtropical monsoonal region. Surface mulching can be applied to protect the soil surface from erosion, enhance moisture retention, increase nutrient supply, and reduce weed growth for enhancing the success of replanting. The replanting work should be implemented in early spring to capitalize on the availability of spring rain for plant water uptake, while avoiding the summer time during which leaching of soil nutrients is strong because of intense rainfall and seedling establishment is challenging because of the high temperature.

5. Conclusions

To conclude, the more rapid ageing and shortened lifetime of urban trees due to climate change should be considered as new ‘normal’ and any citywide tree management plan should always be prepared for earlier replacement and replanting. A farsighted large-scale replacement planting program with indigenous, ‘right’ tree species would thus present an excellent opportunity for enhancing the local biodiversity, ecosystem services, successional development, aesthetic values, as well as reducing the burden of managing potentially hazardous trees. A holistic planting concept with the idea of multifunctionality is a much preferable approach and should later contribute to the building blocks of a sustainable city. Therefore, the long-term planning of elements, structures, and management of urban forests on man-made slopes based on scientific principles is one of the most important services we could leave to the next generations.

Supplementary Materials: The following are available online at <https://www.mdpi.com/1999-4907/12/3/323/s1>, Figure S1. Leaf area index (LAI) variability at sites with *Acacia* forest in Tai Tong from April 2019 to August 2020. Six sample days were taken in April, July, October 2019, January, April and

August 2020. The standard error bars are shown for sites with repeated measurements. Figure S2. Monthly average photosynthesis rate of *Acacia confusa* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S3. Monthly average photosynthesis rate of *Liquidambar formosana* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S4. Monthly average photosynthesis rate of *Trema orientalis* in Tai Tong from April 2019 to August 2020. Figure S5. Monthly ozone dry deposition uptake by *Acacia confusa* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S6. Monthly ozone dry deposition uptake by *Liquidambar formosana* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S7. Monthly ozone dry deposition uptake by *Trema orientalis* in Tai Tong from April 2019 to August 2020. Figure S8. Monthly average dry deposition velocity of *Acacia confusa* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S9. Monthly average dry deposition velocity of *Liquidambar formosana* in Tai Tong from April 2019 to August 2020. Error bar represents ± 1 SD. Figure S10. Monthly average dry deposition velocity of *Trema orientalis* in Tai Tong from April 2019 to August 2020.

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