Urban landscape planning adapting to flood in Can Tho city, Viet Nam

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Abstract. To promote flood resilience and reduce the damaging effects of flood in urban areas, the paper proposes an urban flood adaptation model based on an urban hydrological model, combined with the capacity of the flood ecological infrastructure. This model includes allowing flood to enter the city and restoring the interaction between flood and riparian ecosystems. This approach is called flood adaptive ecological awareness. To implement this idea, the paper translates into urban landscape planning principles that consider flood as a resource for urban ecosystems, establishing flood storage spaces based on ecological infrastructure adapted to dynamics of flood. The ability to regulate, collect, penetrate and purify pollution with water is due to the participation of landscape ecological infrastructure and enhance the regulatory capacity to mitigate the harmful effects of flood on Can Tho urban areas in Mekong Delta region, Vietnam.

1. Introduction

Cities since forming have attached to the element of water as an indispensable condition to exist and develop. However, as the urban process progressed, the city seemed to turn its back to the river, encroaching the lakes and turning these places into polluted sewage and waste. In general, the balance between water and land in urban areas is no longer leading to local flooding, groundwater depletion, and lack of landscape environment related to water. The rapid development in areas adjacent to land and water (estuaries, coastal lagoons, riverside ...) has led to certain conflicts between urban development and the natural environment. Natural canals and low areas are being encroached and filled indiscriminately for urbanization, blocking the flow of water and destroying the storage function of ponds and lakes. The whole stormwater drainage system of many urban cities is overloaded and the integrity is broken. The soil's ability to absorb naturally decreases while the number of concreted areas increases, resulting in an increase in the surface water flow rate while the water table decreases. With the current urban development, the risk of flooding will increase along with the effects of climate change.

Although urban planning in Vietnam currently has integrated tools for environmental protection through strategic environmental assessment and adaptation research, mitigation of risks before natural disasters, floods, etc. These tools and approaches are not strong enough. Most urban planning projects only consider water surface to play the role of landscape and temporary reservoir, mainly focusing on microclimate research and landscape organization but have not yet become a decisive factor of urban. Many countermeasures against flooding due to rain or flooding are mostly passive and propose passive
options as areas such as lakes, rivers, or canals that need protection become urban areas. Town and housing can no longer be preserved. Up to now, urban planning projects in Vietnam mostly consider climate change, especially floods, which are out of the project’s study duration because the projects are studied until 2025 - 2030, and climate change forecast is 50-100 years later. Given the development reality and the remaining issues in urban planning as above, an integrated study of water and urban development issues is necessary to support and provide information on the models landscape planning, specific measures to cope with and mitigate impacts on Can Tho City due to climate change, with a focus on urban flooding.

2. Literature review

In the Mekong Delta and Can Tho City, the impacts of climate change will mainly be reflected in the sea level rise due to rising sea levels and increased rainfall. Furthermore, river erosion is a serious problem, especially for households living in settlements along the river banks. According to the official announcement of the Ministry of Environment and Natural Resources of Vietnam, with the current terrain and infrastructure of Can Tho, the forecast of sea level rise of 1m more will directly flood 19% of the entire area of the city [1].

Figure 1. Current inundation status (left) and forecast of flood effects - saline intrusion when sea level rises by 50 cm (right) in Mekong Delta.

Source: Refer to OSA / WIT / LATITUDE scenario (2010)
Figure 2. Forecast of flood effects when sea level rises in Mekong Delta.

Source: Tan Chau station (October, 2019)

Given the complex developments of global climate change, disaster risks are unpredictable and difficult to resist if they occur. Urban researchers are now more interested in how a city can adapt itself (the whole system) to be able to remain active and "get up" quickly after the "attack" and continue to develop, rather than how the city is not affected or not affected by natural disasters. This point of view began in the 1970s, with pioneers like Holling C.S (focusing on the ecosystem) and then many other authors expanding and in-depth researching related issues to urban areas such as economy, technical infrastructure, community, government. Some definitions of urban resilience ("urban resilience"): 
- The ability to "absorb" disturbances caused by natural disasters while continuing to exist (Holling, 1973); [2]
- Urban resilience to natural disasters with minimal losses to production activities and people's lives (Mileti, 1999) [3];
- The ability to accept losses and recover (UN, 2013) [4]
- The capacity of a city can balance and reorganize almost all activities to minimize damages to urban development (Liao, 2012). [5]

This is the approach and problem solving with the view of "fighting" ("resistance"). Liao (2012) compared and clarified the differences between urban areas that could be “resistant” or “resilient” [6]. Perspectives on the concept of urban resilience have two branches on two different platforms, technology and ecology: "engineering resilience" - which emphasizes the ability to maintain a sustainable system base on the development of technical technology, especially construction technology and forecasting - information management system; and "ecological resilience" - emphasizing viability and long-term equilibrium with self-capacity and ecosystems. In the context of increasing urbanization and increasing risk of climate change flooding, the reliance on flood control infrastructure to reduce flood risks will only result in cities more vulnerable (Liao, 2016) [7].
Figure 3. Differences in urban response to flooding: "Resistant city" and "Resilient city".

Source: Reference from Liao, 2012

Table 1. Differences between technical adaptation and ecological adaptation.

| Content                  | Technical adaptation                      | Ecological adaptation                          |
|--------------------------|-------------------------------------------|------------------------------------------------|
| Theoretical framework    | Adaptation = adaptation + recovery        | Adaptation = endure + reorganize                |
| Assumptions              | A state of balance (one mode) Predictable | Many equilibrium states (multiple modes). Unpredictable and uncertain |
| Action                   | Fluctuate around the ideal state of system function or steady state | Mode change                                    |
| Center                   | Stable / consistent - quickly return to equilibrium | Only stable consistency in current mode         |
| Measure                  | The speed of recovery to a previous stable state | The level of turmoil the system can tolerate and overcome before moving on to another mode |
| The role of disturbances | Disturbance is a threat to the system     | Disturbance is an opportunity to learn and gain experience |

To promote flood resilience in urban areas, many "flood adaptation" models are proposed to prevent flood damage. The theory of the "self-resilience of urban water system" inherits and develops from the "self-healing" platform in ecology and society - ecology, is drawing broad attention extensively in flood management (Walker, Holling, 2004) [8]. The ability to self-recover (or adapt) to floods is not only associated with post-disaster recovery but also is related to minimizing the risk before a disaster. From the point of view (Liao, 2012), flood adaptability is the ability to tolerate floods in order to avoid the risks when a flood is taking place, not at all to prevent floods, or to be able to reorganize in a way rapidly when material damage, socio-economic damage is still happening [9]. Currently, for cities facing unexpected and unpredictable risks of flooding, the concept of "self-recovery" is very important in risk reduction and response plans. In particular, "self-recovery" or "flood adaptability" should be understood as flood resilience and the ability to quickly reorganize.
For cities, the ability to adapt to floods is their ability to tolerate floods, meaning their ability to preserve, not be devastated and still maintain their function when flooded, reorganized quickly if disaster exceeds tolerance, the structure of these cities must adapt to flood. Adaptation here is understood to be measures that are adapted to the flood regime without changing the regime of those floods, adapting to the flood as opposed to flood control. Flood adaptation also includes "living with flood", demonstrating a flood-tolerant lifestyle and lifestyle by enhancing the adaptability of assets and raising public awareness of flood (Liao, 2016) [10]. Within the scope of this paper, flood-adaptive cities are primarily focused on building a natural interaction structure between humans and nature. It allows flooding into the city thanks to flood storage spaces, taking advantage of floods to nourish urban ecosystems (mainly focusing on water-friendly ecosystems). In addition, the construction environment takes into account flood risks and proactively plans for flood tolerance, raises awareness and coping capacity of the community with floods and is ready to switch to flood adaptation mechanism when needed.

**Urban landscape planning should consider floods as a resource for urban ecosystems:**

Today flood control is still considered the optimal solution in flood management, flood always has a negative image through the media and government activities, flood management programs only consider floods as problems trouble, completely by passing the services of flood ecosystems. Urban landscape planning should learn how to adapt to flooding in flooded rural areas, where floods help clean up the environment, floods increase the amount of sediment for agriculture, enrich the source of fishing, and flooding part of tourism development through flood tours, etc. The view here is that floods are a resource for human life (Liao, 2016) [11].

Of course, cities are not exactly the same with these flooded rural areas, but the services of the flood ecosystem are completely the same. For cities facing cyclical floods, floods help restore flooded ecosystems, add biodiversity to urban ecosystems, and provide additional sources of silt to the natural areas around the city. Flood improve the polluted water environment in the urban area, eliminate the accumulation of urban activities, and clean the living environment. However, the conditions here must have space for flood activities and flood dynamics are not obstructed.

In urban landscape planning, it is necessary to take advantage of flood to nurture water-friendly ecosystems such as wetlands and riparian landscapes. These ecosystems are available to adapt to flood, so they can regenerate and recover strongly after flood, contributing to ensuring the balance of the ecosystem. Therefore, in urban design, it is necessary to conserve and restore spaces for this ecosystem, followed by the promotion of natural processes between these ecosystems and flood dynamics. Taking advantage of flood will reduce the harms of flood, change the view of the approach to flood in urban areas.

**Establish flood storage space based on ecological infrastructure (ecosystems) to adapt to flood dynamics**

Water disaster problems are not caused by water itself but by the function of water ecosystems which lose their regulatory function, so the key is the interaction between water and ecosystems. Cities that want to improve flood adaptability need to build an ecological infrastructure to participate in the complex process of the water cycle. The ability to regulate, collect, penetrate and purify pollution with water is undertaken by the ecosystem, so it is necessary to take advantage of the ecosystem to provide hydrological benefits (enhance regulatory capacity) to reduce mitigating flood damage (Gill, Handley, Ennos, & Pauleit, 2007) [12].

First, it is necessary to study the dynamics and spatial distribution of floods. For a city, floods can occur upstream, possibly due to high tides from the sea, or even during local climatic conditions. Determining floods with intensity, frequency and peaks in different approaches will have a better risk reduction plan, and urban structures will be adjusted more flexibly when forecasted. It is necessary to distinguish periodic floods with harmful floods. Small floods, which have ecological significance, are more meaningful for urban development and cannot be combined into large, dangerous floods.

For cities, increasing flood tolerance is an opportunity for the public to better understand floods of ecological value and an opportunity to restore some of the ecosystem services of their children. River
flows through the municipality. By developing riverside parks into natural submerged areas (submerged parks), or naturalizing open spaces, restoring the natural conditions of canals connecting to the main stream will create more submerged environment... Over time, the ecosystem will recover or a new ecosystem may occur during the flooding period in the form of underwater and coastal amphibians (Liao, 2014) [13].

**The urban structure always takes risk situations into account and is ready to switch to flood adaptation**

Environmental design that takes into account adverse conditions and flood adaptation is a normal part of the habitat. Based on flood control models, urban design rarely takes into account bad situations, reducing the risk of flooding is assumed to be a matter of hydraulic engineering. However, typical floods in the world show that flood control models are completely ineffective when the flood exceeds the designed capacity, in some cases it does not work with the small flood flow.

In rural areas of the Mekong Delta in Vietnam, floods can enter villages and easily escape through flexible space. For urban areas, this is more difficult because the population density is often very high and the price of land is expensive, so planning is very limited space for floods. However, urban design measures can allow cities to take into account adverse situations to adapt to flood (Liao, 2014) [13] (Bruno De Meulder and Kelly Shannon, 2010, 2013 and 2015) [14] [15] [16]. Recently, the design of open space for flooding has become a new trend, these spaces are organized for entertainment purposes and at the same time to reduce the risk of flooding.

On large scales, water is centrally managed for easy damage control, but on a smaller scale decentralized water management also attracts the wide attention of urban design experts. Ecological canals, rain gardens, wetlands built in urban areas have created more open spaces to promote the retention, infiltration and treatment of rainwater, creating favorable conditions for green infrastructure to pay attention to more attention in the function of regulating rainwater sources. Not only developing green infrastructure, spaces with hard floors, hard water drainage such as squares, playgrounds and sports areas can also be converted into flood storage.

Functional areas for flooded areas should be paid attention to in landscape planning, natural flooded areas need to be protected to provide flooded space for rivers and lakes during floods. The hydrological function of a flooded area can be protected with solutions, including: limiting construction works, flood-adaptive land use functions (parks, playgrounds, agricultural land) recommended. The flooded area is divided into a completely forbidden construction area and a controlled construction area, through which the border is a flood-safe area.

### 3. Materials and methods

#### 3.1 Context analysis

#### 3.1.1 Climate of Can Tho urban area

Can Tho City is located in the Mekong Delta region, with a tropical monsoon climate, lots of sunshine and rain. The rainy season lasts from May to November, with a peak in September and October, when facing high tide, combined with low terrain will cause immediate flooding in many places in the dry season from December to April of the year after.

The air temperature changes with the seasons, there are two distinct seasons, the temperature is quite high (average from 27.2 to 27.7°C; in which, the lowest is January 24.6 - 26.4°C, the highest is May 29.0 - 30.0°C) and tend to increase rapidly (Compared to the average of the twentieth century, the average temperature in 2014 was higher than 0.7°C). Small daily temperature range (5 - 6°C). The total number of sunny hours in the year is 2,300 hours, the average annual radiation is 150 kcal/cm².

The average annual rainfall varies from 1,309 - 1,711mm and is not evenly distributed seasonally, the rainy season from May to November (accounting for 89.4% of the annual rainfall); of which, September and October alone accounted for 34.8% of the rainfall during the rainy season. Average
annual rainfall is also on the trend of increasing rapidly (compared to the average of the 20th century, the average rainfall in 2014 is greater than 76.1mm). Precipitation varies by region but is not clear. The northwest region has more rainfall than the southeast region of the city.

The relative humidity of the air is on average 80.42 - 81.75% and it does not change seasonally: the rainy season, the high humidity is 80 - 85% and the dry season 75 - 78%. From June to October with the highest humidity, the months with the lowest humidity of the year are February and March.

There are 2 main prevailing wind directions: southwest monsoon, prevailing in the rainy season from May to November with the characteristics of bringing a lot of water vapor, creating cool air and easily causing rain; northeast monsoon, the average wind speed of 3.5m/s; in which, the strongest is June 3.9m/s and the weakest is April 3.2m/s [17] [18].

**Figure 4.** Scope of research in Can Tho city in the territory of Vietnam and the Mekong Delta  
**Source:** Climate Change Research Institute - Can Tho University

**Figure 5.** Map of temperature, air humidity, precipitation, water level over years.  
**Source:** Climate Change Research Institute - Can Tho University
3.1.2 Topography, geomorphology and geology:

Can Tho city is located entirely on the alluvial soils of the Mekong River, which are deposited regularly through the Hau River. The terrain is generally relatively flat. The average elevation is about 1.0 - 2.0m slope from the soil along the Hau and Can Tho rivers towards the interior field (from northeast to southwest). Can Tho City has a network of rivers, canals and ditches quite thick. Besides, there are also dunes and islet.

The geomorphology consists of 3 main types: (1) Along the Hau River, a high land strip (natural dyke) and islets along the Hau River are formed. (2) The western region of Hau River is low and low, affected by annual flood. (3) Delta affects the tide and flood at the end of the crop.

Geology: there are two types of sediments on the surface at the depth of 50m: holocene (new alluvium) and pleistocene (ancient alluvial).

In general, flat topography, convenient for the organization of agricultural farming systems, mixed Agriculture-Fisheries systems. High land is convenient for construction, low-lying areas can organize the construction of reservoirs and water drainage, combining green trees and water surface to create landscapes. However, the terrain is low and there are areas flooded annually (25% of the area). Geology of the soft ground affects the construction of technical infrastructure facilities, especially the development of road transport and urban development [18].

Figure 6. Current status of topography - geology, level of urban development, water network, greenery, Can Tho city infrastructure. Source: Climate Change Research Institute - Can Tho University

3.1.3 Hydrology:

Can Tho city has a dense network of canals and rivers, in addition to the rivers in the Hau river system, there are small rivers flowing into the Gulf of Thailand. These rivers are all connected in a system that covers the entire territory of the city.

Hau River is a tributary of the Mekong River, the section running through Can Tho city has a length of about 60 km, width of about 800 - 1,500 m. The total amount of water flowing into the sea is about 200 billion m³/year, accounting for about 41% of the total water of the whole Mekong system. The average water flow of the Hau River in Can Tho is 14,800 m³/s. The water regime of the Hau River is divided into two seasons: The flood season lasts from July to December, with a peak in
September and October. In Can Tho, the maximum flow reaches 40,000 m³/s. The dry season is from January to June, the lowest is in March and April. The water flow in the river in Can Tho is only 2,000 m³/s. The river level at this time is only 48 cm higher than the sea level.

Can Tho River flows in an arc surrounding O Mon, Binh Thuy and Ninh Kieu districts and flows to Hau River at Ninh Kieu wharf. At the junction with Hau river, the width of the river surface is up to 200 m. The river has a fresh water source all year round so it has great significance in many aspects for the city such as: supplying water for production, daily life, transportation, tourism... In addition, there are many other canals in the city such as O Mon river, Binh Thuy river, Thot Not river, Cai Khe canal, Dau Sau canal.... Besides natural rivers, the city also has many artificial canals such as Cai San canal, Xa No canal, Thi Doi canal, Bon Tong canal... These canals connect the system of rivers and canals in the city, forming a network of rivers and canals dense incision. However, in recent years, the process of urbanization has gradually filled many canals, making the density of canals in the city significantly reduced, reducing the ability to transport by waterways, losing beauty inherent river landscape. In addition to surface water and groundwater being polluted due to the development of industrial urban areas, river and canal systems are affected by semi-diurnal tide regime causing flood and inundation [18] [19].

Figure 7. Diagram analyzing the hydrograph and topography of Can Tho city
Source: Climate Change Research Institute - Can Tho University
In general, the process of forming Can Tho urban area shows the following main characteristics:

- The nature and structure of the city in the form of "Agricultural Urban" (Agrocity), a form of transition from rural to urban. It is the fusion of urban and rural in urban structure, creating a "rural urban" appearance.

- The indigenous nature of the urban area is manifested through the landscape structure: the river - the garden - the architecture - the curves and the large void, in which the water surface constitutes the characteristic of the urban spatial form. Urban development spread horizontally rather than height, towards harmony rather than opposition.

- The form of space associated with the urban river route is an important factor to easily identify the urban spatial characteristics of a river.

**The cause of flooding in Can Tho city**

Throughout the history of formation, the natural canal system has played a leading role in leading the landscape of the delta. Can Tho City has a long and wide waterway system with historical value in territorial distribution. Water elements have shaped the delta, as well as playing an important role in transport, irrigation and drainage. The embankments and high land cover allow to provide a larger area of land for crops and fruit trees. The dispersed locations also allow farmers to access more fields. Thus, the dynamism and complexity in the landscape of Can Tho city was created by a controlled dispersion model with urban nodes being always the most important, in a complex balance, interdependent structures between water and soil, permeable and impervious surfaces, all organized by hydrological systems for water management and soil stability [20].
From the general analysis of natural conditions, conditions of construction and infrastructure development, human activities show that the causes of flooding in Can Tho city include:

**Table 2. Causes of flooding in Can Tho City**

| Causes of flooding in Can Tho City |
|-----------------------------------|
| Climate change, sea level rise    |
| Floods in the upper Mekong do not come back cause large-scale subsidence |
| Increased flood due to heavy, prolonged heavy rain |
| Increased inundation due to urban construction and renovation |
| The canal system is leveled and embankment |
| Urban drainage capacity, limiting the overall orientation |

Flood caused by flood in the upstream of the Mekong River combined with high tides: 1 month in Can Tho City has occurred 2 times of inundation, on average, there is a tide cycle of about 15 days including 1 teak tide and 1 middling tide. -15 lunar calendar. Floods occur around November. The peak of flooding is due to high tides and the flood is around September, October, November.

Flooding due to heavy, prolonged rain, total heavy rainfall: rain in Can Tho city usually lasts from 30 minutes to 120 minutes, rainfall is about 40-70 mm, heavy rain is around September and October. With heavy showers, alleys do not have drainage systems, or there are clogged drains that cannot drain, bulky water rises, causing difficulties for transportation and living for people. When the rain ended about 2-3 hours but still flooded.

Increased inundation due to canal leveling, encroachment and pollution: Can Tho city is built on a relatively flat terrain, and is divided into cells by a dense canal system. This is an advantage for drainage (short, easy to drain). However, this canal system also makes the flood water inland. One of the city’s current anti-flood solutions is to build embankments along both sides of the channel and build the foundation. To ensure good drainage, the canals must be dredged regularly and without obstructions affecting the flow regime (houses, garbage, leveling canals). However, due to the low awareness of the people, there are behaviors such as indiscriminate littering into roads, canals, drainage pipes, building houses encroaching on canals, making drainage situation even more difficult.

Increased inundation due to the process of urban construction and renovation: due to the urbanization process, the natural regulation of the basin surface, the leveling and reduction of natural water reservoirs have been reduced. In the inner city, most of the surface of the soil is concreted, asphalted, built houses and factories, therefore, when the rain falls, almost all the rainwater is concentrated into surface flow, unable to absorbed into the soil or stored. In addition, the limited drainage capacity of the drainage system makes flooding easily happen, some works are under construction due to lack of good construction diversion methods leading to the prevent local flooding around the construction area. The indigenous urban identity of Can Tho is seriously threatened by unreasonable urbanization. The change in territorial structure has a negative impact on the absorption capacity of the natural water permeability landscape. The consequence of the change in the correlation between land and water is the fundamental shift from social community attached to water to social community associated with transport infrastructure, leading to a fundamental change in the spatial
organization of the area. In Can Tho City, the unconscious leveling of lowland areas (up to 2-2.5m high) and an increase in the number of non-absorbent surfaces lead to the consequent rainwater runoff faster and the water table is getting lower.

Flooded due to lack of drainage system: the city has just been developed but due to many different stages, different visions and investment, so far the general infrastructure and drainage system have been. Particularly, it has not met the requirements of water drainage. In addition, the drainage systems, especially in the inner city, are old, damaged, not or have not been regularly maintained, so when it rains (even moderate rain) has also caused inundation of many parts of the city.

Climate change, sea level rise: Global climate change is happening very fast. In the Mekong Delta, the risk of sea level rise due to climate change will increase the influence of the hydrological regime, tides on the large rivers and canals throughout the Mekong Delta in general, the city of Can Tho in particular. The impact of climate change increases the possibility of flooding inherent in Can Tho. Climate change and sea level rise increase the level of the impact of natural disasters on the inherent flooding: flooding caused by floods in the upstream Mekong River, reducing the drainage capacity of the soil and drainage capacity of the urban area. In addition, due to the effect of sea level rise in the future, many areas of Can Tho will be flooded, causing the surface area of Can Tho city to be flooded.

Climate change and sea level rise increase the level of the impact of natural disasters on the inherent flooding: flooding caused by floods in the upstream Mekong River, reducing the drainage capacity of the soil and drainage capacity of the urban area. In addition, due to the effect of sea level rise in the future, many areas of Can Tho will be flooded, causing the surface area of Can Tho city to be flooded.

The current rapid urbanization process can seriously threaten the uniqueness and urban identity value of Can Tho city, especially the deep relationship between delta and urban landscapes. The relationship between soil and water will be severely altered by the widespread increase of the concrete surface (significantly reducing the territory's ability to absorb natural floodwaters) and at the same time increasing the impact of climate change (flooding and acidification of land). Currently, Can Tho is an important agricultural center of the Mekong Delta, in which urban and rural life are intertwined and interdependent. Fruit orchards are an essential element of the city's economy and appearance. But urban expansion has led to a major shift in land use, creating a disturbance of the landscape between urban and rural areas. The main landscape elements that make up the territorial structure, possibly leading to the urbanization process in Can Tho City are the vast waterway network (natural rivers and canals) and topography (decisive) to specific land uses. However, the current urban planning does not pay much attention to the theories about existing landscape foundation. The lack of a clear hierarchical spatial structure and a lack of priority for development makes urbanization almost universal.

4. Research Methodology

The paper is implemented with the following methods:

**4.1 Collection, analysis and synthesis:**
- Collecting, analyzing and synthesizing related documents and documents: The paper uses integrated and systematic analysis methods throughout the process of approaching problems from which to
obtain a necessary amount of knowledge that can clarify the assessment, theoretically as well as evaluate the solutions in the world. Based on that, lessons can be drawn for proposing solutions adapting to flood in Can Tho city.

4.2 Methods of map, remote sensing and Mike Flood/GIS geographic information system

- Analysis, selection of application software technology, database management system and GIS, Mike Flood technology.
- Proposing an additional planning scheme of Can Tho city structural analysis according to the flood risk map, thereby orienting the development and protection zoning suitable for functional areas and transport networks, protection safe high land, key central area. Determining the construction elevation for each area based on the simulation model of flood risk.
- Using GIS, Mike Flood database information for urban landscape planning and zoning function

4.3 Forecasting method:

- Through volatile parameters in Can Tho City, such as developments in natural conditions, climate ... the topic determines the factors that affects the landscape planning solution In Can Tho city, there have been suitable forecasts, which have set the stage for long-term flood adaptation solutions.

5. Research results

To promote flood resilience and minimize the damaging effects of floods in urban areas, the paper proposes a flood adaptation model based on an urban hydrological model, combined with the capacity of the floodplain. This model includes allowing floods to enter the city and restoring the interaction between floods and riparian ecosystems. At the same time, prevent flood damage by adjusting the system in a timely manner and turning to urban flood adaptation mechanisms (including community awareness and self-response). This approach is called flood adaptive ecological awareness. To implement this idea, the paper translates into urban design principles, including: Urban design should consider flooding as a resource for urban ecosystems; Establish flood storage space based on ecological infrastructure adapted to flood dynamics; The urban structure always takes risk situations and is ready to switch to flood adaptation mechanisms; Disseminate flood dynamics and raise awareness of living with floods to the public.

Solutions for structuring urban landscape adapted to flood in Can Tho City should prioritize analysis based on data on natural environment and regional ecosystems to serve as a basis for selective selection of all human construction activities. Remote sensing techniques using Landsat image analysis, GIS tools, Mikeflood...can support spatial analysis and modeling which is being increasingly improved, so that people are more and more absorbing spatial shape - the time of the design area with spaces that are as large as urban.

To survive uncertain hydrological conditions, modern cities need to be “amphibious,” meaning they need to be able to operate in both dry and flooded conditions. The knowledge of an "amphibian ecosystem" should be widely applied to cities that face constant risks of instability and unpredictability of flood. This knowledge is built on the relationship between people and the dynamics of flood. Ecological intelligence here is expressed in adaptation activities rather than flood control, derived from the knowledge of flood ecology, as well as the ecosystem services of the flood. When flood ecosystem services are highly appreciated, the built environment will no longer have the purpose of flood control and suppression.

Awareness of flood adaptation is in stark contrast to flood control activities. Flood control models that lead to the division of canals, levees, changes in upstream water regulation, limiting natural flooding can cause many rivers in urban areas to lose most of their ecological services. There should be widespread dissemination of negative hydrological effects of flood control activities to the public, especially environmental degradation. For flood of a cyclical nature, the key to a flooded ecosystem is that flood is not completely harmful. If there is sufficient knowledge of flood, cities will better interact with natural flood phenomena, thereby minimizing the impact of flood on people and property.
### Table 3. The correlation of landscape planning solutions to adapt to flooding in Can Tho City

| Overall solutions | Regional solutions | Detailed solutions | Architecture |
|------------------|-------------------|--------------------|--------------|
|                  |                   |                    |              |

- **Overall solution**
  - Building urban structure based on flood map
  - Protect safe highland, urban center
  - Preserving the plains and natural wetlands
  - Establish a network of reservoirs
  - Compressed urban areas, mixed land use
  - Restructuring the river bank
  - Ecological embankments
  - Create permeable pavement
  - Ecological embankments
  - Building osmotic lake
  - Construction of artificial wetland, urban park
  - Create rainwater collection and reuse
  - Roots and tree facades
  - Osmotic drainage
  - Structure for flooding constructions

### Table 4. The correlation of landscape planning solutions to adapt to flooding in Can Tho City

| Project            | Solutions                                                                 |
|--------------------|---------------------------------------------------------------------------|
| General Planning   | Identify flooded areas, Protect safe highland, urban development center   |
|                    | Preserving the plains and natural wetlands                                |
|                    | Establish a network of reservoirs                                          |
| Subdivision Planning | Restructuring the river bank                                               |
|                    | Building osmotic lake                                                      |
|                    | Construction of artificial wetland, urban park                            |

- **Overall solution**
  - Building ecological embankments, organizing green corridors for flood drainage along rivers

- **Regional solution**
  - Compressed urban areas, mixed land use
Step 1. Determining flooded areas: Building a city structure based on flood risk mapping, protecting safe high land and central areas.

Within the limits of this paper, climate change and urban development are all considered drivers of flood risk. In particular, the relationship between rising water levels and urban land areas inundated is particularly noticeable. It is therefore necessary to develop a system of land use maps that emphasize current and future construction land exposures, providing specific results of land use exposure as well. such as spatial distribution of soil types exposed to flooding, identifying flooding hotspots in urban areas, in order to effectively serve studies to further adapt to rising water levels.

Build city structure based on flood risk mapping.

The level of flooding is clearly a determinant of land use purposes (production or residence, safe or unsafe, etc.). Flood risk mapping tells us the hierarchical structure of flooding especially due to storm surge due to sea level rise in areas of the city. From there the development orientation and appropriate protection. Developing cities to higher ground is less affected by flooding and sea level rise. Protect important areas that are vulnerable to future impacts. The hierarchy of cities and transportation networks are also based on the structure of flood stratification. From there we carry out strategies to protect the safe land such as dyke upgrading, to lower flooded plains, clear encroachment areas, push dikes deep inland, build drainage channels, regulating lakes, etc.
Structure city according to flood map, steps to establish flood map:

Figure 10. 2020 biggest flood risk map for the low emission scenario (B1) and high (A2)
Recommended for Can Tho city
Figure 11. 2020 biggest flood risk map for the medium emission scenario (B2)
Recommended for Can Tho city

Step 2. Develop scenario of urban landscape planning - urban drainage adaptation to flood, sea level rise.

Scenario 1: No change at all. Can Tho naturally as it is now. Consequences Can Tho city will have to passively resist glare against the current and future flooding events under the impact of climate change, increasing flooding. Can Tho will lose its position and direction in its future development, along with its difficult and degraded people's lives.

Scenario 2: Based on climate change, sea level rise inundates 30-50 cm, the average population grows about 1.2 million people as expected. Strategy that Can Tho city will set out to protect the embankments well, focusing on developing the city in the highlands, in the lowlands using it as a natural water storage medium as well as a nature reserve. The landscape has just created an entertainment space that intersects with non-flooded areas. The areas are connected by a safe road network that is less affected by flooding and sea level rise.

Scenario 3: If a flood occurs larger than 30-50 cm, the population increases rapidly beyond expectation. At this time, the strategy is to protect safe places, lands and key economic areas. Urban compression is formed with a high degree of concentration, well protected, buildings in construction with affordable prices, convenient to work, travel. With a large area of flooded water, it is possible to develop industries related to water and water systems.

Step 3. Building the city structure based on flood risk mapping, protecting safe high land and central areas

In view of flood adaptation, sea level rise and climate change, the model of high-rise urban areas and compressed urban areas is a sustainable urban form, which is conducive to the adaptation of urban risks and corruption. The concentration of urban dwellers with high density in one location helps to create empty spaces, areas of interest to build infrastructure, public spaces, landscapes, which helps
increase drainage water easily when flooding occurs, with more free space to enhance penetration into the ground.

**Figure 12.** Flood risk assessment map for Can Tho city
Responding to climate change and sea level rise scenarios

**Figure 13.** Structure of the city according to the flood map adapted to flooding until 2050
The result identifies the flooded area, to carry out protection and adaptation of the developmental focus area
Figure 14. Urban landscape planning adapted to floods in Can Tho City

Source: Author

Step 4. Expanding the storage space to store water when there are floods and heavy rains

A flood plain is a flat area adjacent to rivers and streams and is frequently flooded. Including lowlands, artificial or natural marshes, fields, gardens, parks, vacant areas along canals, dunes and islets, etc. are storage and expansion spaces during floods and flood reduction. Is the area most clearly affected by flooding and sea level rise. This area is made up of two components:

- Areas where construction is prohibited: including natural marshes, ecological conservation, natural rivers, ponds and lakes, which are always subject to the impacts of floods, tides and sea level rise.

- Buffer zone: the area that is less affected by flood causes, the impact cycle may be only once a year, and it is likely to expand when sea level rise or flooding occur seriously. The impact is considered according to the extent to which the flood law is different.

Protection of floodplains, reconnection of floodplain areas with external river networks, establishment of land use standards, as well as strengthening of land use regulations and urban control in floodplain areas are absolutely necessary.

Figure 15. Agricultural spatial planning (fields and gardens) and fisheries,
Natural and manmade marshes adapt to floods in Can Tho City

Source: Author
6. Conclusions

Adapting to floods requires ecological understanding, which is the basic foundation for harmonizing the symbiotic relationship between humans and nature. Building a symbiotic relationship with floods can lead to a more sustainable city, where the city will be safer from floods, where people can be flood-friendly, the ecological benefits of floods will be. With deeper understanding, cities can look forward to a better future. The task of urban designers, flood managers and ecologists needs greater
cooperation to continue exploring the ecological services of flooding in cities to spread the role. their to the public. It is necessary to clarify and classify floods, in which the models of flood adaptation will be accepted if the public really understands the floods, in order to accept living with floods in the future.

Currently in Can Tho city, rivers are often separated from residential areas by dykes and flood walls, emphasizing the role of flood control, causing floods to be removed from view, out of the center. people's minds. The temporary regulation of the invisible invisible flood control system makes the public less interested in the state of the river and lacks awareness of the riverine hydrography. In order to raise public awareness about the ecology of floods, urban design needs to bring rainwater and flooding into the minds of people in urban areas. Integrating riparian parks into flood ecology can give the public better access to phenomena related to the dynamics of floods. These include, giving the public an understanding of their ability to regulate floods and improve water quality of riparian wetlands, or seasonal river water regimes and sediment accretion to habitats. along the development of riverside, observing the richness of amphibian ecosystem over time is a way to raise public awareness about floods. The design of flood storage spaces in urban areas, especially open spaces, also helps people better understand the dynamics of floods, thereby better understanding natural floods.

To promote flood resilience and minimize the damaging effects of floods in urban areas, the paper proposes a flood adaptive urban amphibian model based on an urban hydrological model, combined with capacity. of ecological infrastructure. This model includes allowing floods to enter the city and restoring the interaction between floods and riparian ecosystems. At the same time, prevent flood damage by adjusting the system in a timely manner and turning to urban flood adaptation mechanisms (including community awareness and self-response). This approach is called flood adaptive ecological awareness. To implement this idea, the article translates into urban landscape planning principles in Can Tho city, including: Urban landscape planning should consider flooding as a resource for urban ecosystems; Establish flood storage space based on ecological infrastructure adapted to flood dynamics; The urban structure always takes risk situations and is ready to switch to flood adaptation mechanisms; Disseminate flood dynamics and raise awareness of living with floods to the public.

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