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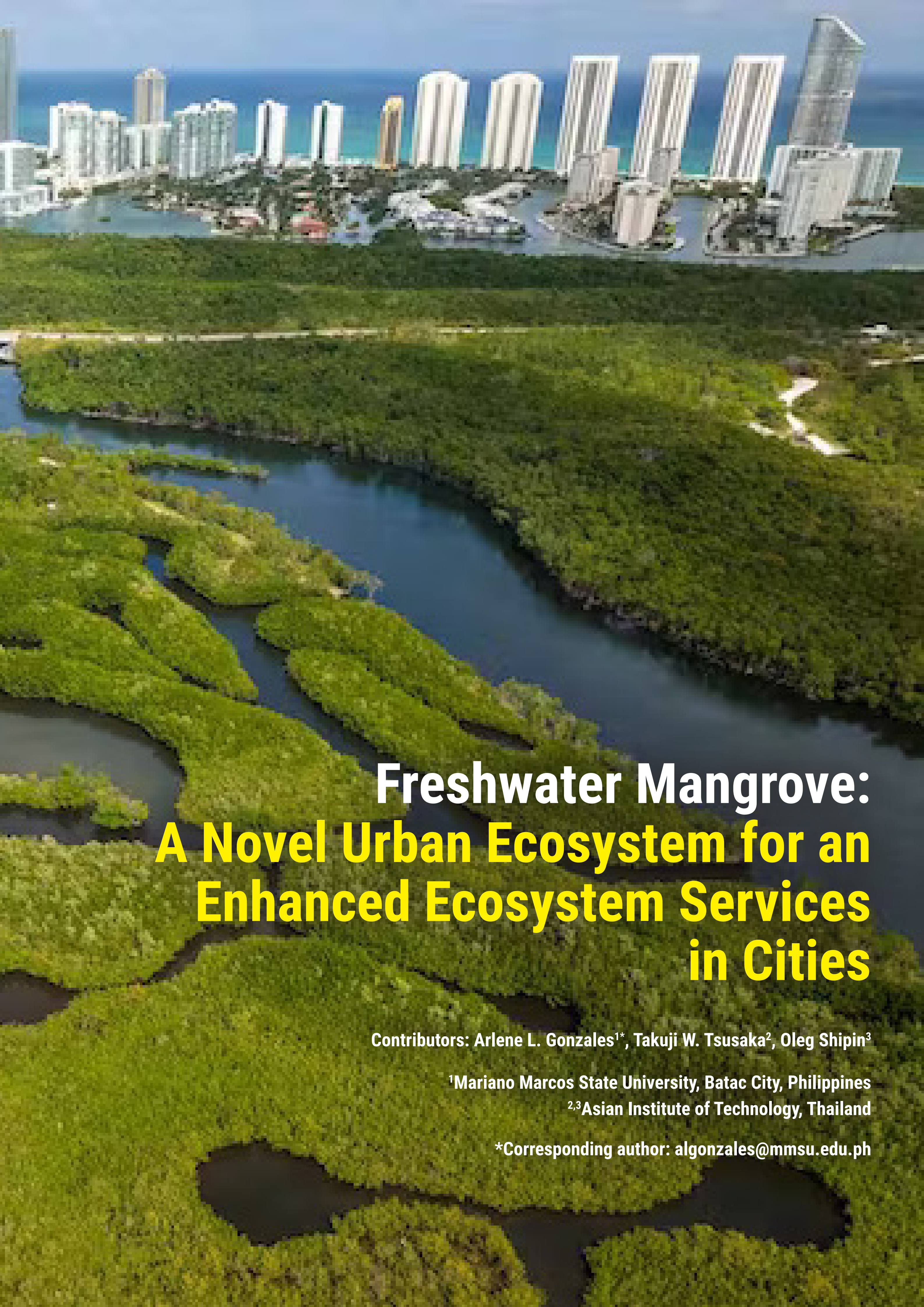

Freshwater Mangrove: A Novel Urban Ecosystem for an Enhanced Ecosystem Services in Cities

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https://ozfish.org.au/2020/11/unpack-habitat-mangroves/

Abstract

This R and D on ecological engineering using freshwater mangrove addresses a problem of urban wastewater and, at the same time, water pollution and its health concerns, climate change mitigation, as well as typically low aesthetic appearance of cities. The ecotechnology turns the problem of wastewater flowing into lake from adjacent restaurants into solution for many urban challenges including use of nutrient rich water as a fertilizer for mangrove trees in a Novel Urban Ecosystem (NUE).

Introduction

Environmental problems in urban landscapes have become increasingly challenging, applying pressure on urban natural resources to meet the rising demand for various forms of ecosystem services (ES). Solutions to urban problems would call for nature's help, i.e., employing biodiversity to address rising urban challenges (Ahern, 2016). Integration of novel ecosystems (NE) has been proposed as an alternative approach to ecological restoration that can obtain a more realistic outcome in addressing the dilemma of ecosystem restoration in this new Anthropocene epoch (Sack, 2013).

Urban wetlands are well accepted as cost-effective for flood mitigation and treatment of stormwater and wastewater. However, emergent and free-floating macrophytes need frequent harvesting to maximize nutrient removal and avoid

nuisance due to massive growth. When left to proliferate on site, the decomposition of this vegetation may return nutrients rapidly into the water. Therefore, there may be an advantage in substituting soft-tissue plants with woody vegetation. Mangrove trees, having unique features that are superior to macrophytes for wastewater treatment, have been studied and applied in urban wetlands even in the absence of tidal flushing and salinity. This emerging technology of using freshwater mangroves for water quality improvement has recently been integrated into urban landscaping, particularly in urban wetlands. This new approach of utilizing mangroves presents promising benefits, however, there is no well-documented study that focuses on the efficiency of freshwater mangroves in delivering different ecosystem services.

Thus, this study is to investigate the potential of an eco-technology based on freshwater mangroves to deliver projected ecosystem services by following the principles of ecological engineering and NUE based on the impact path of a pilot-scaled NUE established in the campus of the Asian Institute of Technology, Thailand.

Methodology

The success rate of planting mangroves in freshwater and their growth rate were measured. A total of 353 mangrove seedlings and saplings at ages from 8 months to 1.5 years were planted at West Lake, of which 10% (35 trees) were sampled at the age of 1.5 years old for monitoring and evaluation of the growth rate. Their height increase was monitored using a steel tape while the girth development was measured using a caliper.

The ecosystem services were assessed based from the gathered data on water quality monitoring, carbon sequestration potential through biomass estimation.

Water quality monitoring used the parameters NH3-N, TP, TKN, and TOC to determine the reduction of concentration in the water over time. The result was compared to the initial monitoring conducted when no freshwater mangrove is present at West Lake. A long-term monitoring of water quality was conducted considering that a continuous inflow of wastewater was present up to present.

The carbon sequestration was calculated using the total biomass per area multiplied by the conversion factor in obtaining carbon equivalents.

$$CS = W \text{ x carbon coefficient}$$

where CS is carbon sequestration in g $m^{-2}y^{-1}$ W is dry weight estimate of biomass in g and carbon coefficients are roughly averaged at 0.50 (Kauffman and Donato, 2012). Carbon accumulation and its projection were determined by multiplying the dry weigh biomass by carbon coefficients which are 0.45, 0.48, 0.50, or roughly averaged at 0.50 (Kauffman and Donato, 2012). Since the carbon concentration rate in woody biomass is usually slightly less than 50%, it is a common practice to convert biomass to carbon by multiplying 0.46-0.50 when the local or species-specific value is unavailable.

Results and Discussion

The ability to thrive in a new environment is the first indicator of the effectiveness of establishing an NUE. The survival and growth rates of freshwater mangroves established in a shallow lake (West Lake) on the campus of the Asian Institute of Technology (Thailand) challenge the conventional knowledge that the absence of salinity is fatal to mangroves.

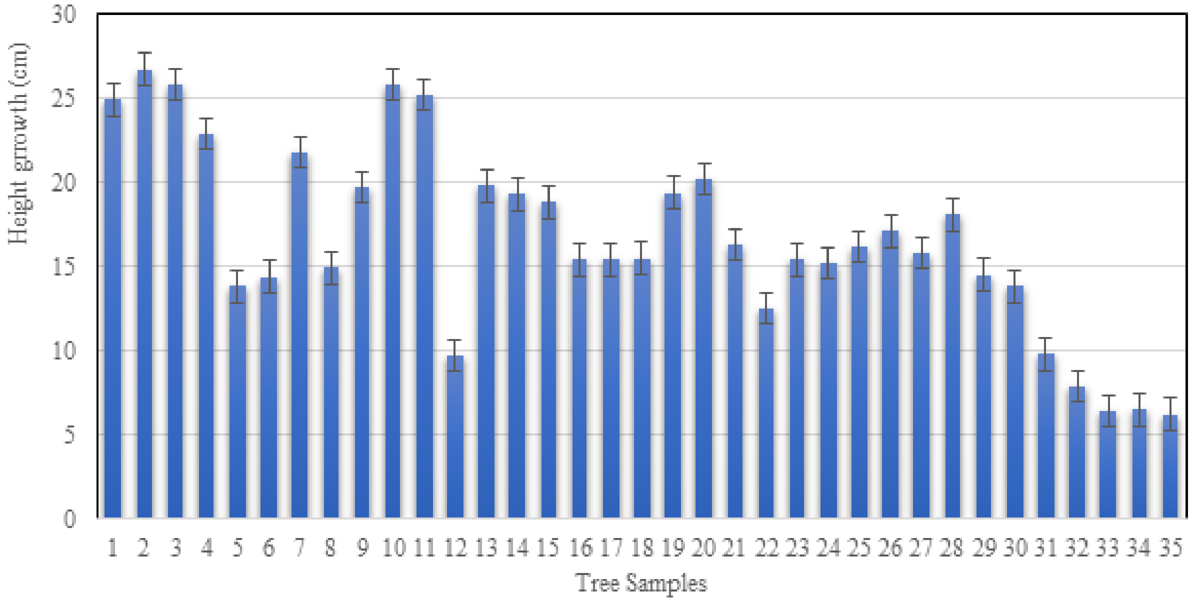
Table 1 shows the results of the three-year survival of mangrove trees introduced at West Lake. Freshwater mangroves' survival and mortality rates were 87.2% and 12.8%, respectively. The survival rate indicates that the mangrove species *Rhizophora* spp. does not necessarily require saline environments for their survival and growth. The different batches of trees introduced at West Lake varied in age to determine whether age is a limitation in planting mangroves in freshwater conditions. The result indicates that the survival rate is booming regardless of age, ranging from 77.8% to 96%.

Table 1. Three-year survival and mortality rate (%) of *Rhizophora* spp. introduced at West Lake, AIT

Batch of Trees	Total num. of trees	Survival	Mortality	% Survival	% Mortality
1	27	21	6	77.8	22.2
2	30	26	4	86.7	13.3
3	30	46	4	92.0	8.0
4*	100	92	8	92.0	8.0
5*	120	98	22	81.7	18.3
6	25	24	1	96.0	4.0
Total	352	307	45	87.2	12.8

* Saplings less than one year old

In addition, the annual average increase in height and girth of the sample mangroves in freshwater were 16.6 ± 0.95 and 1.6 ± 0.10 cm, respectively.



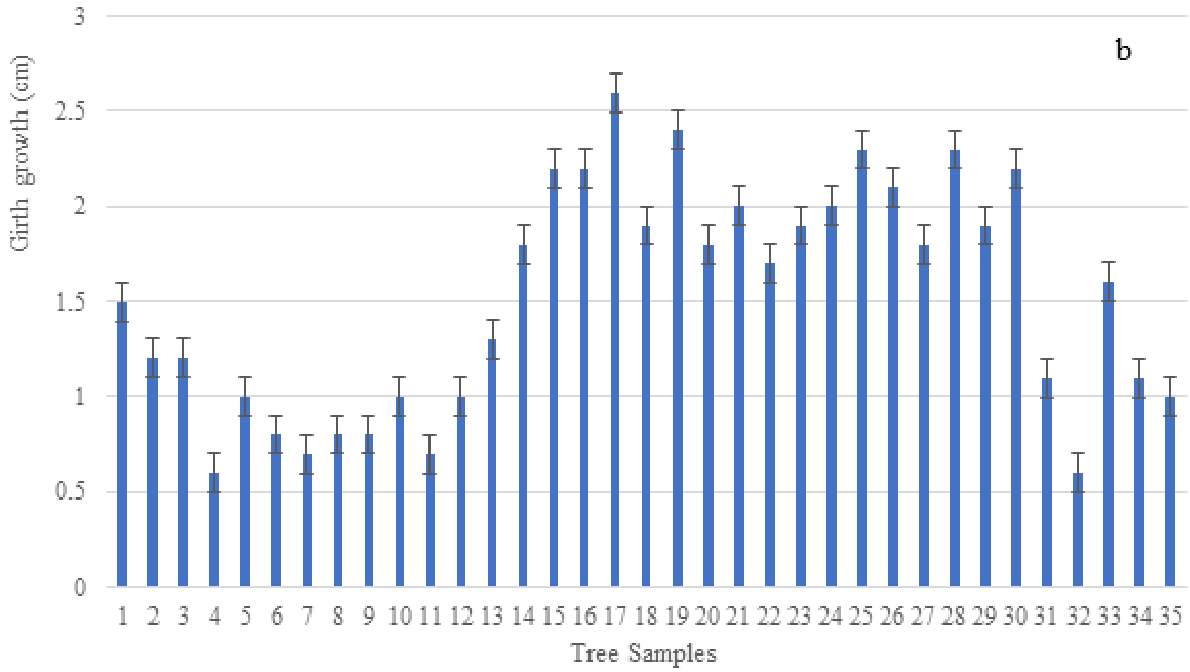


Figure 1. Annual growth in (a) height and (b) girth of *R. apiculata* planted in freshwater at West Lake.

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Potential Ecosystem Services of Freshwater Mangroves as NUE in Cities

Water Quality Improvement in Wetlands

Initially, the pollutant ion concentrations at West Lake were 1.47 (NH3-N), 2.45 (TKN), 0.08 (TP), and 3.13 mg/L (TOC). A 44.6% reduction in NH3-N concentrations was recorded at the end of the monitoring period. The final percentage reduction in TKN, TP, and TOC concentrations was 61.6%, 41.2%, and 63.7%, respectively. The mangrove ecosystem introduced into West Lake, coupled with water circulation and aeration, was likely successful in improving the eutrophic conditions of the lake water.

Monitoring chlorophyll levels is a direct way of tracking algal growth. Surface waters with high chlorophyll conditions are typically high in nutrients, generally phosphorus and nitrogen. Initial assessment of the chlorophyll-a at the Library Lagoon had six species of microphyte at a concentration of 334 μg/L and is fluctuating according to season, such as monsoon season that, brings dilution. The long-term impact of the mangrove is the diversification of the species of microphytes while reducing their concentration in the water. For almost ten years, a change in the diversity was observed while simultaneously decreasing the concentration to 112 μg/L. A notable development in the pilot area of freshwater mangrove on-campus was the complete disappearance of *Spirulina*, significantly when mangrove trees were increased. The same observation was noted at West Lake, where Spirulina was present during the water quality baseline assessment and disappeared when the eco-engineering components were introduced, such as the mangrove introduction, soil mounds creation, and the enhancement of water circulation and aeration through a water pump. In addition, the relationship between the abundance of macrophytes, DO concentration to the population of rotifers, and the Potential Nitrification Rate (PNR). As the mangrove root's volume and spread increased over time, it helped enhance DO in the water. DO measurements indicate that water adjacent to the mangrove root systems had the DO concentration of 0.12 to 0.52 mg/L, slightly higher than in the sites distant from the mangrove trees. When oxygen is available in an almost anoxic bottom substrate, it augments the microbial activity for the bioconversion process.

Carbon Sequestration Potential

A comparison of carbon sequestration estimates between our study and the literature shows that saline water mangrove accumulated higher biomass at early ages than freshwater mangroves. However, the difference may vary depending on the species. Among the mangrove species planted in freshwater, *Sonneratia* spp. accumulated the largest biomass during the first three years of plantation, while *Lumnitzera racemosa* revealed the least biomass gain. As a result, the carbon sequestration capacity is proportional to the biomass gain. The first three years after the mangrove plantation was projected to sequester above and below ground. *Sonneratia* spp. is expected to capture 287 ± 136 g C m-2 y-1, followed by *Rhizophora* spp. and *Lumnitzera* spp. 345 ± 66 and 30 ± 17 g C m-2 y-1, respectively. Belowground sequestration is twice lower in comparison to the aboveground sequestration capacity of mangroves.

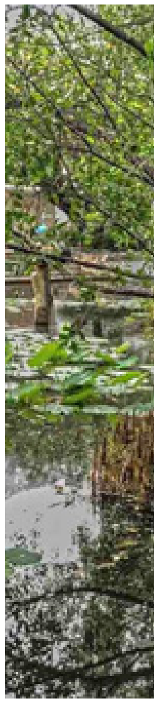

Table 2. Estimated carbon sequestration rates of freshwater mangroves in comparison with sea water mangroves.

Species	Tree age, years	Above [Below] ground [root] sequestration rate* g C m^{-2} y^{-1}, calculated [1]
Rhizophora mucronata and *R. apiculata*	Saline water (Xiong et al., 2019)	
	1	18 ± 5 [4 ± 2]
	3	345 ± 66 [89 ± 50]
	5	357 ± 95 [164 ± 49]
	10	498 ± 160 [234 ± 106]
	25	527 ± 183 [248 ± 101]
	40	696 ± 179 [327 ± 156]
	85	637 ± 241 [300 ± 138]
	This study (freshwater)	
	1	14 ± 3 [6 ± 2]
	3	245 ± 109 [113 ± 49]
	5	409 ± 142 [95 ± 34]
Sonneratia spp.	Saline water (Xiong et al., 2019)	
	1	25 ± 10 [8 ± 4]
	3	287 ± 136 [132 ± 53]
	5	631 ± 315 [291 ± 141]
	10	554 ± 166 [255 ± 145]
	20	246 ± 78 [116 ± 61]
S.caseolaris		This study (freshwater)
	3	281 ± 138 [78 ± 29]
	12	691 ± 244 [393 ± 156]
S.ovata	6	235 ± 64 [95 ± 35]
Lumnitzera racemosa	Literature data (Saline water) (Xiong et al., 2019)	
	3	22 ± 7 [10 ± 5]
	10	135 ± 43 [62 ± 29]
	This study (freshwater)	
	2	30 ± 17 [10 ± 6]
	8	598 ± 270 [439 ± 199]

Mangrove is among the trees with the highest primary productivity, accumulating and storing significant amounts of carbon in their biomass. The high primary production and slow decomposition processes in mangrove soil supposedly cause unusual carbon dynamics (Komiyama et al., 2008). The soil of mangroves can store three times as much carbon as its biomass (Kauffman & Donato, 2012), surpassing terrestrial trees' carbon storage capacity. Moreover, the literature suggests that the carbon sequestration potential of mangroves is inversely correlated with water salinity (Rahman et al., 2015; Perera et al., 2013) as higher salinity induces mangroves to spend more energy maintaining water balance and ion concentrations than primary production and growth (Perera et al., 2013).

Our results indicate that the capacity of mangroves to sequester carbon is similar between saline and freshwater environments. This implies the suitability of mangroves under urban environments to contribute to climate change mitigation while simultaneously functioning for water pollution mitigation. Different mangrove species may possess different carbon sequestration capacities. This study focused on *Rhizophora* and *Sonneratia* because *Sonneratia* is a fast-growing species (Chen et al., 2012), and *Rhizophora* has a large wood mass per unit area and relatively high bulk density (Wiarta et al., 2019), translating into higher potential for carbon absorptions than other species.

Conclusion

It was demonstrated that novel "Freshwater mangrove ecosystem" introduced at the West Lake is one of the very few urban novel ecosystems described scientific literature. This novel ecosystem of considerable diversity was shown to develop naturally and successfully over the period of 3 years since a start-up from baseline state in March 2019. This novel ecosystem has proven to provide several ecological benefits such as: (1) nutrient absorption leading to an efficient growth of mangrove

A well-established freshwater mangrove in a wetland of AIT campus

trees and other macrophytes at the treatment area; (2) carbon sequestration in relation to the enhanced biomass accumulation at the treatment site; (3) Water quality improvement gradual decreaset of NH3-N, TKN, TP, Chlorophyll a concentration at west lake from the baseline situation to current condition. Thus, the novel urban ecosystem of freshwater mangrove is a sustainable and cost-effective approach to solving ecological crises in the urban environment.

Acknowledgements

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References

Ahern, J. F. (2016). Novel Urban Ecosystems: Concepts, Definitions and a Strategy To Support Urban Sustainability and Resilience. Landscape Architecture Frontiers, 4(1), 10–21.

Chen, L., Zeng, X., Tam, N. F. Y., Lu, W., Luo, Z., Du, X., & Wang, J. (2012). Comparing carbon sequestration and stand structure of monoculture and mixed mangrove plantations of Sonneratia caseolaris and S. apetala in Southern China. Forest Ecology and Management, 284(November), 222–229. https://doi.org/10.1016/j.foreco.2012.06.058

Komiyama, A., Ong, J. E., & Poungparn, S. (2008). Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany, 89(2), 128–137. https://doi.org/10.1016/j.aquabot.2007.12.006

Kauffman, J.B. & Donato, D. C. (2012). Protocols for the measurement, monitoring and

reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor, Indonesia., (January).

Perera, K. A. R. S., Amarasinghe, M. D., & Somaratna, S. (2013). Vegetation Structure and Species Distribution of Mangroves along a Soil Salinity Gradient in a Micro Tidal Estuary on the North-western Coast of Sri Lanka. American Journal of Marine Science, 1(1), 7–15. https://doi.org/10.12691/marine-1-1-2

Sack, C. (2013). Landscape architecture and novel ecosystems: ecological restoration in an expanded field. Ecological Processes 2013 2:35. https://doi:10.1186/2192-1709-2-35

Tam, N. & Wong, Y. (2014). Constructed wetlands with mixed Mangrove and non-mangrove plants for municipal sewage treatment. International Conference on Future Environment and Energy. Vol. 61 (2014) IACSIT Press. Singapore. 10.7763/IPCBEE.2014.V61.11

Wiarta, R., Indrayani, Y., Mulia, F., & Astiani, D. (2019). Carbon sequestration by young Rhizophora apiculata plants in Kubu Raya district, West Kalimantan, Indonesia. Biodiversitas, 20(2), 311–315. https://doi.org/10.13057/biodiv/d200202