RGC Ref. No.:
UGC/FDS25/M05/16
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines: *1. Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
*2. Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Air Purification and Carbon Sequestration by Urban Park Trees in Hong Kong

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Hao ZHANG/ Associate Professor	Horticulture and Landscape Management programme / Faculty of Design and Environment / THEi
Co-Investigator(s)	Lee Man CHU/ Associate Professor	School of Life Sciences / CUHK
Others	Sifeng WANG/ Research Assistant	Horticulture and Landscape Management programme / Faculty of Design and Environment / THEi

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2017	NA	NA
Project Completion Date	31/12/2018	30/06/2019	06/04/2018 (approved by Institution)

Duration *(in month)*	24	30	NA
Deadline for Submission of Completion Report	31/12/2019	30/06/2020	NA

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To analyze the vegetation structure of urban parks in Hong Kong;
2. To quantify dust deposition by tree species commonly found in urban parks in Hong Kong;
3. To quantify the biomass accumulation of tree species commonly planted in urban parks in Hong Kong;
4. To assess the total amount of common air pollutant (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO) removed by trees at urban parks, and the total amount of carbon sequestered by trees at urban parks;
5. To estimate the monetary values of urban parks for air pollutant and carbon removal from atmosphere;
6. To develop guidelines for urban park designs and management practices in order to maximize the effectiveness in air purification and carbon sequestration.

5.2 Revised objectives

Date of approval from the RGC: NA

Reasons for the change: NA

1. NA

2. NA

3. NA

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

Objective 1 has been achieved by conducting a plot-based tree survey in 32 urban parks which represented varied park attributes (e.g. ages and land use type of its location). A total of 319 plots across the city were surveyed. Field data were used to calculate the tree species richness, diversity and evenness of each park and further compared between different park attributes respectively. Multivariate analyses were used to investigate the spatio-temporal variations of tree composition and performance in urban parks. The important value index and species indicator analysis were calculated to identify the most dominant species in urban parks.

Objective 2 has been fully achieved. Ten common tree species, representing different origin (e.g. native or exotic), leaf size, and leaf surface structure were selected from the result of Objective 1 for dust deposition quantification. The leaves of each species were sampled for three times from three healthy individual trees in four urban parks respectively and sent to the laboratory for experiments. In the laboratory, the dust was washed off from the leaves, then dried and weighted to calculate the total weight per unit area. Then, the dust suspensions were performed on a laser particle size analyzer to measure the composition ratios of different-sized particles (e.g. PM2.5, PM10). Therefore, the capability of dust deposition of each species was compared.

Objective 3, 4&5 has been achieved using the field data incorporating into computational modelling software, i.e. i-Tree Eco. The species-specific information (e.g. growth rate, longevity) were collected from books, peer-reviewed papers, government technical reports, and relevant websites to upload to the i-Tree Database. Besides, the data of hourly air pollutant concentration and hourly local precipitation were obtained from the Environmental Protection Department and Hong Kong Observatory respectively and incorporated into the model. The model analyzed the tree structure in urban parks, and further assessed the leaf biomass, carbon storage, carbon sequestration, and air pollution removal based on the species-specific and local-specific data. With the benefit prices given (e.g. carbon pricing), the monetary values of urban parks for air pollutant and carbon removal were estimated.

Objective 6 has been achieved by using the data and results obtained from the previous objectives. Tree characteristics (e.g. leaf area index), tree structure (e.g. dominant tree species), tree performance (e.g. tree health condition), tree layout (e.g. single tree or tree cluster), and park attribute (e.g. park age) were incorporated to give the recommendations on urban park design and tree management regarding maximizing the ecosystem services in air purification and carbon sequestration.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To analyze the vegetation structure of urban parks in Hong Kong	✓	100%
2. To quantify dust deposition by tree species commonly found in urban parks in Hong Kong	✓	100%
3. To quantify the biomass accumulation of tree species commonly planted in urban parks in Hong Kong	✓	100%
4. To assess the total amount of common air pollutant (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO) removed by trees at urban parks, and the total amount of carbon sequestered by trees at urban parks	✓	100%
5. To estimate the monetary values of urban parks for air pollutant and carbon removal from atmosphere	✓	100%
6. To develop guidelines for urban park designs and management practices in order to maximize the effectiveness in air purification and carbon sequestration	✓	100%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

Tree structure and performance in relation to park attributes (Part C 8.2&8.3)
In total, 2801 trees belonging to 181 species were recorded in 319 plots across 32 studied urban parks. Tree species were highly dominated by broad-leaved, exotic species. Multivariate analyses resulted in good discrimination between park ages, but not between land use types, using either tree community or tree trait data. The most common and dominant tree species in urban parks have changed substantially, with more ornamental exotic species planted in newly established parks. The species richness and diversity decreased in new parks due to frequent use of very few common species. Besides, trees in old parks were older, larger and unhealthier than those in new parks. It highlighted a temporal variation and spatial homogenization of tree structure in urban parks. Proper tree management measure should be implemented in consideration of tree growth and health condition in old parks. Tree selection and park design should consider the varied functions of parks in different land use types.

Performance of dust deposition of common tree species in urban parks (Part C 8.5)
The variations of particulate matter (PM) deposition between different species were highly significant. In general, native species had better performance on PM2.5 deposition than exotic species. Exotic species, such as *Lagerstroemia speciosa* and *Acacia cofusa* have higher deposition of PM10. *Spathodea campanulate* and *Plumeria rubra*, performed the best in all PM categories while *Bauhinia x blakeana*, *Michelia x alba* and *A. confusa* did the worst. The hairy micro-structure on the leaf surface of *S. campanulate* and *P. rubra* assisted in retaining more PM on the leaves. However, the wax cuticle on leaves (e.g. *B. x blakeana*) and relatively smooth leaf surface (e.g. *F. microcarpa*) negatively influenced the PM accumulation. The PM deposition among four parks indicated the total amount of air pollutants were mainly affected by the traffic volume surrounded and the topographic structure of the parks. Parks should be avoided establishing at a near-road area, otherwise, barriers should be set up to separate parks from roads.

Performance of dust dispersion of trees in urban parks (Part C 8.1)
A series of indicators associated with tree morphology and landscape were derived from the field survey and their influence on air pollutant dispersion were modelled. Dense trees with a low crown base (e.g. *Juniperus chinensis 'Kaizuca'*) were found effective in improving air quality within parks when planted as barriers with a width of ~15m at borders. Tall trees (e.g. *Ailanthus fordii*), which allowed the wind to penetrate the under-canopy space, tended to have little influence on airflow at the pedestrian. Trees in moderate height with a low crown base and dense canopy (e.g. *Ficus microcarpa*) can slow down the airflow and lead to localized increases in pollutant concentrations. These planting strategies aiming to optimize air quality should be encouraged in park design.

Structural and functional values of trees in urban parks (Part C 8.4)
In total, trees covered about 81% of the urban parks and provided 348 ha of leaf areas. The total leaf area was greatest in Sha Tin Park followed by Victoria Park and Tuen Mun Park. The amount of carbon annually sequestered was increased with the size and health of the trees. The total gross sequestration of trees in studied urban parks was about 419 metric tons of carbon per year with an associated value of 18,755 HKD. Besides, trees were estimated to store 7,390 metric tons of carbon with an associated value of 330,150 HKD. Of the species sampled, *Ficus* spp. (e.g. *F. microcarpa*, *F. benjamina*, *F. viren*) stored the most carbon and sequestered the most. Pollutant removal by trees in studied

urban parks was greatest for O_3. It was estimated that trees removed 9.1 tons of air pollutants (i.e. O_3, CO, NO_2, PM2.5, SO_2) per year with an associated value of 677,350 HKD. Tree species with tall height and large trunk (e.g. *Adenanthera microsperma*, *Casuarina equisetifolia*, *Celtis sinensis*) performed better in pollutant removal at the species level. Therefore, the tree management strategies to help improve air quality included increasing the number of healthy trees, sustaining existing tree cover, sustaining large and healthy trees, utilizing evergreen trees for particulate matter, and supplying ample water to vegetation.

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

1. Future developments should be focused on using quantitative methods to investigate the size and shape of particulate matters deposited on leaves. It involves using the scanning electronic microscope (SEM) to observe the micrographs of tree leaves, and count the particulate matters. This improvement will also help us understand the micro-structures of leaves related to the performance of dust deposition.

2. As the i-Tree Eco was developed by a US research team, the built-in species database might not be compatible with the local species. Estimation of ecosystem service values and monetary values might deviate from the real situation. Therefore, developing a local species database, including leaf area index, allometric equation, tree density, is necessary and urgent.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

It is generally accepted that urban vegetation improves air quality and thereby enhances the well-being of citizens. However, beyond landscaping aesthetics and recreational purpose, park design and tree planting based on their ecosystem services always received limited concerns in Hong Kong. This study incorporated field survey, laboratory test and modeling methods to understand the role of urban trees of Hong Kong in atmospheric quality and carbon sequestration. The results found that tree diversity, structure and performance significantly differed between old and new parks. The deposition of airborne particulate matters by trees was mainly affected by the micro-structure of the leaf surface of tree species. While the dispersion of air pollution was related to the tree morphology and landscape. Trees in urban parks stored and sequestered a large amount of carbon every year, with an associated value of ~350,000 HKD. Besides, trees could remove ~9 tons of air pollution per year with an associated value of ~680,000 HKD. To maximize the ecosystem services of urban parks and achieve a more environmentally sustainable city, tree characteristics, structure, and landscape should be considered in park design and tree planting plans.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				**Author(s)** *(denote the correspond-ing author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2019				X Yang, P Brimblecombe, S Wang, H Zhang*	(8.1) Tree distribution, morphology and modelled air pollution in urban parks of Hong Kong/ Journal of Environmental Management 248: 109304	No	Yes	Yes	Yes
		√		Wang S, Zhang H*	(8.2) Tree composition and diversity in relation to urban park history in Hong Kong, China/Urban Forestry & Urban Greening	No	No	Yes	No
		√		Wang S, Chu LM, Zhang H*	(8.3) Park attributes on tree species composition and performance in urban parks of Hong Kong/ Ecological Indicator	No	No	Yes	No
			√	Wang S, Zhang H*	(8.4) Delivery indicators for ecosystem services of trees in urban parks	No	No	/	/
			√	Wang S, Zhang H*	(8.5) Variations in deposition of particulate matter by common tree species in urban parks of Hong Kong	No	No	/	/

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered
(Please attach a copy of each conference abstract)

Month / Year / Place	**Title**	**Conference Name**	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
03/2019/ Amherst, USA	Tree Composition and Structure in Relation to Urban Park History and Land-use in Hong Kong, China	6th Fabos Conference on Landscape and Greenway Planning	Yes (2018)	No	Yes	Yes
07/2019/ Milan, Italy	Air Purification by Urban Par Trees in Hong Kong	10th IALE Word Congress	Yes (2018)	No	Yes	Yes

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning
(Please elaborate)

1. Approximately6 students (including graduates) were trained in field data collection, lab experiments and modelling analysis of this project. The students gained specialized knowledge of some state-of-the-art methods and developed the skills to design and conduct the field and lab experiments independently.
2. The PI used the results in teaching modules, such as Biodiversity, Research Proposal, Research Thesis and Project.

11. Student(s) Trained
(Please attach a copy of the title page of the thesis)

Name	**Degree Registered for**	**Date of Registration**	**Date of Thesis Submission / Graduation**
	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2016	Jun 2018
	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2017	Jun 2019
	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2017	Jun 2019

	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2015	Jun 2019
	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2016	May 2020
	Bachelor of Arts in Arts (Honours) in Horticulture and Landscape Management	Sep 2018	May 2020

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

1. We collaborated with Professor Peter Brimblecombe from the City University of Hong Kong and published a paper in the Journal of Environmental Management.
2. A 3D-model illustrating the relationship between tree layouts and air pollutant reduction in urban parks was made using a 3D printer.
3. The PI was invited to give a speech on the Hong Kong Flower Show 2019 to share the results of the tree structure in urban parks to the public.
4. The PI was interviewed by news.gov.hk to share the results of tree performance in air pollutant reduction (www.news.gov.hk/chi/2019/06/20190628/20190628_170837_705.html) (Appendix III).

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	**Conference Papers**	**Scholarly Books, Monographs and Chapters**	**Patents Awarded**	**Other Research Outputs (please specify)**	
No. of outputs arising directly from this research project	1 (published) 2 (under review) 2 (under preparation)	2 (two abstracts accepted to oral presentation)	0	0	Type Newsletter Interview	No. 3 1

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
NA	NA