Flood Risk and Adaptation in Floodplain Cities - Toward Flood-Resilient Urban Design in the Mekong Delta

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Abstract. Studies in Mekong Delta (MKD) proves that experiments and observations in water management over generations lead the indigenous people to the understanding of complex physical - ecological principles of the environment and thereby to sustain local resources. By studying the complexity of MKD landscape system on both natural and urban aspects, the paper shows (1) the logic of complex equilibrium principle in territorial organization and (2) that the combination of indigenous wisdom "living with flood" helps to maintain local landscape system in the context of serious flooding threats in the lower Mekong region. It is argued that functions of indigenous landscape and wisdom of "living with flood" should be respected and applied to urban design to enhance flood adaptation over time.

1. Introduction
Flood is a leading challenge for riparian cities around the world. Despite many flood control infrastructures (FCI), no cities have been successful in flood control [5]. In the context of increasing urbanization and unpredictable flooding from climate change, by relying on only flood control models to minimize flood risk, cities are rather more vulnerable [14]. Therefore, developing a method of flood adaptation is essential for riparian cities.

This study uses "flood resilience theory" as an alternative framework to flood control for riparian cities in Mekong Delta (MKD) of Vietnam. This framework is based on researchs of urban ecology to analyze the correlation between four factors namely riparian urbanization, water networks, indigenous landscape, and local wisdom. The study concludes there are complex dynamics in equilibrium and adaptability of the eco-social system of MKD. A scenario of flood adaptation management for the three largest riparian cities of MKD (Can Tho, Cao Lanh, and Long Xuyen) is built to discuss about the impacts of flood adaptation and restoration of riverine ecosystems.
2. Results and discussion

2.1. Research questions

**General research question:** The concept of flood resilience (FR) has been recently proposed and widely discussed, its applications in practice are limited. Some general research questions need to be clarified such as: How can FR theory be an approach that is suitable for socio-ecological conditions of MKD? How to properly apply this theory to urban practice to bring real and long-term benefits to MKD?

**Research questions on local wisdom in MKD:** The initial field study on the wisdom "living with flood" in flooded areas in 3 research sites proved that floods are rather harmless and may bring some benefits. The questions are: How is local wisdom expressed in flood resilience in MKD? What lessons can be learned for urban design?

**Research questions on research sites:** What would be a more sustainable and less vulnerable model of urban development in MKD? How can urban design integrate with indigenous landscape and local wisdom in order to create a liveable and flood resilient city?

2.2. Literature review:

The idea of resilience has its long history in ecology and engineering but its applications in disaster management are relatively new [2]. The concept of resilience (recovery) has two interpretations: engineering resilience and ecological resilience [9]. These two interpretations lead to two different approaches applied to flood risk management [15].

**Engineering resilience** refers to disturbance threatening functional stability engineering systems: if a disturbance occurs, the system can quickly recover its normal functionality [20]. The faster the adequate functionality is restored, the greater resilience is [8]. In flood control, engineering resilience includes resistance (preventing floods by flood control infrastructures) and recovery from the disturbances [20]. Recovery is concerned with the ability to bounce back to the pre-disaster condition which is considered as an optimal state. However, an optimal state does not exist in human-natural systems [2]. Basically, engineering resilience is concerned with preventing floods initially by flood control infrastructure, such as channelization, dikes, dams, pump stations, diversion canals [14, 15]. In reality, despite many flood control infrastructures, cities in the world are still vulnerable to floods [1]. Flood disaster occurs when flood control infrastructures fail to prevent extremely large flows, and sometimes they even fail with small flows.

**Ecological resilience** is the ability of the system to absorb disturbances and still persist [10]. It is concerned with the ability to tolerate system’s changes and the ability to renew or reorganize the system [3]. Ecological resilience emphasizes on system’s flexibility; if a disturbance occurs, the system will transfer to a new regime and can persist in any regime [10]. Two key arguments of ecological resilience theory applied to flood risk control include: (1) Resilience is built from adaptation to variability, uncertainty, and surprise of the nature [6]; (2) Resilience arises from experiencing and learning from changes and disturbances [10]. Flood is an agent for resilience since after experiencing each flood, cities can adjust their structures, processes and build knowledge, thereby cities can develop diverse coping strategies by the knowledge cumulated over time [7, 12]. Thus, the theory of urban resilience to flood focuses on the ability to adapt to disturbances rather than retaining the system’s stability [16]. Since flood is a part of urban dynamics, resilience is neither the resistance to floods nor the ability to bounce back to pre-flood state, resilience is the tendency to continuously survive in the context of complex hydrological conditions [12].

**Urban resilience** to flood is the ability of a city to tolerate flooding and reorganize if physical damage and economic interruption occur, thereby deaths and injuries are minimized [13, 15]. Flood resilience emphasizes the ability to tolerate flooding or floodability that refers to as unbreakability and to maintain the functionality when experiencing floods. Thus, reorganization in the new regime after flooding is more important than restoring the preflood conditions, this requires that the built environment must adapt to flood [16]. Urban resilience to flood consists of three main properties: Localized flood resilience (local resilience); Timely adjustment after each flood; and Redundancy in...
alternative systems (subsystems) [13]. For riparian cities, developing flood resilience basically is a process of adaptation rather than resistance [14]. Cities need to make acquainted with cyclical floods, enable the floods to enter the cities in order to learn and adapt to the disturbances over time [15]. As flood control prevents this learning opportunity, it is hard for the cities to adapt to flood [11]. The practice has proved that FCI has contributed to the lack of knowledge about flooding and the wrong feeling of security, that increase flood risk in the long-term [4].

**The wisdom “living with flood” in MKD.** Urban resilience to flood is similar to the wisdom “living with flood” maintained by rural communities in the floodplain of MKD [15, 18]. “Living with flood” refers to a living style of acceptance and tolerance to flood by enhancing the adaptation of people and assets [19]. By distinguishing beneficiary cyclical floods and flood disaster, local people adapt their lives and surrounding environment to flood dynamics and explore benefits from floods in agriculture [15]. “Living with flood” is expressed in adaptive activities rather flood control activities by using the knowledge about flood ecology and ecological services of flood. This is an expression of ecological wisdom – a wise decision and a wise way for the human to interact with nature based on knowledge about nature.

Currently, restoring the functionality of floodplain in rural and urban areas to prevent floods in downstream has attracted so much attention, such as project "Room for river" in the Netherlands, policy "Space for water" in the United Kingdom. Specifically, the project in Kampen, Netherlands is a typical example of integrating urban expansion and infrastructure to ecological programs. The policy “Room for river” may be effective by utilizing hydrological dynamics to reestablish the regime of “living with flood”. For MKD, the change toward flood-resilient urban design is essential; the foundation for the change is socio-ecological dynamics rather than stability of environment [17]. Giving up the stability and permanence, riparian cities need to build adaptive, flexible and variable structures which are the most practical method to live on flood plains.

2.3. Research approach:
This paper analyzes two aspects of flood resilience of the socio-ecological system in MKD. Firstly, the complex relationship between changes of hydrological landscape and urban expansion is analyzed by using the "triple layer approach", this layered model presenting the complex interactions and adaptations of urban pattern, landscape system and hydrological dynamics by time and space. Secondly, field study about the wisdom “living with flood” in lowland rural floodplains of MKD to understand how local knowledge contributes to the stability of the landscape system in this area (see Figure 1). To apply “triple layer approach”, digital data, maps, hydrological data of the area are collected and studied. In particular, the data on terrain elevation maps, flood maps, water networks, urbanization map, etc. are classified to understand the territory organization of MKD. This clarifies how hydrology and landscape of MKD have been formed and transformed to adapt to the complex hydrological conditions of the region.

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Research framework of the thesis
Field studies are used to analyze the role of local knowledge in building a flood resilient environment. Surveyed sites are the villages affected by cyclical floods in three cities (Can Tho, Long Xuyen, and Cao Lanh). Semi-structured interviews with about 30 households in each village were conducted in June, August and December 2019 which were before, during and after the flood season respectively. Each interview lasted 1.5 - 2 hours related to the knowledge on flood resilience. In addition, case studies and comparative analysis are used to analyze and summarize the adaptive methods of the cities in the world with similar characteristics. This enhances persuasiveness and scientificity for the study.

2.4. Initial Findings

The initial objective of this study is to explore the complex interaction between the hydrological landscape - urbanization and the value system connecting different factors (local wisdom, hydraulic civilization). Initial studies draw the following key issues:

**MKD is a good example of the concept "hydraulic civilization"** - a form of urban/rural society based on hydraulic engineering and water control. Over the past 300 years, MKD has become a water-based society where residents develops various adaptation strategies to create a tamed social-ecological system like today. "Hydraulic civilization" is proof for the persistent efforts of the delta residents to transform and shape the environment (see Figure 2). Research on "hydraulic civilization" shows that sustainable development relies not only on engineering solutions to tame and control the delta environment, but also on a new approach of using natural processes to ensure safety and sustainability for the eco-social system.

**The logic of complex equilibrium in the territorial organization.** In MKD, a difference in elevation even small (only some centimeters) can significantly affect territorial organization. This difference is closely related to the level of flooding and dry area, is a key factor to determine land use purposes (production - living, flooding - safety). In the micro perspective, the terrain complies with the equilibrium of "excavating and filling". Excavated soil from ponds or irrigation ditches can be used for road embankment or building dike. The landscape system here has existed for centuries in a complex equilibrium, the interdependent structures of water and soil are organized by reasonable hydrological systems to manage water and stabilize the soil. As a small difference in elevation may create completely different conditions, retaining the original nature of terrain becomes a very powerful design tool.

**Wisdom “living with flood” in MKD.** Contrary to the tradition of building flood control works in Red River Delta in the North, the attitude towards flooding in MKD in the South is acceptance rather
than resistance. This approach is reflected in the local term "living with flood" which expresses the willingness of indigenous peoples toward flood risks. The wisdom "living with floods" is important for modern cities in MKD, flood management needs to understand natural dynamics as it is the basic foundation to regulate the relationship between people and hydrological dynamics.

2.5. Actual Works
The study selects 3 cities in MKD as research objects to evaluate localized flood resilience and their challenges in the context of urban development in MKD (see Figure 3). Field studies are conducted in each city to explore how local knowledge can create the sustainability of the landscape system. Three selected cities have typical landscape characteristics of MKD region, such as a large water network intertwined with the rich agricultural landscape; affected by cyclical floods including upstream flood, seasonal flood, and storm surges; and shifting from the water-based society to the community associated with roads and urban infrastructure. The research focuses on the following issues: (1) analyze and evaluate the impact of urbanization on the hydrological landscape; (2) analyze the complex equilibrium of territorial organization; (3) evaluate the ecological value of agricultural landscapes.

A field study was conducted in flood-affected villages at three studied cities. The flood season starts at the end of July, lasts 3-4 months and drains in November. Settlements of all villages are located in the middle of the field, spread on natural strips of land along the rivers and canals. The interviews focused on the questions related to seasonal flood regime, organization of agricultural landscapes - houses - traffic during the flood season, experiences and awareness of floods.

Figure 3. Location of studied cities in landscape system of MKD

3. Conclusion
This study argues that flood resilience - the ability to cope with sudden and uncertain risks of natural disaster is the best strategy to survive in a changing world. The theory of adaptation - resilience needs to be supported to become a nucleus in urban flood risk management. Researches on flood management in riparian cities of MKD initially show the potential to transform to flood-resilient model. Learning about the landscape system and indigenous knowledge in MKD will promote the awareness that flood is not only a threat but also a social-ecological asset. We may however note that immediate challenge can be on how to promote the transition from flood control model to flood-resilient model in the cities today. Finally, the results of this study may contribute to the argument about the relevance of resilience theory to the development of flood-resilience for riparian cities in the world.
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