Characterizing Urban Development Patterns for Informed Climate Adaptation: The Case of Can Tho City, Vietnam

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Abstract. Urban adaptation a critical issue for Can Tho located in Vietnam's Mekong Delta, where despite significant scientific unknowns and uncertainties, strategic and robust policy decisions and action plans are urgently needed. This paper presents the classification of the city into different spatial units based on housing archetypes, functions, infrastructure, degree of planning, density, accessibility and open space. The official land-use plan for Can Tho until the year 2030 was used to accurately map 78,527 polygons into 53 distinct structures reflective of actual land-use and densities. The findings show that the current built-up land cover of the city is 6,677 ha (4,227 ha urban residential, 1,580 ha public use, and 868 ha industrial). Interestingly, informal temporary housing was seen to cover 128 ha, while currently another 503 ha of land is under construction. The analysis gives special emphasis to the understanding urban flood risks, and the socioeconomic fabric of the city in support of informing effective adaptation responses.

Keywords: Urban structure types · Can Tho city · Flood risk · Adaptation · Urban development

1 Introduction

The cities of Vietnam have a dual role to play in the context of responding to climate change. As expanding concentrations of people, industry and critical infrastructure, they account for the majority of greenhouse gas emissions, yet are also themselves heavily exposed to the impacts of a changing climate [1–3]. It is increasingly important for urban areas in Vietnam to develop and implement both low carbon and adaptation pathways at various spatial scales to reduce risks and enhance the resilience their communities and infrastructure to impacts such as urban flooding, heat stress seal level rise, droughts and other extreme events. Yet impacts of a changing climate presents a significant challenge for planners. Future urban and regional planning, assessment methodologies are needed that evaluate and take into account a variety of impacts and their interrelationship to the environment, society, and economy. The exposure and sensitivity, and adaptation potentials of various social groups, settlement types, and infrastructure which make

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up the urban milieu ultimately determine how significant impacts are. Concurrently urbanization resulting in both the socio-economic and structural changes to urban areas modify both exposure and vulnerability patterns. To develop appropriate adaptation solutions in a cost effective manner, a vast array of both physical and socioeconomic characteristics need to be taken into account in order to determine firstly the degree of physical exposure to climate impacts and secondary socioeconomic vulnerability.

For assessment and planning purposes cities are frequently separated into spatial units with comparable physical and socioeconomic characteristics (e.g., building types, age, densities, accessibility, open space arrangements, and functions). In some instances, socioeconomic factors including residents' ages, incomes, and access or distance to basic urban services are also taken into account. Thereafter, knowledge of classified urban structure types can play a major role in evidence led sustainable urban development and climate change adaptation, as the physical arrangement of buildings, streets, and open spaces can greatly impact a city's ability to cope with environmental change such as extreme weather events, heat islands and sea level rise. Moreover, individual urban structure types may be impacted by climate change and weather events differently due to their unique properties. For example, the exposure, sensitivity or adaptation options to climate-related events such as heat stress or flooding can be influenced by the type or age of buildings, their heights, and density. This contribution outlines the urban structure type classification and mapping of Can Tho city. We investigate how the various areas of the city are classified for adaptation and how urban typologies are an important tool to identify adaptation needs or hotspots and transition towards climate resilient development.

2 Can Tho City

As Vietnam's fourth-largest city, Can Tho functions as an important economic and service centre for the surrounding provinces that make up the country's Mekong Delta region. The city became a Class 1 city in 2004, and has since undergone rapid urban development with significant economic growth and infrastructure investment. Can Tho has a current official population of approximately 1.24 million and a growth rate of growth rate of 0.67 [4]. Divided into nine districts, five are designated urban districts, Ninh Kieu, Binh Thuy, Cai Rang, O Mon and Thot Not with a population of 0.8 million inhabitants (70%), and four rural districts namely Phong Dien, Thoi Lai, Vinh Thanh, Co Dom, with a population of 0.4 million (30%) [4]. The city center is located Ninh Kieu district, which hosts governmental institutions, and commercial, financial, bank, educational and health services and the highest population densities. The city is located on the west bank of the Hậu (Basac) River, a main branch of the Mekong River, approximately 80 km upstream from the East Sea, and crisscrossed by a complex system of tributaries canals, all affected by tide. Flooding has been one of the city's most critical problems in recent years [5–8]. While the city has a long tradition of living and coping with small floods and has built up a certain degree of resilience. Events still cause injury, damage to property and infrastructure, as well as interruption of essential services and business supply chains. Such events also cause substantial personal stress and hardship to affected households, particularly in the more vulnerable of society. Moreover, past studies have identified Can Tho as one of the nation's most exposed and vulnerable locations to adverse climate change-induced impacts [2]. This requires an urgent paradigm shift from merely coping with flood waters to reducing overall flood risks. Local policymakers are concerned that the city is faced with a projected increase in both the intensity and frequency of pluvial and fluvial flooding and extreme heat waves, while already being confronted with environmental stresses, such as increased freshwater demands for domestic and industrial purposes, salt water intrusion, significant land subsidence and uncontrolled rapid urbanisation. According to the most recent climate change scenarios released by the Viet Nam Ministry of Natural Resources and Environment, a sea level rise of one meter, would result in 20% of the urban area inundated [9]. Yet despite an increased understanding of the growing risks, both planners and policy makers struggle to adequately develop robust adaptation responses into the rapid urban development processes (Fig. 1).

Fig. 1. Photograph of street inundation following a hightide event in November 2021

3 Methodology

The UST mapping methodology involved the classification, refinement and reclassification of building archetypes, building densities and open space configurations for the city. Typologies, in all scientific disciplines are used to functionally characterise and to reduce the complexity of the real world by combing and summarising similar elements, features or phenomena into groups or sets with the same characteristics. Therefore, in any classification of USTs, it is important to find a balance between reducing complexity to a manageable level yet maintaining real-world reality. The Can Tho Department of Natural Resources and Environment provided the official digital version of the land use master plan through 2030, which served as the basis for the methodology proposed by [2, 3], to precisely define the UST of Can Tho. This required the manual and visual analysis satellite images.

4 Classified Urban Structures

In total, 6.9% of Can Tho was classified as one of 13 distinct residential USTs. This were further sub-divided into shophouse based- (10 types), villa (1 types), apartment (1 types) and rural residential (1 types) types. Moreover, in total, 1.1% of the city was classified as of public, commercial or special use. Industry use was seen to make up 0.6% of Can Tho total administrative area, while green and open spaces was seen to account for 81% of the total Can Tho administration area (Table 1 and Figs. 2 & 3).

Table 1. Classified USTs of Can Tho

	No. of UST	No. of blocks	Surface area (ha)	Urban residential area (%)	Total surface area (%)
Total UST	53	78,527	129,110	–	89.7
Residential	13	40,237	9,910	–	6.9
Urban residential	12	22;416	4,227	100.0	2.9
Shophouse regular	4	3,036	1,715	40.5	1.2
Shophouse regular new	–	126	224	5.3	0.2
Shophouse regular new community	–	238	494	11.7	0.3
Shophouse regular with alley	–	1,437	359	8.5	0.2
Shophouse regular with yards	–	1,235	639	15.1	0.4
Shophouse irregular	3	6,213	740	17,6	1.7
Shophouse irregular high dense	–	2,167	270	6.4	0.2
Shophouse irregular with yards	–	2,841	346	8.2	0,3

(*continued*)

Table 1. (*continued*)

	No. of UST	No. of blocks	Surface area (ha)	Urban residential area (%)	Total surface area (%)
Shophouse irregular temporary	–	1,205	128	3.0	0.1
Shophouse irregular Peri-urban	3	13,155	1,767	41.8	1.2
Shophouse irregular scattered	–	26	16	0,4	0,0
Shophouse irregular clustered	–	9012	1576,6	37,3	1,1
Shophouse irregular with large gardens	–	4117	174,36	4,1	0,1
Villa	1	11	13	0,3	0.0
Apartments	1	1	8	0.3	0.0
Rural residential	1	17,821	5,662	–	3,9
Public and special use	15	1,517	1,580	–	1.1
Industrial	4	629	868	–	0.6
Green and open space	21	36,144	116,755	–	81.1
Remaining transport and surface water	–	–	14,790	–	10.3

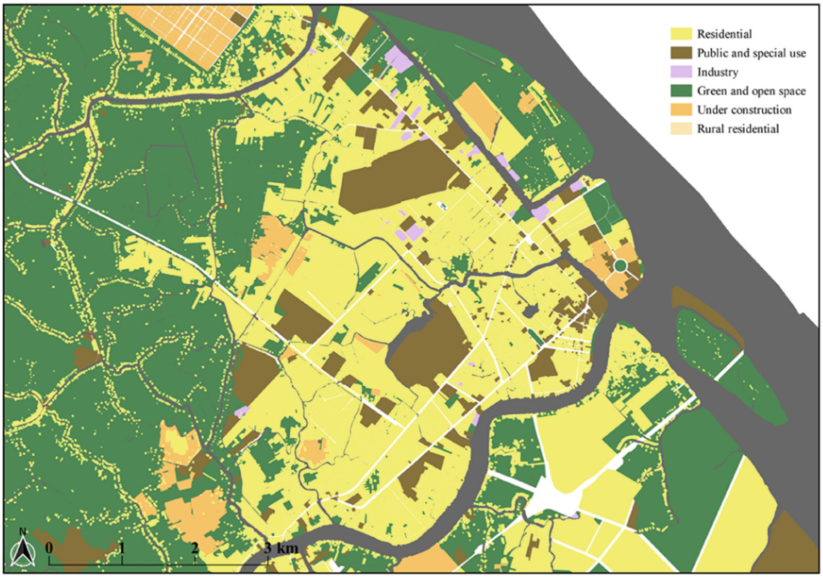

Fig. 2. Mapped main utilisation categories for Can Tho (Note: Rural residential and construction sites USTs are shown to highlight the urban boundary, and the current directions urban development respectively)

Fig. 3. Selection of different shophouse based USTs for Can Tho city

5 Informing Adaptation

Traditionally in Can Tho, decision-makers have relied on built structural engineering solutions for risk reduction. Yet, nature-based solutions may offer more flexible no-regret, win-win measures, and well-documented environmental, social, and economic benefits. If strategically planned, they can be seen as long-term solutions for peri-urban and rural areas and provide a diverse range of ecological services. However, they may be unable to handle the magnitude of expected future dangers, and they may demand too much room for older dense areas, such as the urban centre. In this case, hybrid, green-grey systems may offer an approach that reduces the traditional dependence on solely grey infrastructure and utilizes combined grey and green infrastructures potentials, such as bioswales, rain gardens, green roofs, and other engineered ecosystem approaches for adaptation (Fig. 4).

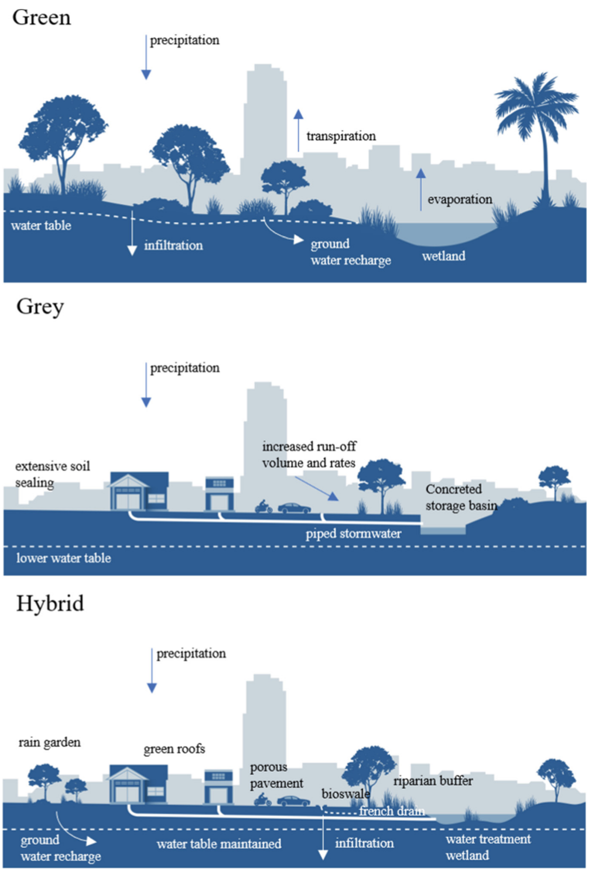

Fig. 4. Illustration of green, grey and hybrid options for managing the current and future challenges of precipitation and stormwater in Can Tho. Closely adapted from [10]

The construction of decentralized sustainable urban drainage systems at the block level can help improve both runoff water retention and treatment, minimize floods, and increase drainage capacity can offer an alternative to end-of-pipe treatment systems. Furthermore, de-sealing would reduce run-off and flash flooding. This could be enhanced by the development and conservation of green space and planting of moisture retaining species, increase evapotranspiration and reduce rainwater run-off. Final solutions may be land-use density controls and strategic retreat. In some locations however, risks may be so sizeable that they can be reduced only by hard engineering solutions such as embankments, walls, weirs, sluices and pumping stations. Proper management of solid waste, safe evacuation route planning; to identify safe paths out of risk areas and early warning systems are also important considerations at the block or neighbourhood level.

In Can Tho individual buildings show incremental adaptation solutions that are more reactionary than anticipatory. A typical protective measure to keep water out of homes is the elevation of properties or ground floors. This is very often a reactionary coping response following the elevation of adjacent roads or alleyways in the city. Dry proofing techniques also include the installation of property flood gates, sand bags, and pumps to offer quick flood responses. In this respect, general property repair and maintenance is also a low-cost and a low-skill, coping response that helps to protect against flood damages (Fig. 5).

Wet proofing homes, allows water to enter the home, while valuables and utilities are placed, moved to or installed at higher levels. More advanced structural changes include elevating homes on piles or mounds, floating homes or even amphibious homes.

Additional measures include the installation of "green roofs" to compensate for an increase in sealed surfaces. These minimize run-off and increase evapotranspiration. The abandonment of properties may be seen as a last resort to remove populations and structures exposed areas. Often these intuitive, inexpensive, and accessible responses can be implemented for both new-build and the retro-fitting of existing properties and can become transformational when they are used to a greater scale, or with greater uptake among owners.

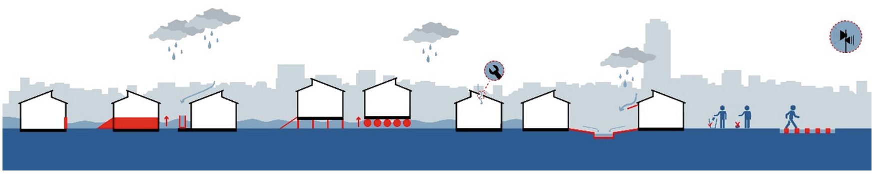

Fig. 5. Illustration of a range of household adaptation solutions for managing the current and future challenges of heavy precipitation and stormwater in Can Tho

6 Conclusions

The roll out of planned adaptation within Can Tho city is still in its infancy. The city's recent rapid urban development and over-exploitation of land resources has challenged the capacity of local planners and decision makers to respond to climate change impacts.

To precisely characterize the city's morphology, function, and socioeconomic fabric, this contribution outlines the urban structure type mapping of the city, useful to strengthen the city's capacity to reduce urban risks in the context of climate change. The understanding of USTs and their various over time and place is a useful tool for examining land-use and density changes, as well as identifying the major mechanisms and linkages at work. The findings can help increase knowledge of adaptation pathways to deal with climate change uncertainty in the context of fast urbanization, and the findings are expected to contribute to current discussions in Vietnam.

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