Urban wetland in ho chi minh: an investigation of plant diversity and implications for sustainable urban development

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Abstract. Urban wetland has played an important role in creating a live well environment for people and creatures. The rapid urbanization was considered to be the main cause of narrowing wetland area instead of impervious surfaces and construction areas. Thu Thiem is an only remaining wetland in Ho Chi Minh metropolitan where is facing a series of urban problems such as urban heat island, air pollution episodes and flooding. This research aims at investigating plant diversity in the entire Thu Thiem wetland area covering various landuse. The findings show that plant species of Thu Thiem is considered to be diverse with 137 species of tracheophyta plants of 121 genera, 58 families with dominant species. The Shannon diversity index is 3.36, 3.6 and 4.11 for wetland located in forest land-cover, agriculture land-cover, and bare soil respectively. The simultaneous existence of both brackish and freshwater plant species was also found in this research area. In addition, water quality in 75 investigation points of Thu Thiem wetland was analysed based on modern physicochemical method. Water quality index shows that this area has been organically polluted. Based on these findings and ecological function of an urban wetland, various suggestions have been proposed for sustainable development strategies, design and planning which aim at mitigating the various urban problems e.g. water pollution, flooding, ecological landscape and urban life in the metropolitan of Ho Chi Minh.

1. Introduction
Ho Chi Minh is the biggest city in Vietnam located in the low terrain condition and surrounded by river and streams with high density. The region is known for an abundant wetland ecosystem with the existence of various plants and species that represents a transitional ecosystem between freshwater and saltwater in the tropical zone [6]. However, urban expansion is considered as the main threat of wetlands that affects land-use configuration and climate change [7, 8]. Indeed, the urban wetland has been declined seriously by urbanization storm in Ho Chi Minh and Thu Thiem is the last natural area remained in the urban core. In the tropical area, the wetland is widely known as a typical land with plant and species diversity that contributes as an important ecological service including wild-life environment, flooding control and erosion resistance [5]. Urban wetlands are highly valued for improving water quality, micro-climate regulation, groundwater recharge, flood control and providing recreational place.
for surrounding residents [3]. Owing to various ecological functions, urban wetland is the main target of plenty of urban planning, management agendas; various wetland conservation and rehabilitation projects were implemented worldwide [1, 9]. Nevertheless, in Vietnam, wetland research which is still limited derived from investigating vegetation cover in urban wetland areas. Therefore, when the ecosystem function, benefits and values in urban area are recognized, the resurgence of wetland will play a key role in mitigating the negative impacts of urbanization and contributing a quality of life.

Currently, plant species composition and diversity in wetlands located in the different land-use area in Thu Thiem have not been thoroughly studied. Assessment of wetland condition originates by plant species investigation [4] that contributes comprehending the species diversity and proposing proper treatment for local vegetation conservation and beyond that is choosing the proper plant in urban wetland landscape design. This study aims at understanding (1) plant species composition and diversity of wetlands in different land use; (2) water quality in the urban area; (3) the characteristics of freshwater and brackish plant distribution under the impact of floods and tides. The findings contribute to urban wetland planning and management in Thu Thiem and surrounding area with similar conditions.

2. Materials and Methods

2.1. Study site
Thu Thiem is a small peninsula with an area of 737 hectares across the Saigon River from the urban core of Ho Chi Minh City. Because of surrounding by rivers, this area still retains pristine natural conditions (Figure 1). Thu Thiem new urban area has a tropical climate, specifically a tropical savanna climate with high temperature in the year. The average temperature is about 27-degree Celsius; the average rainfall of about 1.949 millimetres annually, usually lasts from May to November. The tide of Thu Thiem peninsula is regularly low at -0.4 m and high at +1.10m. The highest tide level is +1.3m above the mean sea level (June to July annually).

![Figure 1. Thu Thiem location and study area](image)
2.2. Sampling collection

2.2.1. Vegetation sampling method. The investigation was conducted to statisticize natural vegetation in the southern delta of Thu Thiem from July to October 2016 and from February to April 2017. For natural trichophyte, the observation was carried out within 600 main blocks (1 block = 50x50 m) that located in three main landuse. Among each main block, 5 sub-block (one sub-block = 5x5m) was randomly [2] selected as illustrated in (figure 2).

2.2.2. Water sampling method. The water sampling was conducted based on hydrological system, master planning map of Thu Thiem new urban area and Quick Bird satellite image. This information helps to adjust the sampling position properly with research objectives, water body and research area. In specifically, the investigation randomly selected 75 sampling location in entire of Thu Thiem area. Each location collected 3 water samples in accordance with 3 period times of tidal range including neutral, flood tide, and ebb tide (Figure 3).
3. Results and discussion

3.1. Species composition

There are 58 families with 121 genera and 137 species of tracheophyta plant were identified in three types of agriculture, forestry and bare land located in the south of Thu Thiem’s wetland (see Appendix A). Poaceae family found overwhelmingly with 17 genera and 18 species corresponding to 13.14% of the total number of surveyed species. The second overwhelming family is Fabaceae which contributes 7 genera and 8 species corresponding to 5.84% of the total number of studied species. Moreover, four families including Cyperaceae, Asteraceae, Verbenaceae and Rubiaceae with 6 species accounts for 4.38%. Euphorbiaceous family consists of 5 species that accounts for 3.65%. There are 9 families including Myrtaceae, Convolvulaceae, Moraceae, Acanthaceae, Araceae, Apocynaceae, Lecythidaceae, Mimosaceae and Vitaceae contribute three and four species for tracheophyta diversity in this area. The rest of family existed 1 or 2 species for each. Regards to genera, Cyperus and Ficus mostly prevail with 4 species for each genre; Barringtonia genre prevails with 3 species. The rest contributes 1 to 2 species for each genre (see Appendix A). Concurrently, the finding shows that a total of 63 Herbaceous plant species accounted for 45.99% in all three kinds of land use; 38 woody plant species (27.74%); 20 creeper plant species (14.6%); and 16 shrub plant species (11.68%).

Table 1 shows the number of vegetation species classified by life form within three kinds of land use including agriculture, forestry and bare land. The findings show that herbaceous plants prevail in agriculture and bare land with 34 (accounts for 60.32% of the total species existed in the same land category) and 38 (accounts for 60.71 % of the total species existed in the same land category) species respectively (figure 4).

Table 1. Life form of plant classification in Thu Thiem’s wetland area

| Life form of Plant | Agriculture Land | Forestry Land | Bare Land | Entire Area |
|-------------------|------------------|---------------|-----------|-------------|
| Herbaceous        | 34               | 14            | 38        | 63          |
| Shrub             | 7                | 4             | 13        | 16          |
| Woody             | 7                | 24            | 18        | 38          |
| Creeper           | 8                | 6             | 15        | 20          |
| Total             | 56               | 48            | 84        | 137         |
Table 2. Regarding the Shannon’s species diversity of wetlands

|                      | Agriculture Land | Forestry Land | Bare Land |
|----------------------|------------------|---------------|-----------|
| Species richness S   | 56               | 48            | 84        |
| Species diversity H  | 3.60             | 3.36          | 4.11      |
| Species evenness J   | 0.89             | 0.87          | 0.93      |
| p-value              | 0.019            | 0.023         | 0.045     |

3.2. Species richness, diversity and evenness
The results show the total number of species (Species richness) in three types of agricultural, forestry and bare land are 56, 48 and 84 respectively (table 2), and the average value of trichophyte plant diversity (beta diversity) of these three land-use types is 0.89, 0.87 and 0.93 respectively (table 2). These average species richness (beta diversity) were calculated by combining various samples on each sampling location located on three land-use categories.

Regarding the Shannon’s species diversity of wetlands is 3.36 (forestry land), 3.6 (agricultural land) and 4.11 (bare land). Similarly, species evenness on wetland is 0.87, 0.89 and 0.93 respectively (table 2).

3.3. Species composition characteristics and species similarity in wetland

3.3.1. Species composition feature. In total of 137 surveyed trichophyte plant species, there is a difference in species composition diversity and dominant species with frequent occurrence in three kinds of agricultural, forestry and bare land (Figure 5)

![Figure 5](image_url)
Figure 6. Species composition similarity existed in wetland located in three types of landuse

In agricultural wetlands, Nypa fruticose Wurmb. And Cocos nucifera L., which belong to the Areceae family are the two most dominant species with 370 and 287 individuals respectively, and accounted for 12.65% and 9.81% respectively in all three kinds of land use. These two species were found in both wetland of forestry bare land.

Subsequent dominant species, which occur in the agricultural wetlands is Pluchea indica (L) Less belonging to the Asteraceae family with 183 individuals (accounts for 6.25%); and Grangea maderaspatana (L.) Poir. Belonging to Asteraceae family with 126 individuals (accounts for 4.31%). These above-mentioned species only existed in agriculture wetland.

Regarding to forestry’s wetland, the research found that the Intsia bifuga (Colebr.) O. Ktze (249 individuals) belongs to the Fabaceae family, followed by Premna latifolia Roxb. (194 individuals) related to Verbenaceae family and Avicenna Alba Bl. (103 individuals) belongs to Avicennia family with the percentages of 12.14%, 9.46% and 5.02% respectively. Similarly, Ficus microcarpa L. which belongs to the Moraceae family is the most frequently occurrence species in the wetlands of bare land with 121 trees (accounts for 6.52%). The dominant species in forest wetlands and bare wetlands are typical species that found only in that wetland e.g.

3.3.2. Species composition similarity. Wetland conservation area south of Thu Thiem peninsula is divided with 3 different types of land: agricultural wetland, forestry wetland and unused wetland. In all three areas,

The species similarity index of three different types of land-use including agricultural, forestry and bare wetland is very low. The finding shows that there are only 10 species concurrently appear in the entire three areas (accounts for 7.3%). The highest similarity rate was found in the middle of agricultural and bare wetlands (accounts for 24.56%). Meanwhile, the similarity between agricultural wetlands and forest wetlands is 13.04. % and the similarity of bare wetlands and forestry wetlands was measured is about 18.9% (Figure 6).

Focusing on each type of land use, there are unique species found as details: (1) for agricultural wetlands, there are 28 species belonging to 15 families only occurred in this area. Asteraceae and Poaceae families prevailed with 4 and 5 species respectively; (2) Similarly, the forestry wetland occupied 13 families including 25 species; (3) Endemic species of bare wetlands occupied large numbers with 84 species of 28 families, of which the Poaceae family prevailed with 10 species (Figure 6).
3.4. Water quality assessment in the Thu Thiem’s wetland area

As can be seen in table 3, the difference in water quality at different period times of tidal range including flood and ebb tide is negligible. Regards physicochemical parameters, pH index fluctuates between 5.97 (TT11) and 6.83 (TT02) at flood tide and pH ranges from 6.09 (TT50) to 6.72 (TT23) at ebb tide.

These results show that the water has weak acidity and been classified into B category that appropriate for Agriculture and Aquaculture (pH: 5.5 until 9.0 - TCVN 5942: 1995). Electrical conductivity (EC) varies from 47.23 mS / m (TT32) to 167.4 mS / m (TT52) when the flooded tide and varies from 50.82 mS / m (TT73) to 108.53 mS / m (TT74) at ebb tide. The averaged electrical conductivity indicates that the EC is lower during ebb tide period. This can be explained when the ebb tide occurred, the river water with the pollution of organic compounds flows into wetlands area and mixes together that make electrical conductivity decrease.

Table 3. Water quality indexes

| Parameter | Flood tide | Ebb tide | Vietnamese Standard(TCVN) |
|-----------|------------|----------|---------------------------|
| pH        | 5.97 (TT11) | 6.83 (TT02) | 6.09 (TT50) | 6.72 (TT23) | pH: 5.5 - 9 TCVN 5942: 1995 |
| EC        | 47.23 mS/m (TT32) | 167.4 mS/m (TT52) | 50.82 mS/m (TT73) | 108.53 mS/m (TT74) |  |
| DO        | 0.3 ppm (TT51) | 2.8 ppm (TT14) | 0.08 ppm (TT09) | 2.8 ppm (TT21) | DO>2ppm; TCVN 5942: 1995 |
| BOD       | 4.12ppm (TT 28, TT44) | 13.84ppm (TT47) | 4.71ppm (TT64) | 11.19ppm (TT22) | BOD< 25 ppm TCVN 5942: 1995 |
| COD       | 15 ppm (TT33) | 47.1 ppm (TT38) | 14.8 ppm (TT64) | 40.0 ppm (TT68) | COD< 35 ppm TCVN 5942: 1995 |
| N-NO₃     | 0.116 ppm (TT40) | 4.33 ppm (TT11) | Invariable | Invariable | N-NO-3: 1.5 ppm; TCVN 5942: 1995 |
| N-NO₂     | 0.010 ppm (TT47) | 0.063 ppm (TT12) | Invariable | Invariable | N-NO-2: 0.05 ppm TCVN 5942: 1995 |
| N-NH₄     | 0.311 ppm (TT32) | 1.907 ppm (TT55) | Invariable | Invariable | B (TCVN 5942: 1995) |
| P-PO₄     | 0.015 ppm (TT52) | 3.372 ppm (TT51) | Invariable | Invariable | TCVN 6980 |
| Fe³⁺       | Qualified | Qualified | Invariable | Invariable | TCVN 5500: 2003 |
| TSS       | 4.4 ppm (TT25) | 216.5 ppm (TT47) | 8.4 ppm (TT29) | 143.00 ppm (TT59) | TCVN 5942: 1995 |
| Al³⁺      | 0.021 ppm (TT52) | 0.037 ppm (TT55, TT58) | 0.022 ppm (TT06) | 0.050 ppm (TT07) | Al³⁺ < 0.5 ppm TCVN 5502: 2003 |

4. Conclusion

The research findings identify 137 species of trichophyte plants belonging to 121 genera, 58 families. Among them, the Poaceae family mostly prevails in Thu Thiem’s wetlands. Herbaceous plants dominate in agricultural and bare wetlands, while woody plants are dominant species in forestry wetlands. The study also shows that Shannon’s species diversity of agricultural, forestry and bare wetlands is 3.36, 3.6 and 4.11 respectively.
These results indicate the richness of the wetland ecosystem in Thu Thiem peninsula. However, urbanization in this area leads to natural disturbance and encroachment that is the main reason of organic water pollution.

Therefore, some key recommendations have been proposed including urban water infrastructure, vegetation diversity preservation and conservation that contribute mitigating urbanization problems based on wetland ecology. This study identifies various local species which have benefits in wastewater treatment, landscape and flood reduction should be considered in urban development strategy including urban planning and design in various dimensions e.g. urban green infrastructure development, flood resilience.

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