



Photo by Jiming Huang

LEARN FROM THE PAST, ADAPT TO THE FUTURE

An adaptive framework for ecosystem in rural-urban transition in the Pearl River Delta, the case of Jinsha

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Graduation project

MSc 3 Urbanism

Faculty of Architecture and Built Environment, TU Delft

Learn from the Past, Adapt to the Future

An adaptive framework for ecosystem in rural-urban transition in the Pearl River Delta, the case of Jinsha

MSc Thesis

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MSc Architecture, Urbanism and Building Science

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1. Introduction

1.1. Motivation

As one of the most densely urbanized regions in the world and one of the economic engines of China, the Pearl River Delta has gone through a thirty-year period of rapid urbanization since 1978. In 2006, the urbanization rate of Pearl River Delta has reached 79.6% which was 16.26% in 1978 (Xu & Li, 2008). The dramatic spatial transformation took place in the Pearl River Delta has drawn much attention from all over the world. Behind the phenomenon of urbanization, rural industrialization has played an important role. Unlike the common process of industrialization in the world which is a result of urban industrialization expansion and population flows from rural area to cities, rural industrialization in the Pearl River Delta since 1980s is driven by the local development of labor force, land and natural resources which were administratively fixed in agricultural production. As the restricted farmer-land relationship was loosened, the emerging economic opportunities initiated the rise of rural industrialization across the area.

However this spontaneous and self-organized pattern of rural industrialization could be problematic, though it did contributed to absorbing the large amount of surplus rural labor forces and the rapid transformation of rural economic structure. A great deal of agricultural land including farmland and ponds, the main components of the traditional “dyke-pond system” was transformed into non-agricultural land use. In this process the former permeable surface was displaced with impermeable surface which result in faster convergence of run-off and reduction of infiltration (Zhu, 2010). Thus as the functionality of the traditional dyke-pond system was gradually undermined, the delta is more vulnerable to high peak discharge of rivers and flooding. Moreover the scattering distribution of rural industries geographically dispersed pollution while utilizing resources at a low efficiency. Backward technologies and irrational exploitation of resources lead to severe waste in development and ecological damage (Zhu et al., 2003).



Dacheng Wheat Flour Factory, the first factory established by foreign investment
In 1980s, Shekou, Shenzhen

Source: <http://chuansong.me/>

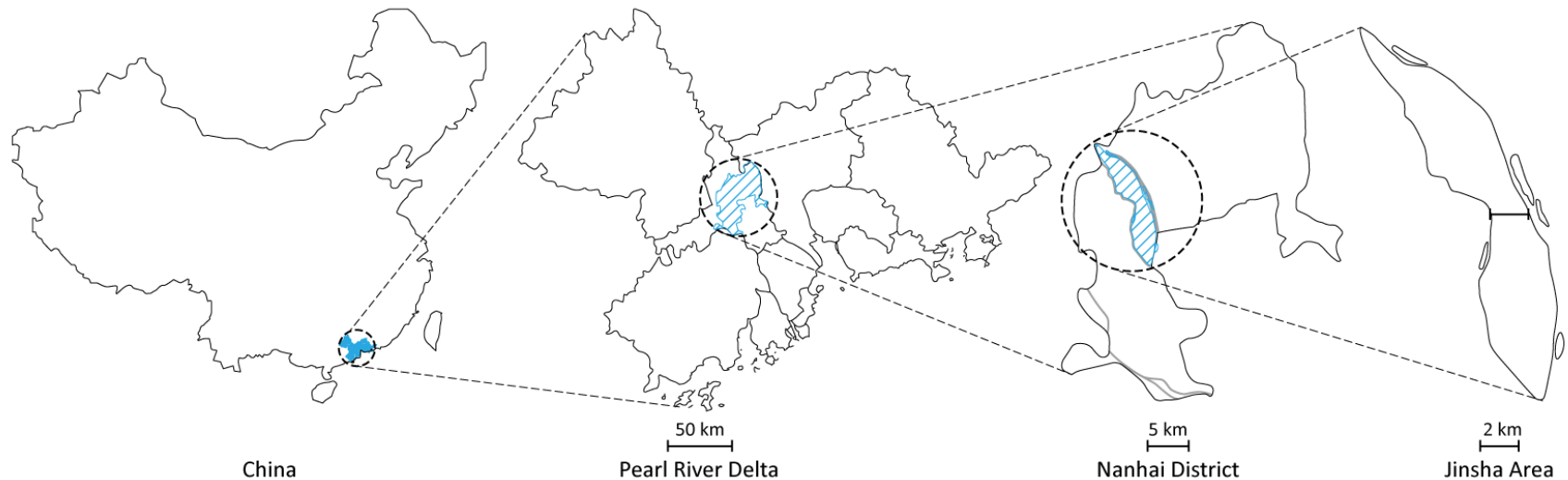
The mode of rural industrialization in the Pearl River Delta was widely criticized for the problems it caused though it was initiated with the hope of integration of urban and rural society and obtained outstanding achievement. A new mechanism of urbanization and modernization is in urgent need. As an urbanism student and bred in the Pearl River Delta, I am eager to contribute to a more delightful future of the region.

1.2. Project aim

The influential factors and mechanism of rural industrialization in the Pearl River Delta is complicated. It is an interwoven result of economic, political, cultural and environmental forces. The transformation from rural landscape to urban landscape, the transition from segregated urban-rural relationship to integrated and intersected relationship is irreversible and will be continue in the near future. As the gradual deconstruction of urban-rural dual system is occurring at present, the former rural area as a vibrant landscape and potential pleasant living environment deserves more attention.

This thesis intends to contribute to the transition towards new approaches to urban planning and urban design in the Pearl River Delta. It focuses especially on systematically understanding the interaction between different actors and sub-systems in the Pearl River Delta as a whole. By presenting and discussing the transition of the Pearl River Delta in different layers, the thesis attempts to tackle new possibilities and opportunities for future development under the context of endogenous forces restructuring and changing exogenous factors. The task of design is to explore pathways to sustainable development and address new opportunities for land use and spatial composition.

1.3. Study scope



Study scope of this thesis By author

2. Context

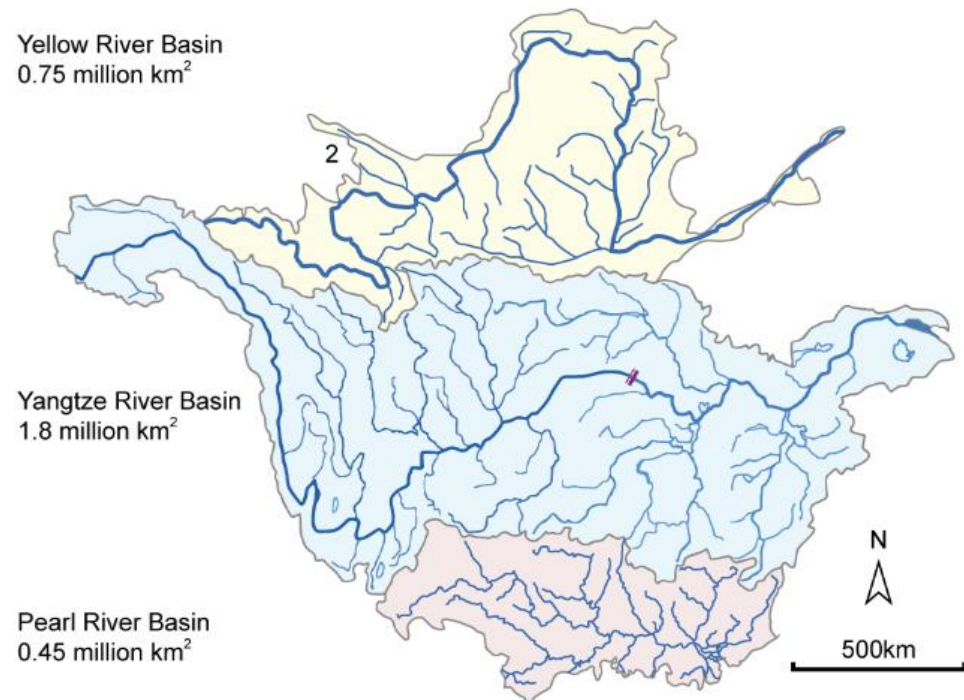
2.1. The Pearl River Delta

2.1.1. Pearl River: the basin and the delta

The Pearl River is the largest river system in southern China. Measured from the farthest reaches in Yunnan Province, the Pearl River System is China's third longest river, 2400 kilometers, after the Yangtze River and the Yellow River. The Pearl River Basin covers 453,700 square kilometers, the majority of South Central and parts of Southwest in China, as well as Northeast of Vietnam. It comprises the watersheds of the Xi River (West River), the Bei River (North River), the Dong River (East River) and other tributaries flow through the Pearl River Delta (PRWRC, 2011). These rivers converge in the Pearl River Delta and drains in South China Sea through eight major channels. Total discharge of this river system is approximately 302 billion m³/year or an average of over 9500m³/sec. Due to its subtropical climate and location, discharge is highly seasonal with nearly 78% of the annual volume occurring between April and September. During the summer peak-flow months, around 95% of the annual suspended load of 72.5 million tons is discharged through the delta, contributing to the deltaic plain.

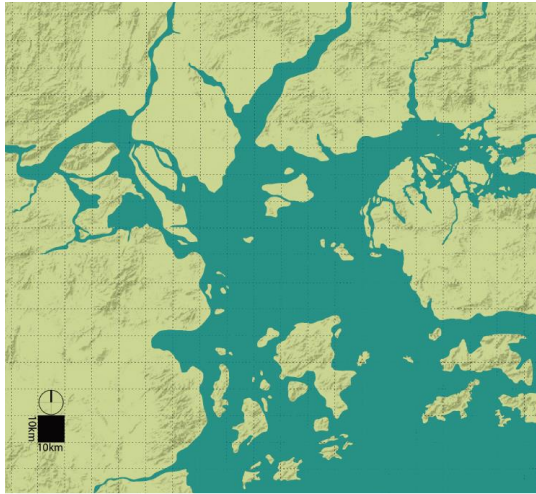
(Disc.sci.gsfc.nasa.gov.)

With an area of 41,600 km² (Zhou, 2003), the Pearl River Delta is a low lying delta, comprising a complicated network of tidal creeks and major distributary channels with bell-shaped mouth typical of tide-dominated distributaries. Around 24% of the area lies below 1 m (1954 yellow sea datum) and 80% below 3 m. The average gradient of the delta is as small as 1/5000 (Zhu, 2010). Although sedimentary processes produce complicated delta morphology under low wave energy, moderate tide and river-dominated conditions, much of the present delta actually represents reclaimed land produced by a combination of manmade embankment and natural sedimentation forced by tidal flow (Disc.sci.gsfc.nasa.gov.).

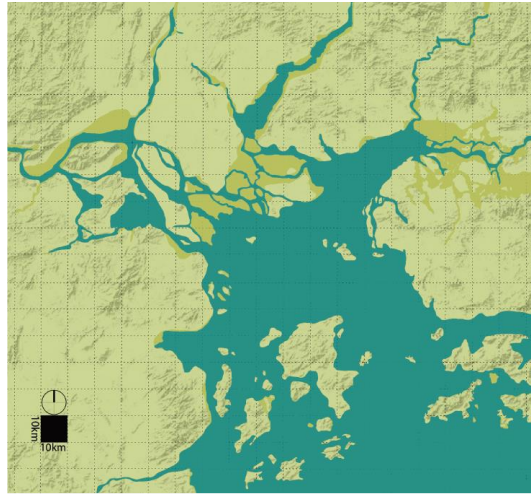


The three largest river basins in China

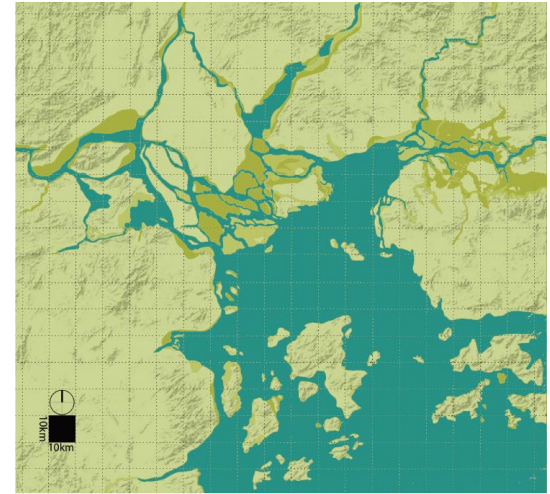
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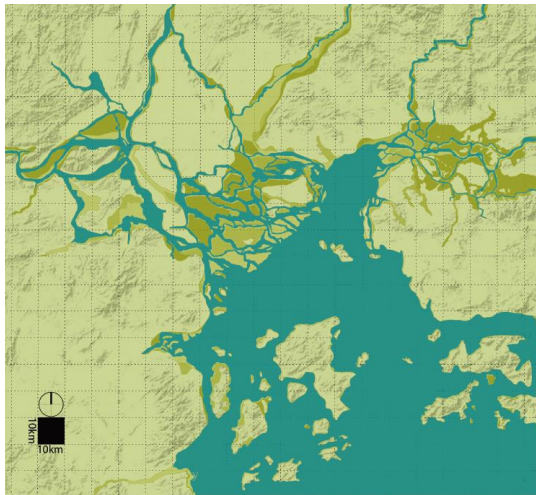
4000 BC



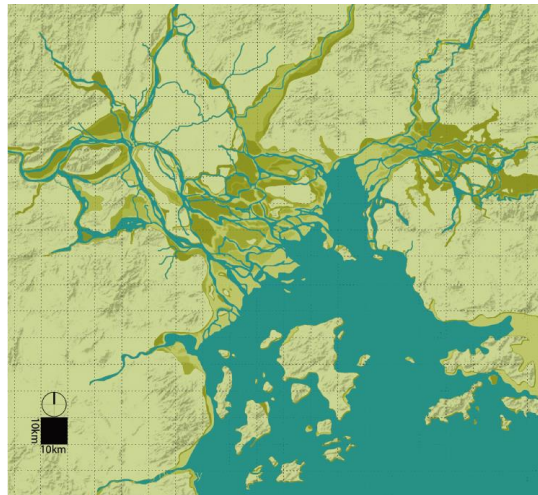
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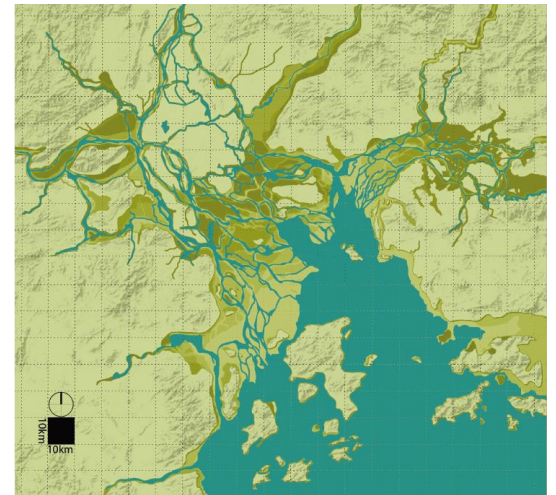
200 AD



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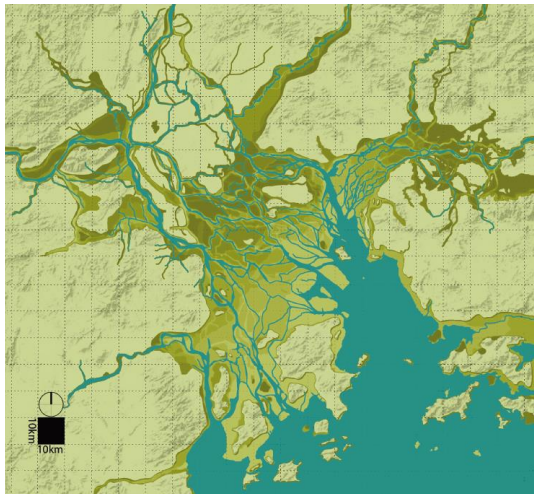


1300 AD



1600 AD

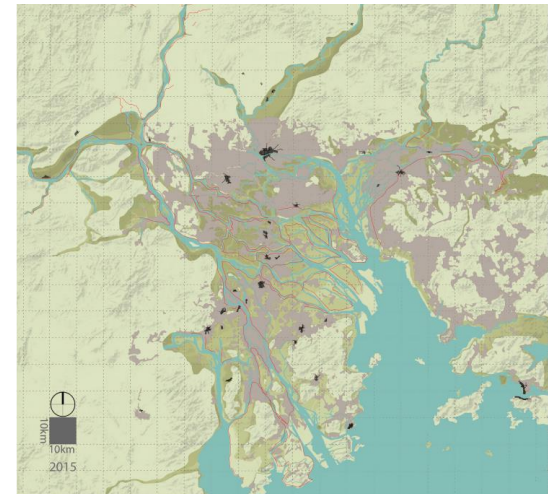
The forming of the Pearl River Delta *Source: maps by Liang Xiong*



1900 AD



1950 AD



2010 AD

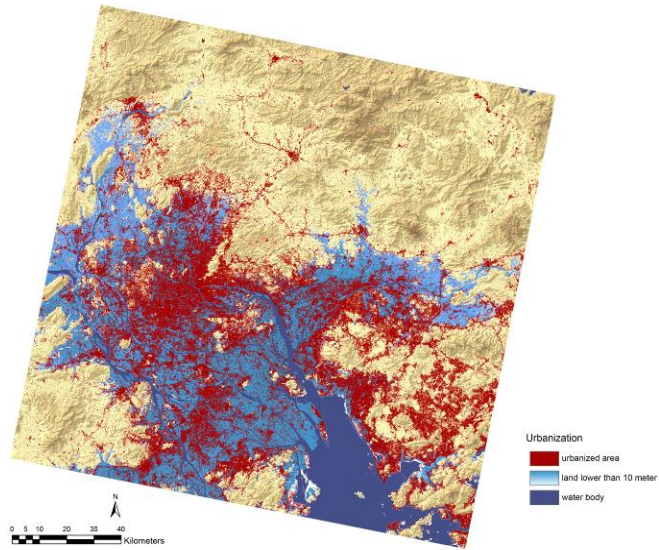
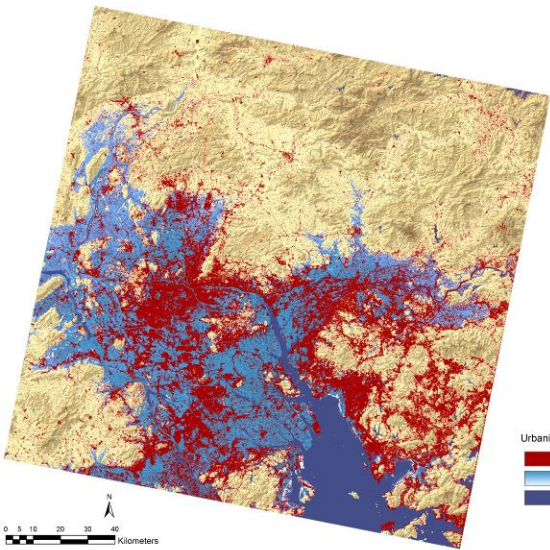
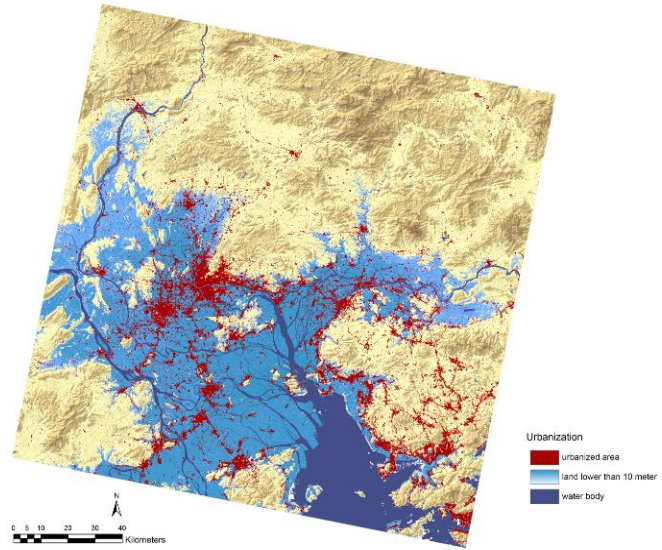
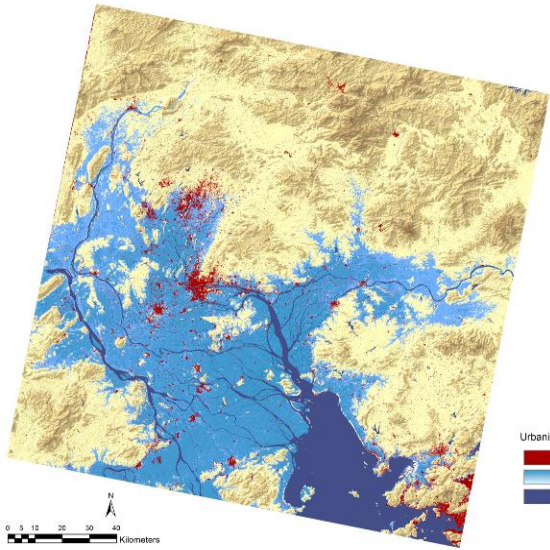
The forming of the Pearl River Delta *Source: maps by Liang Xiong*



Nine cities and two SAR in PRD *By author*

The commonly used term “Pearl River Delta” involves nine cities and two Special Administrative Regions. Situated in Guangdong Province, the nine cities are Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhongshan, Huizhou and Zhaoqing, The close connection between Guangdong and Hong Kong as well as Macau, of which Shenzhen and Zhuhai in particular, has formed an economic and financial center in southern China.

As the laboratory of the Chinese economic reform, the Pearl River Delta region has drawn attention from all over the world. In 2006, the region has taken up 10.3% of the size of the economy of the whole country, while occupying only 0.43% of the territory and 3.28% of the total registered population. In correspondence to its economic development, urbanization rate boosted from 16.26% in 1978 to 79.6% in 2006. Twenty four million migrants from all over the country flow into the Pearl River Delta. 346 organic towns agglomerated in the delta. The population density reached 1039/km². The Pearl River Delta has become one of the regions with highest agglomeration of economic and demographical factors. (Xu & Li., 2009)



Expansion of built-up area in the Pearl River Delta, 1987-2015

By author

2.1.2. The dyke-pond system: a traditional method of land-water ecosystem

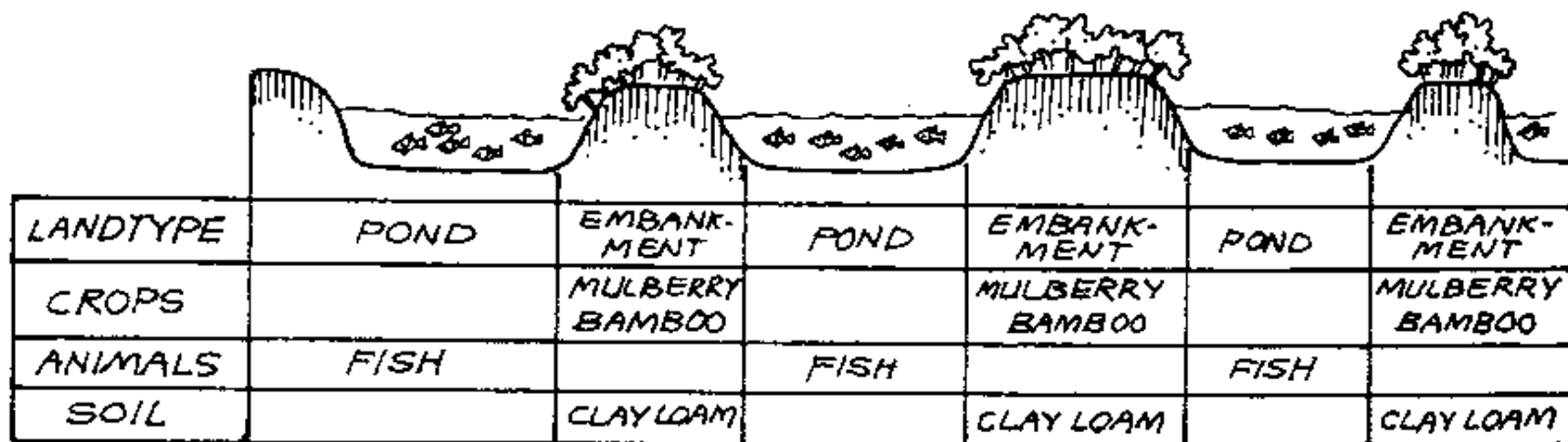
The dyke-pond system has constructed a unique landscape in low-lying, ecologically sensitive areas in the Pearl River Delta. Since an interrelated ecosystem that combined the co-production of mulberry growing and sericulture with fish farming, where the banks of fish ponds were turned into mulberry dykes, was first introduced at around 16th century, this practice in the Pearl River Delta has stimulated the productive potential of humans and their environment.

The mulberry (cane, fruit tree) dyke and fish pond complex is a traditional method of mulberry growing, sericulture and fish farming. It contains two interrelated systems of dyke and pond. The dyke is the land ecosystem for the growth of mulberry trees whereas the pond is the water ecosystem, consisting of fish and aquatic plants. This complex, as an artificially constructed ecosystem, serves two major functions: (a) achievement of a general ecosystem balance through the harmonization of well-coordinated activities and functions embedded in the ecosystem, and (b) transformation and regeneration of organic substances based on a multi-layer trophic ecosystem structure, which helps contribute successfully to sustainable economic development in the delta region. (Lee, 2004)

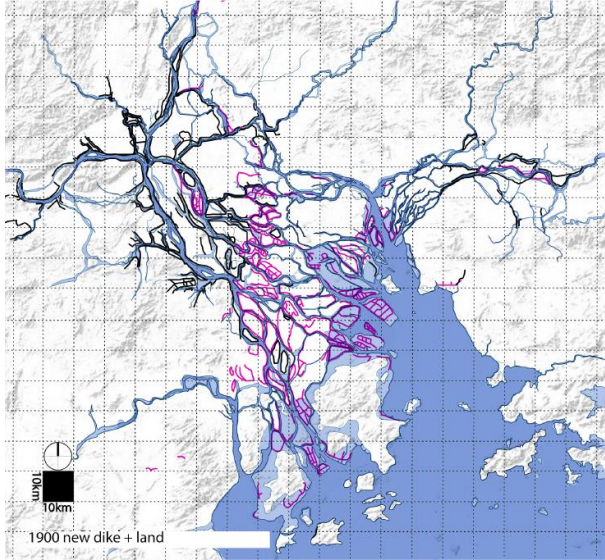


Regional distribution of Mulberry-dike-fish-pond in the Pearl River Delta in heyday

Source: Guo & Situ, 2010



Mulberry dyke fish pond integrated farming model Source: Capistrano-Doren et al., 1992



Dyke rings in the PRD, 1900 Source: *Liang Xiong*

Within the system, mulberry leaves are fed to the silkworms, whose excreta are used as fish food. The fertile pond mud, consisting of fish excreta, organic matter and chemical elements, is brought up from the bottom and used as manure for the mulberry trees. In addition, the mud acts as a weed killer, retards water evaporation and maintains soil fertility for a long period of time.

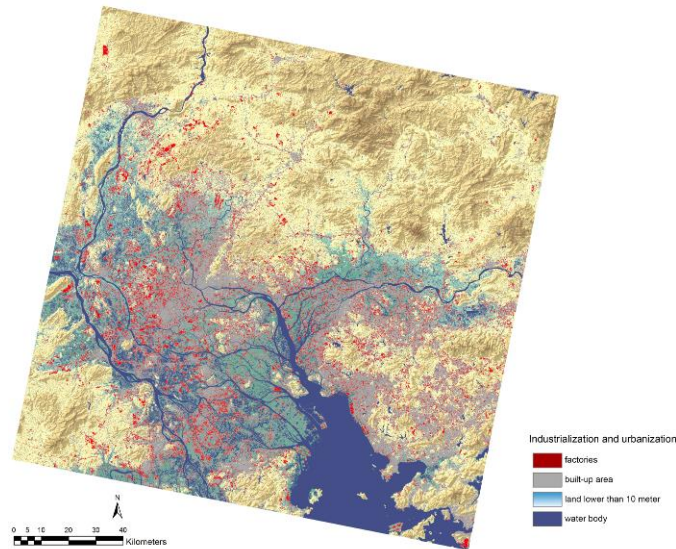
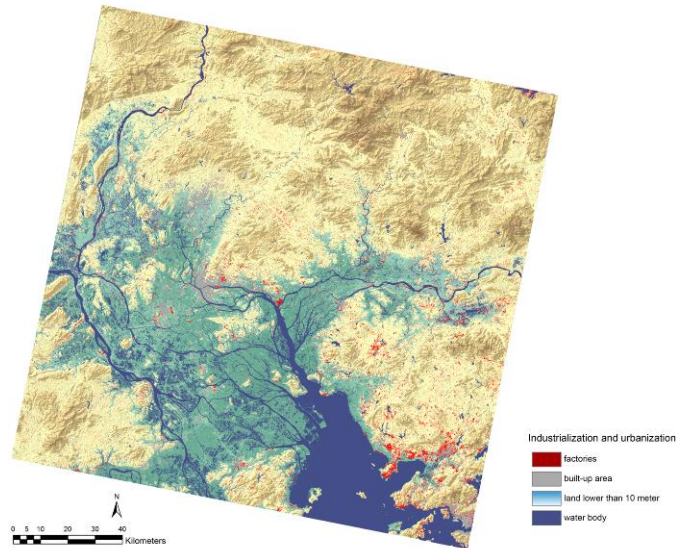
The dyke-pond system not only contributes to the economic benefits and ecological significance, but also represents a wisdom that people adapt their production practices to suit changing environmental ecological conditions. To construct the dyke-pond system, farmers dig ponds in low lands and use the mud to build high lands and dykes. The annual flood of Xi River and Bei River during the summer peak-flow months used to be the greatest threat to agricultural production in the central Pearl River Delta. To resist the floods, a larger scale of dyke system was built over the local dyke-pond system around villages' terrain. In addition to small fish ponds, creeks inside the dyke rings connects some lakes which could deposit water in rainy season. Thus, the dyke-pond system together with the dyke rings constructs a flood resistance system that "flatten" the high peak discharge of surrounding rivers and store excessive water.



Aerial photo of dyke-pond system in Shunde, Foshan

Photo by *Guo Jihua*

2.1.3. Rural industrialization in the delta



Rural industrialization is a worldwide phenomenon since 50s and 60s 20th century (Zhu et al., 2003). However not until the urban-rural dual structure in the Pearl River Delta was loosen when rural industrialization underwent the fastest development since 1980s. According to recent studies on rural industrialization during this period, a relatively comprehensive definition of rural industrialization is: in order to change the dual economic structure, to fully exert the efficiency of a large number of surplus rural labor resources, and to eliminate poverty of peasant and herdsman households as soon as possible, farmers have to rely on market, their own strength and small towns in rural areas to develop rural modern industry, so that labor forces engaged in secondary and tertiary industries may account for the vast majority of the total rural labor force, industrial output value may exceed agricultural output value, rural areas may basically realize urbanization, and material and cultural life in rural areas may basically catch up with that in city (Zheng, Zhou et al.,).

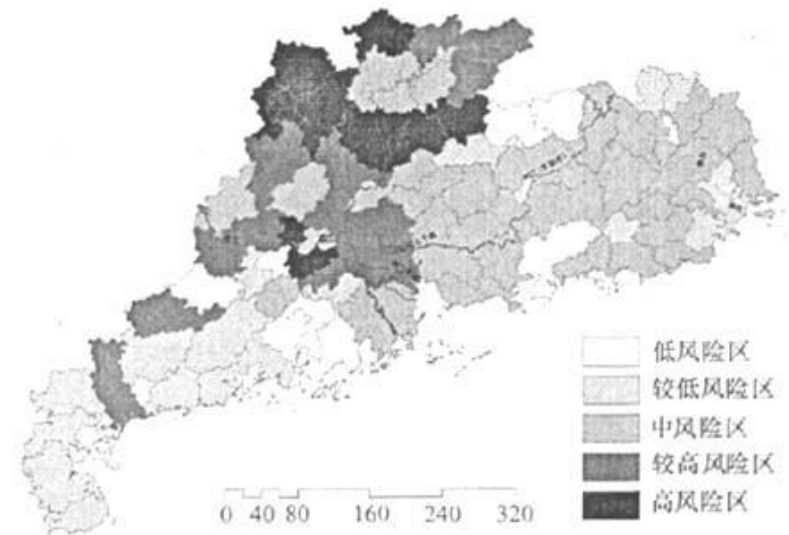
The rural industrialization in the Pearl River Delta follows a “bottom-up” pathway (Lin, 2015). The industrialized areas would be soon transformed into rather semi-urbanized area than urban area for its distinguishing characteristics. The most significant feature of these areas is the collective land ownership. In China’s context, knowing the ownership status is the direct way to judge whether a land belongs to rural or urban system. Since at the very beginning of self-organized rural industrialization, what could be built and where to be built was not under control of urban planning system and mostly driven by economic profit and personal or collective will, the land use pattern was highly mingled with all kinds of functions. Industries organized by different units of different level, such as county, town, village and clan, co-exist in vast scope of semi-urban and rural areas. This complicated organization result in the fragmentation of industrial land use. Thus low efficiency of land use and low quality of living environment is a common problem.

Industrial expansion in the Pearl River Delta, 1987-2015

2.1.4. Impact and challenges

The impact of human intervention on the regional ecosystem is dynamic. As time went by, the atrophy of dyke-pond system and the on-going rural industrialization altered the landform of the Pearl River Delta. Farmland, meadow, pond and forest were transformed into construction land in which procedure pervious surface and/or water storage were replaced by impervious surfaces. While developing industries and human settlement, ground grading is a usual measure to gain flat land. However, the large scale of ground grading caused severe loss of soil and water body and lower confluence of surface run-off. Due to limited technology and ignorance, the newly industrialized areas lacked a robust sewage system where domestic sewage and industrial waste were often drained directly into natural water body. Concluding all the factors brought by industrialization and the process of urbanization, the affected infiltration and surface run-off increased the vulnerability to flooding and inundation in the Pearl River Delta.

In addition, climate change may also be influential on the Pearl River Delta. Considering sea level rise and the subsidence of delta, it is estimated that the relative sea level rise is 40 – 50 cm (Wu, 1995). The rising temperature and the drastic change of frequency of precipitation has been proved in the past 50 years. Significant change of temporal and spatial distribution of precipitation is predicted. Extreme weather and disruptive events such draught and flood are seen frequently. Around the coast, the inundation area in low land will increase and the near sea ecosystem will degrade. As for the cities and urbanized area, water supply and power supply are facing more stress in the future due to the unstable natural environment. Human habitat will confront the challenges of flooding, draught, disease and deterioration of environment at the same time.(Guangdong Climate Change Assessment Research Group, 2007)



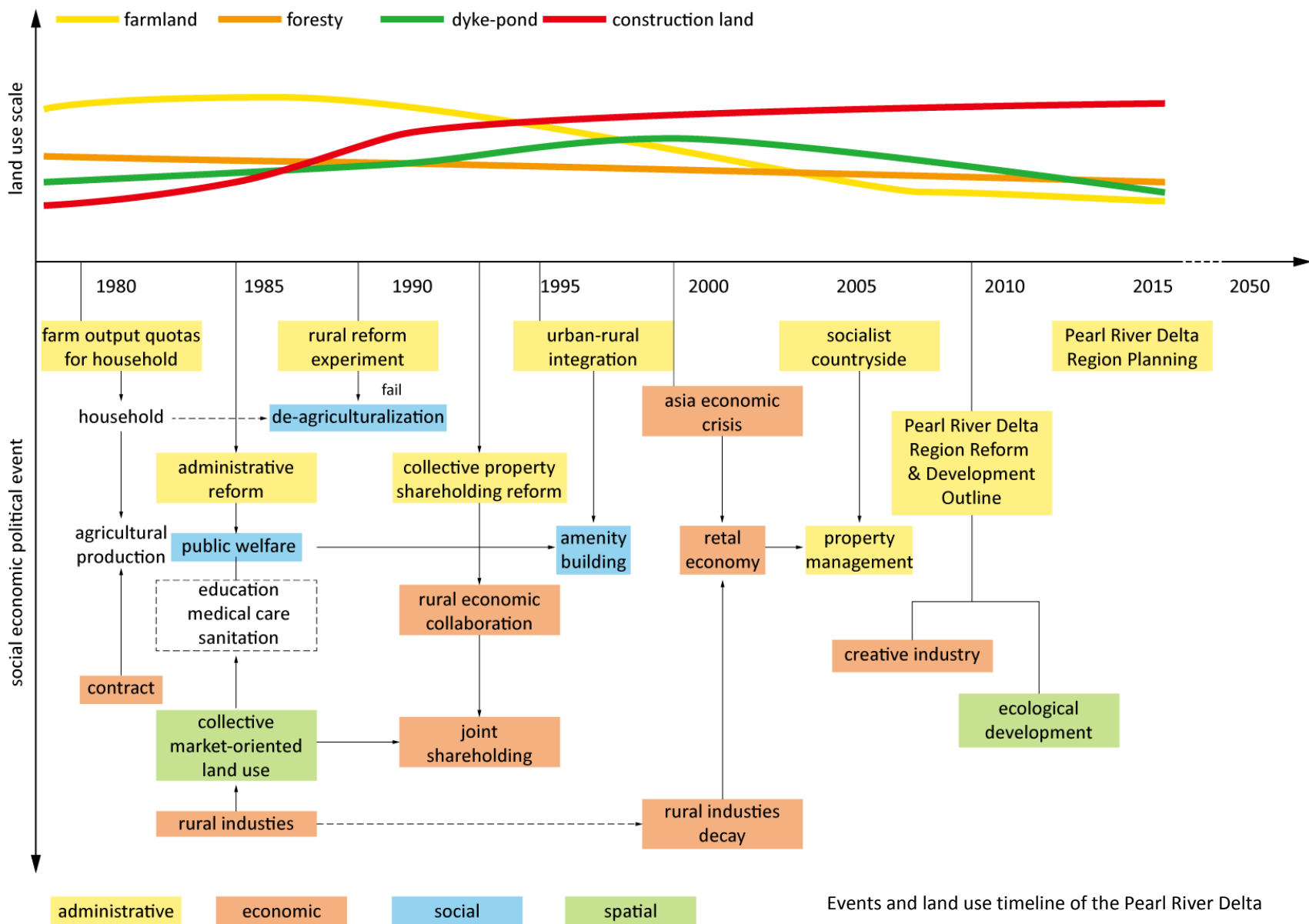
Integrated risk zoning map of flood/waterlogging disaster

Source: Gong et al. 2009



Inundation in semi-urbanized village, Nanhai District

Source: n.cztv.com, 2015



Events and land use timeline of the Pearl River Delta
By author

2.2. Nanhai District

The first human settlement arose around 6000 years ago in Nanhai area (now Xiqiao Town, Nanhai District). The administrative boundary used to cover a large area including today's central area of Guangzhou city since 14th century. In 2002, Nanhai was empowered to be one of the five districts of Foshan city. Nanhai District governs one sub-district and 6 towns. Covering seven township within 1072 km² land (Planning Bureau of Nanhai District, 2010), Nanhai District recorded a population of 2.58 million in 2010 (Census, Statistics Bureau of Nanhai District).

Nanhai is typical representation of the Pearl River Delta. Since 15th century, the abundant labor force enable the dyke-pond agricultural production to thrive in Nanhai. This area is considered the traditional place of silk production. The mulberry (cane) dyke fish pond model continuously exist as a major agricultural model in Nanhai.

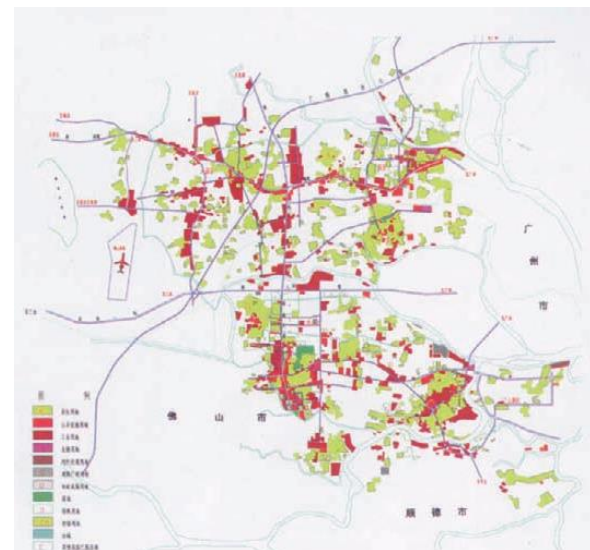
Since 1980s, Nanhai found its new characteristic in the region. The rural industrialization started. Villagers built up their factories on the collectively owned land. Although the villagers did not leave their home, the transition from agricultural sector to industrial sector has in fact occurred. Nanhai was identified as one of the strongest towns of industry. However, this bottom-up development mode did not directly lead to urbanization. The distributive industrial land use did not form a compact agglomeration. To lower the cost of infrastructure and basic investment, industrial land usually located along the existing road. As the rural settlements scattered in a large scale of rural area, factories that set up behind their yards often sited near farm land, ponds and natural water body. A unique landscape of semi-urbanization emerged in the periphery towns and villages.

Driven by economic profit, the process of rural industrialization has caused loss of soil and water while transforming agricultural or natural land to flatten construction land. The damage dealt on the original ecosystem such as pollution, loss of vegetation led to environmental deterioration as well. The quality of human well-being was lower down.



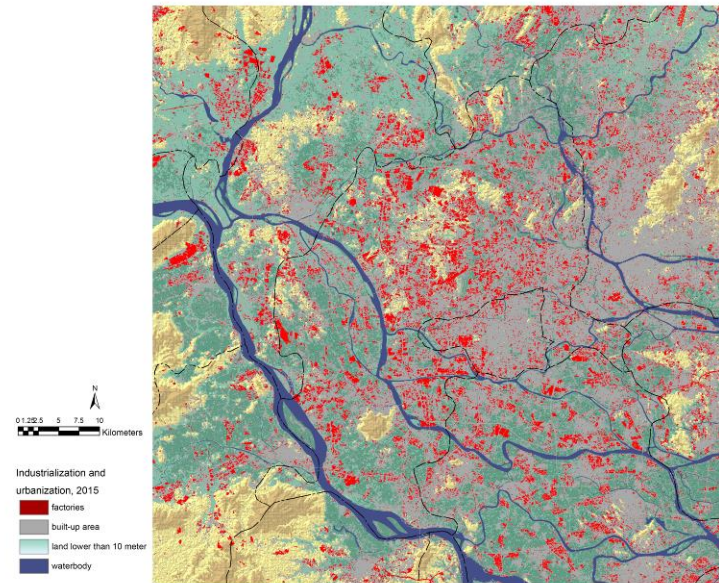
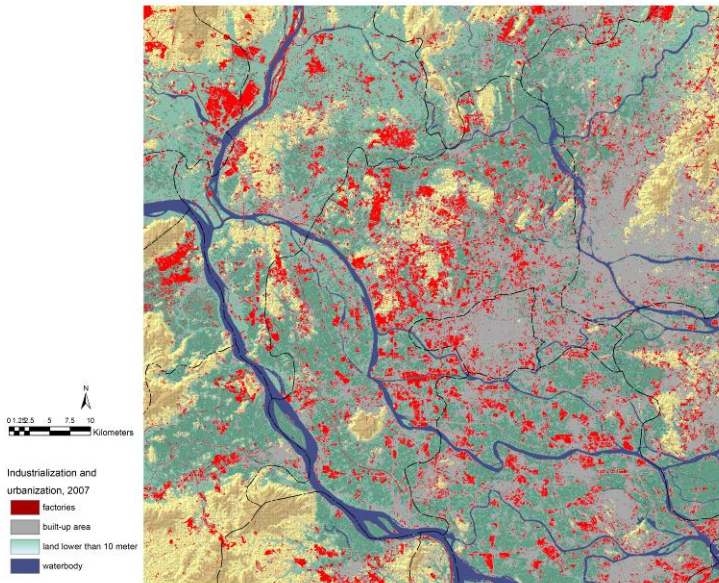
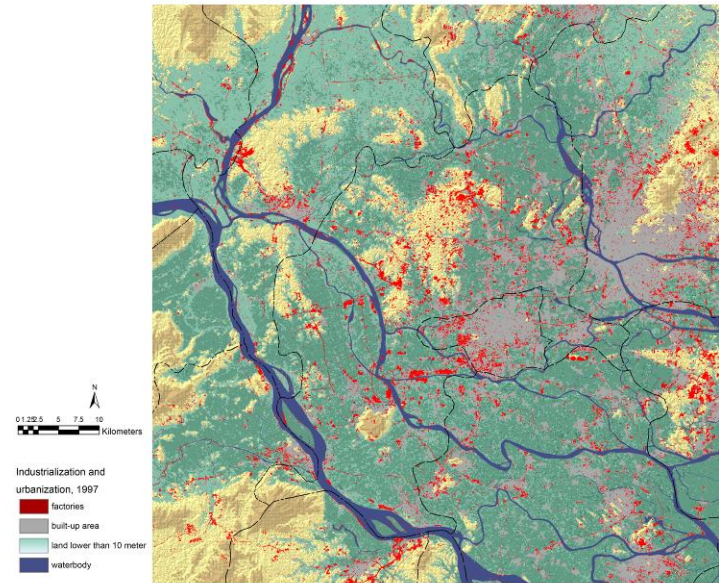
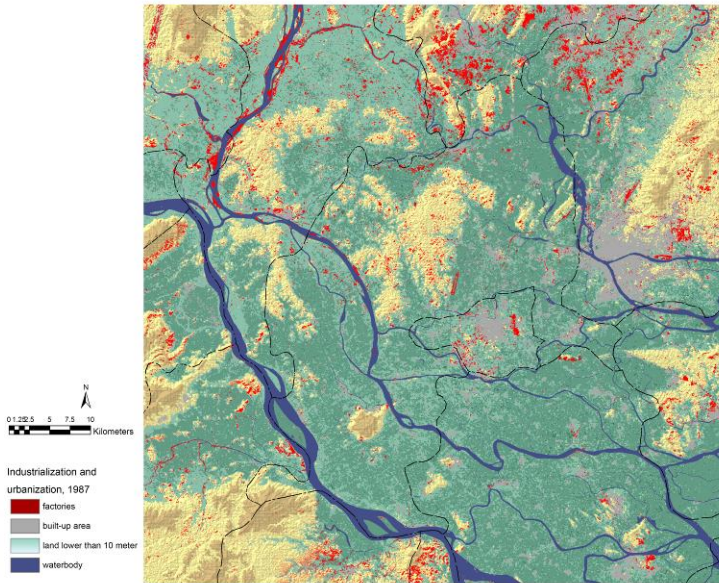
Location of Nanhai District in Foshan city

By author



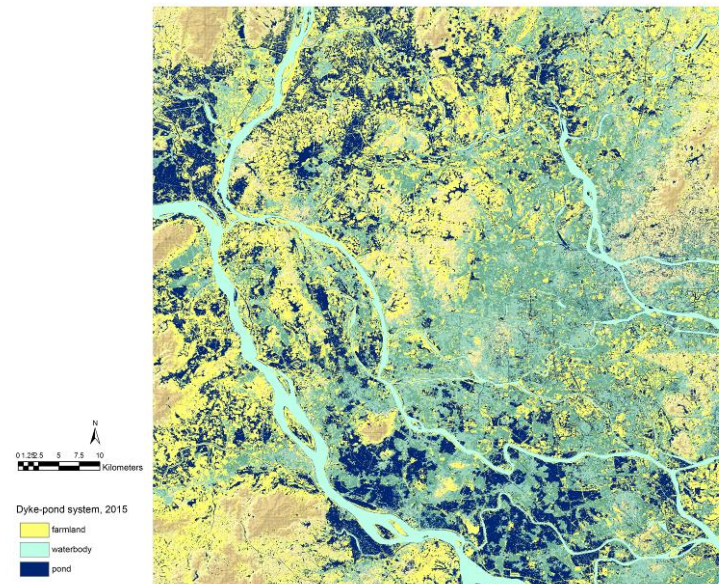
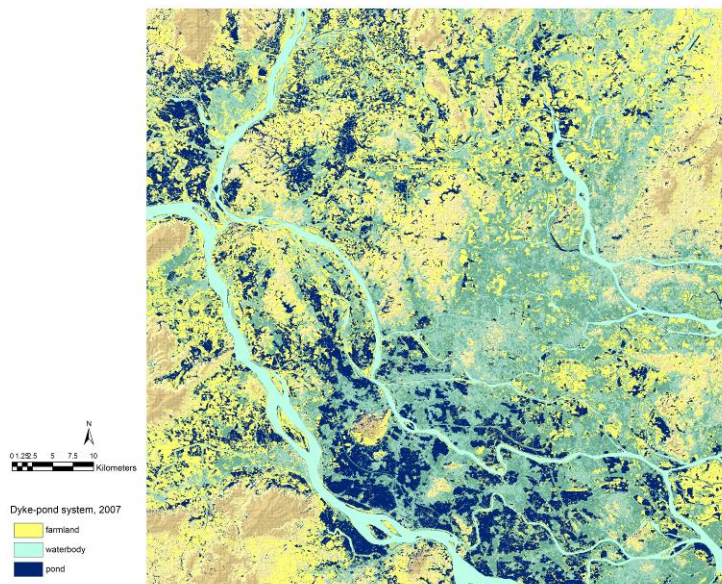
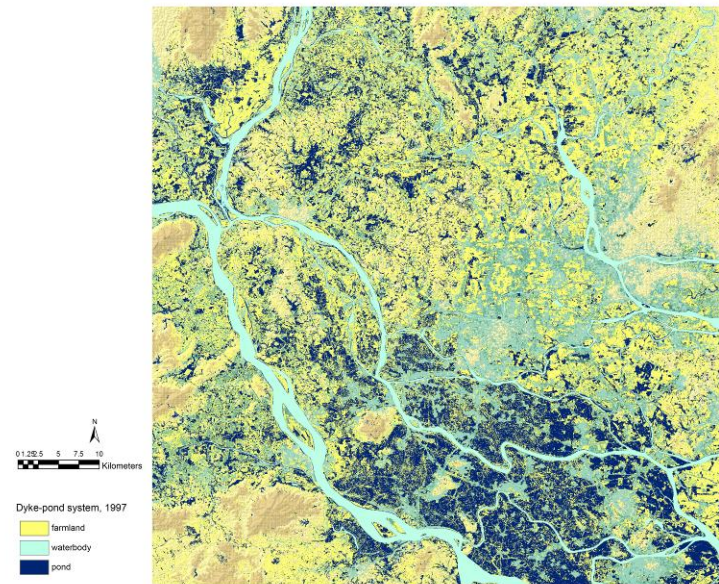
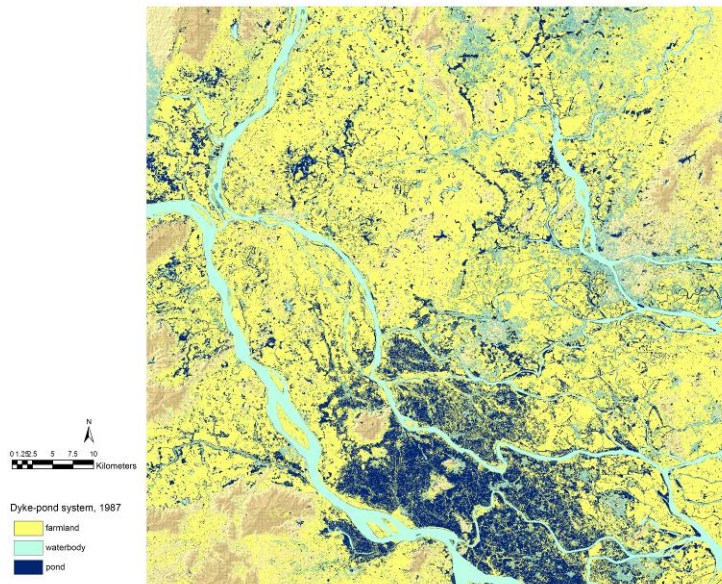
Land use of Nanhai, 1995

Source: Yuan et al., 2008



Factories and built-up area expansion over time, 1987 - 2015

By author



Dyke-pond system distribution over time, 1987 -2015

By author

2.3. Jinsha Area

Situated next to the Bei River, Jinsha area occupied a special location in Nanhai District. Protected by a ring of dyke, Jinsha area possesses abundant farmland and fish ponds. As a traditional agricultural zone, rural industrialization has influenced the land use pattern of the area. Scattered factories mingled with real estate development. Farmlands and ponds intersected with new constructions.

Jinsha area covers an area of 59.6 km². There are 38 thousand local residents and 30 thousand working migrants in the area.



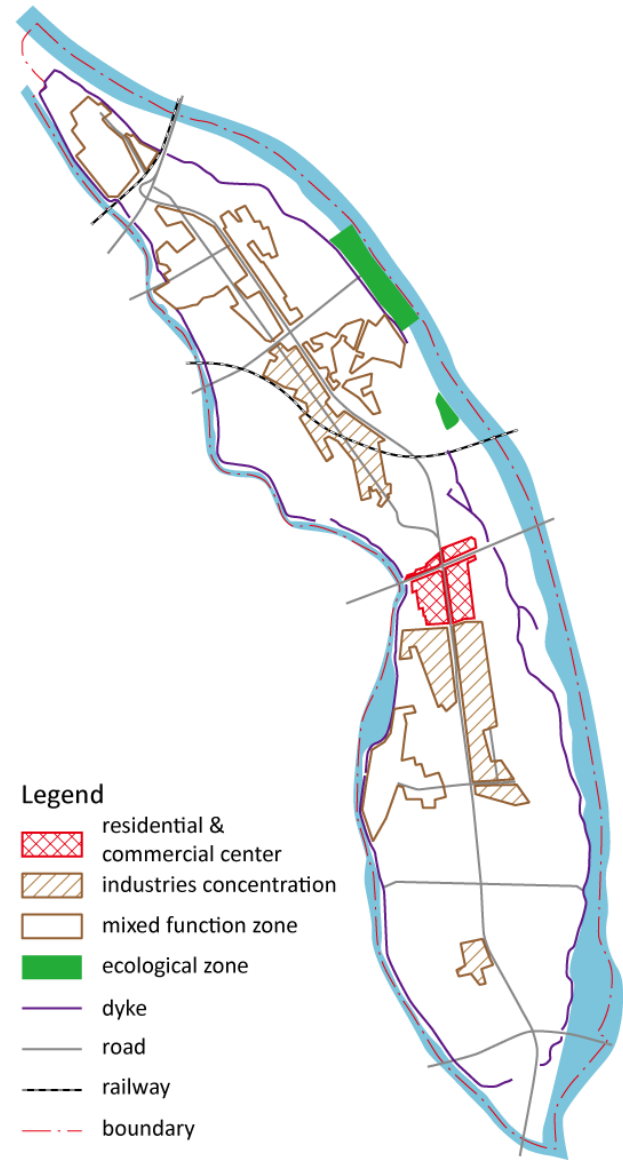
Jinsha area in Nanhai District

By author



Water management system of Jinsha area

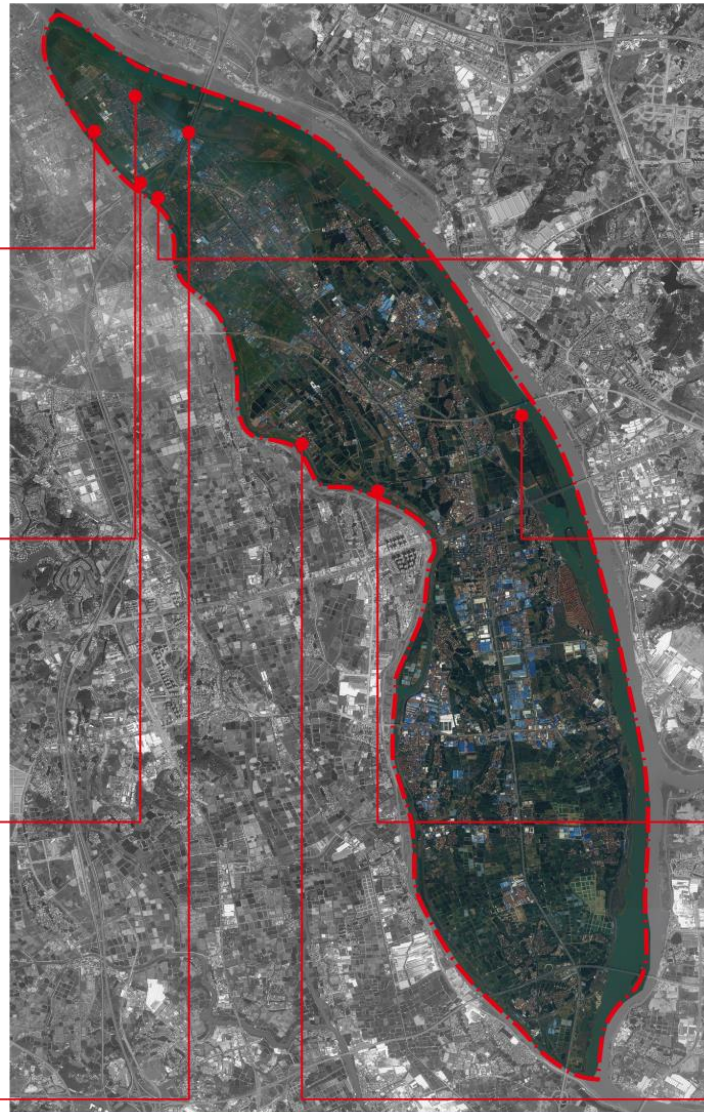
Source: Nanhai government



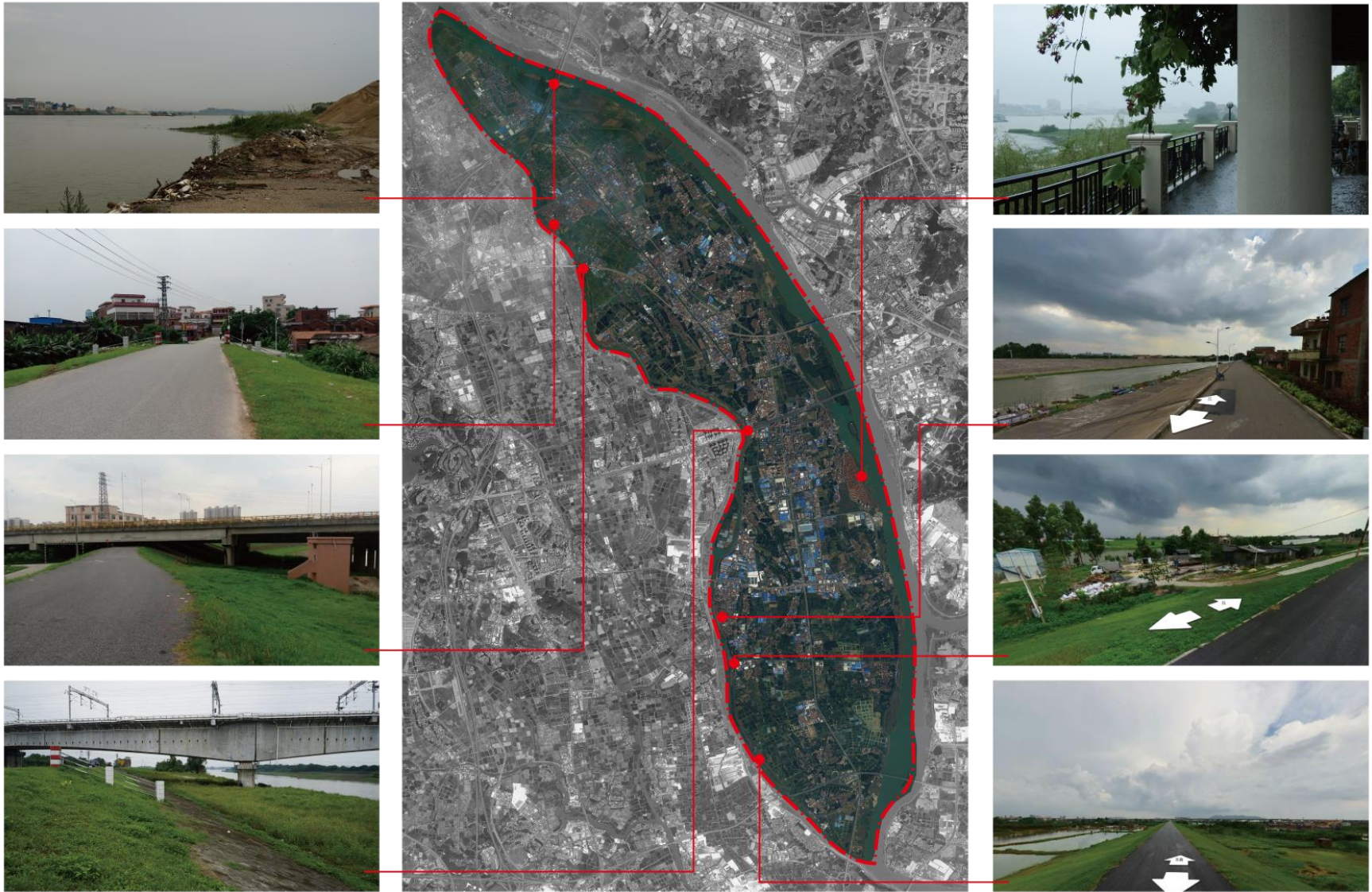
Features of the site

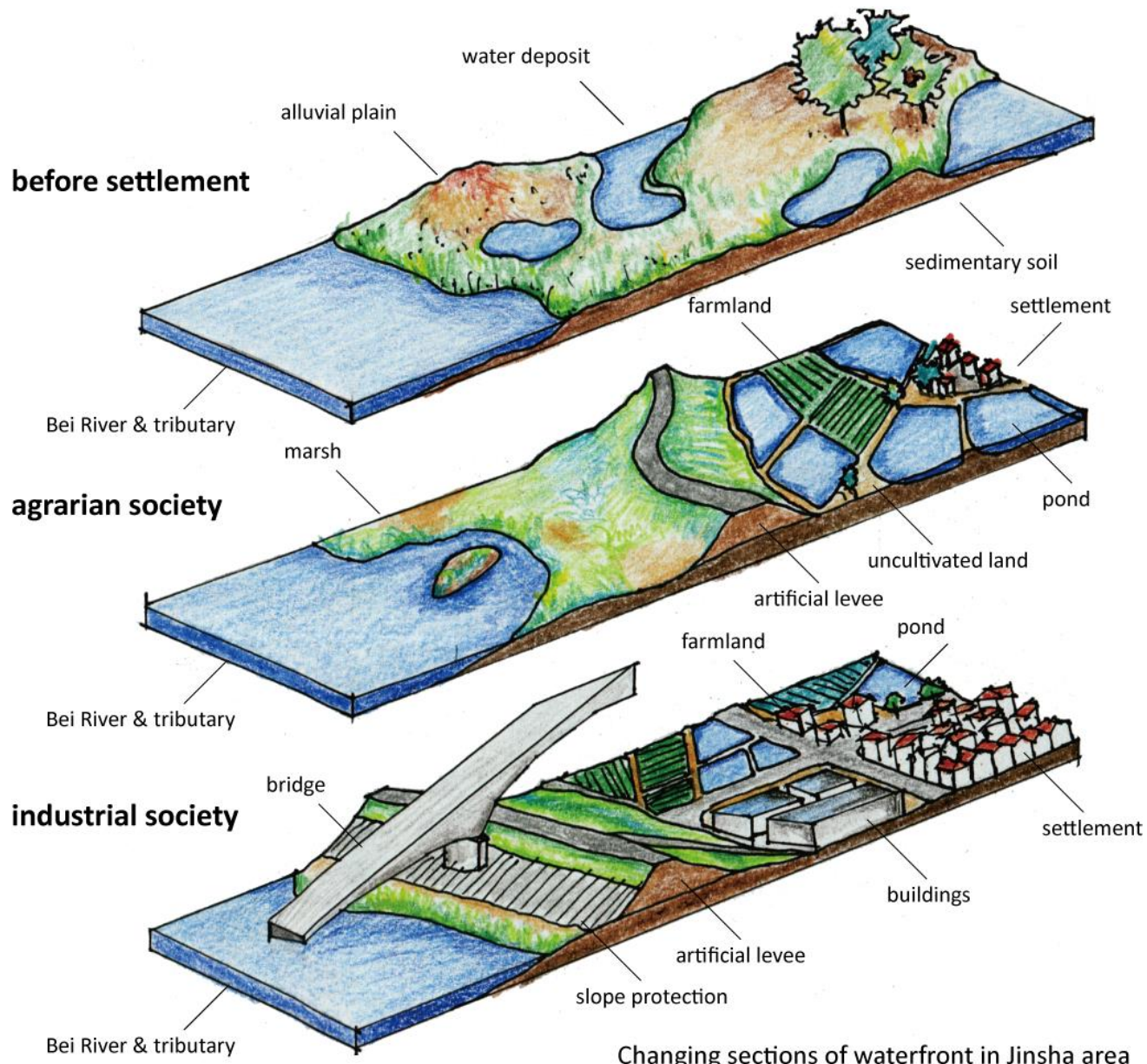
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Site overview



Site Overview

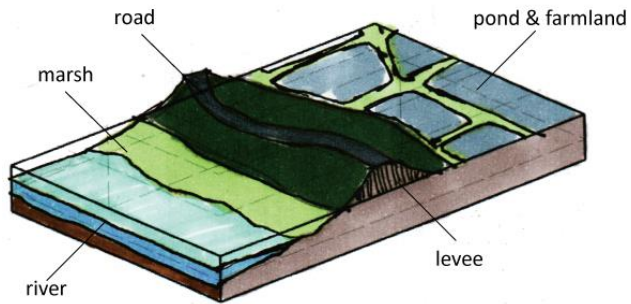




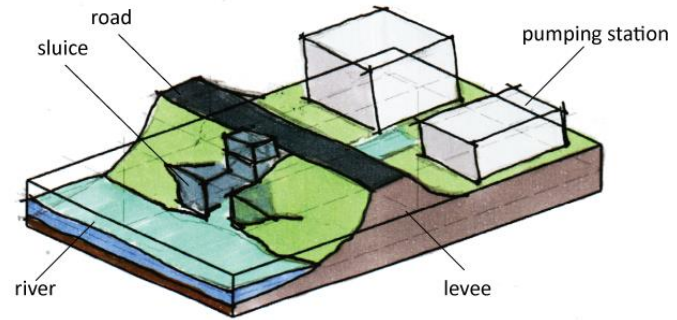
Changing sections of waterfront in Jinsha area

The evolvement of waterfront in Jinsha area

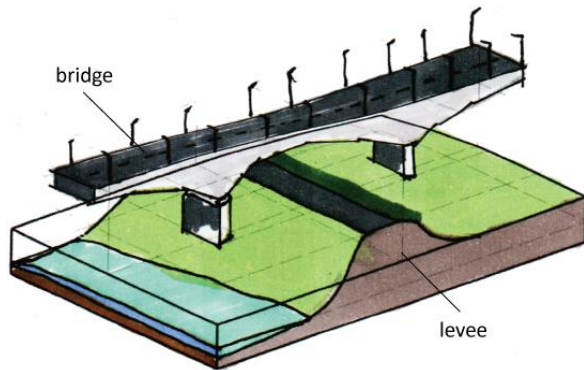
Source: By author



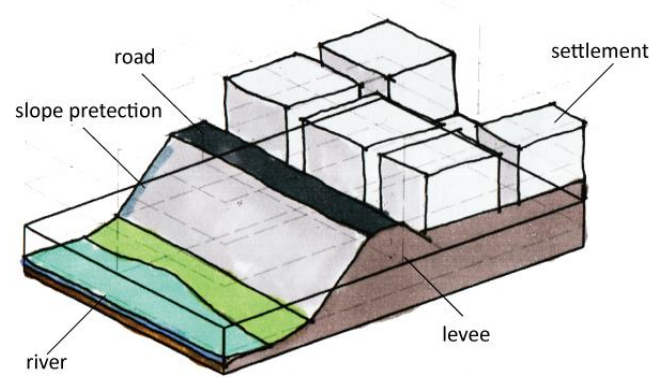
- Embankment covered with grass on both sides
- Ponds and farmland located behind levee



- Sluice and pumping facilities



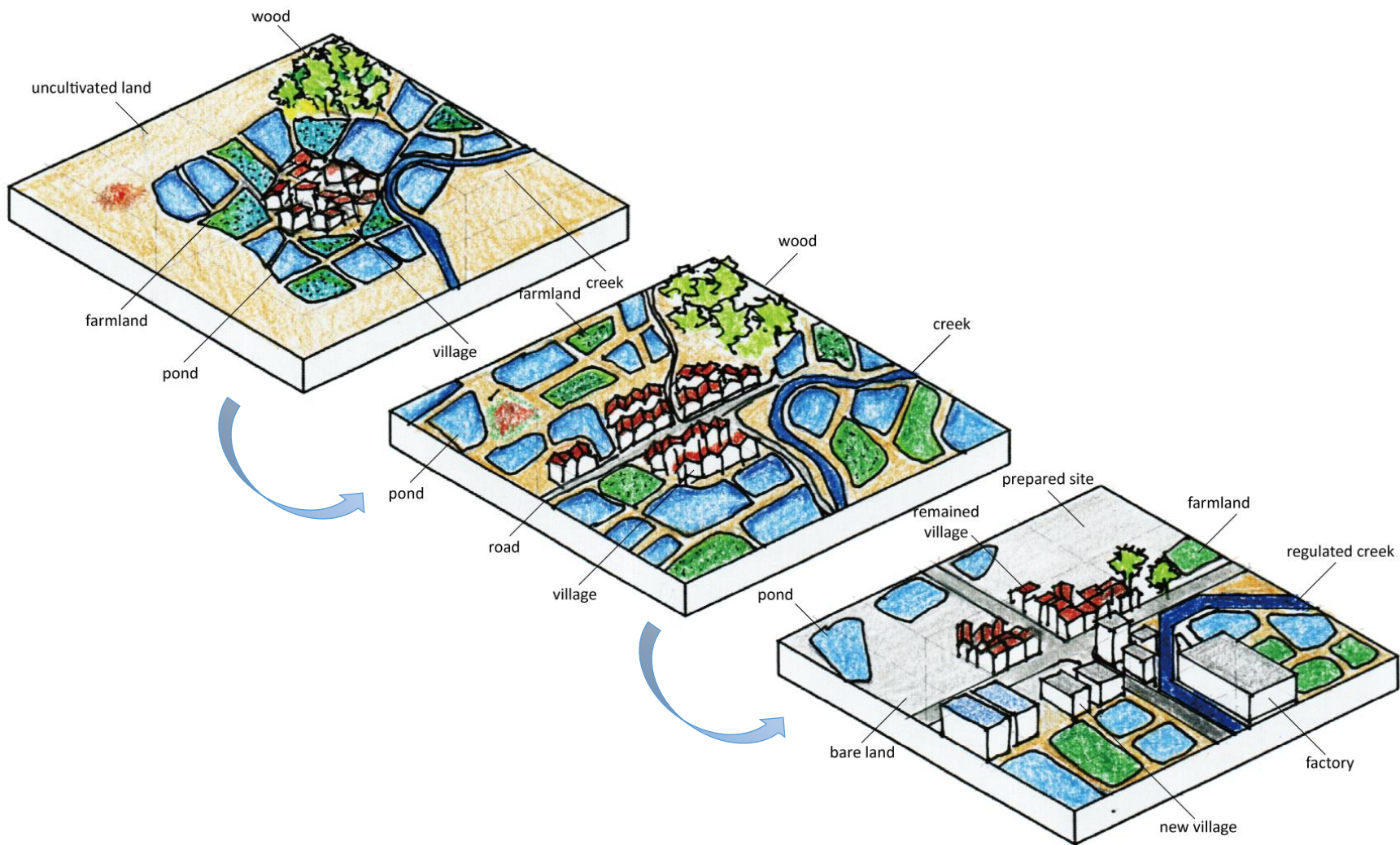
- Bridge cross over the levee



- Slope protection on the waterside
- Buildings on near elevation as the levee top

The types of waterfront in Jinsha area

Source: By author



The evolvement of settlement in Jinsha Area

Source: By author

3. Problem statement

For hundreds of years before industrialization occurred, the Pearl River Delta has developed a sustainable method to maintain prosperous agricultural production while adapting to the particular climate and environmental conditions. Limited by manpower and technology, the dyke-pond system adopted since 14th century in central delta area could be considered a way to adapt to the hydraulic features and climate rather than merely resisting flooding.

Since the implementation of Chinese Economic Reform and the slack of urban-rural dual structure which constrain people and capital to move, the Pearl River Delta, as the frontline connecting to the world, has gained great economic benefit and urban growth. It was not only a brave act but also a leap in the dark. On the one hand, cities in the delta underwent a rapid process of urban expansion and transformation. Those changes contributed to higher quality and convenience of urban life as well as a series of urban problems. On the other hand, the trend of rural industrialization which was more spontaneous than regulated, became irreversible.

Rural industrialization causes essential changes in both natural processes and artificial environment. The delicate balance of the dynamic ecosystem which integrated agricultural production and water management gradually inclined to an unrecoverable stage. People pay less attention to coping with water but suffer more from inundation and vulnerability to flood. The extensive industrial land use created enormous impervious surface and a large scale of ground grading which greatly weaken the infiltration and confluence of surface run-off (Zhu, 2010). The atrophy of dyke-pond system shrank the capacity of water storage when confronting high peak discharge or flooding. In addition, the severe and scattered contamination and abusive resource exploitation deals damage to the ecosystem. These changes increase vulnerability of the ecosystem due to a decreasing supply of ecosystem services which is vital to human well-being (Schröter et al., 2005), such as declining water availability, deteriorate spatial quality, increasing risk of inundation in built up areas, especially in the delta region.

Furthermore, climate change may also play a role in affecting the natural system and the lives of inhabitants of the delta region. The probable increase of extreme weather and disruptive surge may bring more unpredictable challenges such as flood events, land subsidence and salinization.

To cope with those problems, a new development strategy which could adapt to changing conditions and re-achieve robust supply of ecosystem services is needed.

4. Research questions

Main research question

Regarding to rural-urban transition, what aspects would contribute to rebuilding a robust ecosystem in the urbanizing areas in the Pearl River Delta and how to achieve it via developing an adaptive framework?

Sub Questions:

How does the delta function as an ecosystem before the emergence of rural industrialization?

What is the impact of rural industrialization on the on the traditionally dyke-pond system dominated region?

What ecosystem services should be highlighted for the human well-being and economic prosperity?

How to develop an adaptive design/planning framework to support a robust urban ecosystem?

5. Relevance

Societal relevance

The impact of rapid rural industrialization since 1980s in the Pearl River Delta on natural landscape and socioeconomic aspects has been realized by scholars. Once the economic value was highlighted and the social, spatial and ecological values of the former rural and urban landscape were neglected. Recently the economic driven force which used to be the foreign direct investment is seen a significant decay. The drawbacks of rural industrialization in the past thirty years has re-drawn wide attention. On the other hand, climate change, as an ongoing and predicted fact, has become a new common which is discussed in almost every aspect. As the awareness of ecological and social benefits arises in public, there is call for enhancing sustainability, health and quality of life.

This thesis attempts to propose a way to achieve a sustainable balance between urban development, environmental quality, flood defense and economic vitality which may be an answer to the call mentioned above.

Scientific relevance

Seeing delta as a complex system and meanwhile an ecosystem, many scholars has made their effort on deltas in the world.

The concept of ecosystem has been raised since early 20th century. The city as an ecosystem, also drawn the attention from scholarship. It is not possible to construct sound ecological science without explicit attention to urbanization as a key driver of global ecological change (Seto et al., 2013). There are many methods to access the ecosystem services as “natural capital” in a monetary way from regional scale to local scale. But yet there is not sufficient knowledge applying the values of ecosystem service into actual intervention concerning the complexity and uncertainty.

The complex adaptive system approach proposed by Meyer and Nijhuis illustrate the complex relationship between the natural landscape and human interventions. It provides an insight that adaptive framework should create conditions for short-term societal changes as well as for long-term adaptation to possible changes of natural substratum. The Dutch delta as an example of complex urban landscape, is a testimony of this approach. Though the Pearl River Delta shares some common characteristics with the Dutch Delta, it has not been thoroughly investigated if the Dutch approach could achieve the same effect in the Pearl River Delta.

This project intends to adopt the ecosystem theory and the approach of complex adaptive system as the foundation. It attempts to identify and evaluate the challenges and vulnerability of the urbanizing Pearl River Delta. Thus this project could proposed an adaptive framework which highlight the ecological values of the delta and tackle the challenges such flooding which may contribute to human well-being.

6. Methodology

In order to answer the research questions, several steps will be processed with various methods. The study is associated with concurrent mixed methods due to the complexity of actors and their interrelationship to natural processes and human intervention in the specific context in the Pearl River Delta. Research and design are involved in the whole process. Research for design is to inform design and planning and provide practical examples. Research by design is a way to generate new ideas and questions, as well as exploring possibilities.

Literature review

To gain a better understanding of theories and studies on the research field, books, reports, papers and conference are to review. (see Chapter 9. Bibliography)

Layer approach

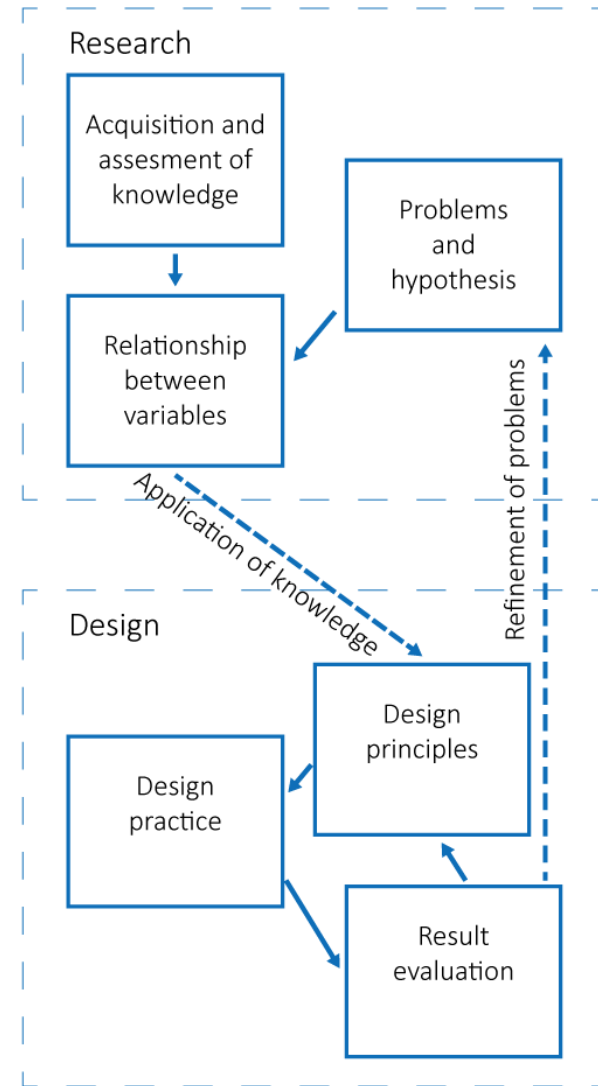
Delta is treated as a complex system. Using layer approach in the research intends to conceptualize the mutual relations between different processes which are considered as various urban layers with different speeds of change (Meyer & Nijhuis, 2016).

Mapping

To define the problems on different scales and understand the specific context of the Pearl River Delta, mapping as an important method is adopted.

Case study

Deltas in the world have common similarities and differences. Though every delta has its unique characteristics, it would be beneficial to study various cases to obtain insights on dealing with problems and experience. The selected cases should cover a wide range of scales, problem types and methods used.



Relationship between research and design as an intellectual process

By author

Site visit

Literature review and other methods may generally provide insights on the study field. However, as for a designer, it is important to pay a visit to the study site. The process of perception is holistic in which human mind recognizes the many discrete bits of information that enter through the senses for the contribution they make to a larger organization (Bosselmann, 2012).

Scenario study

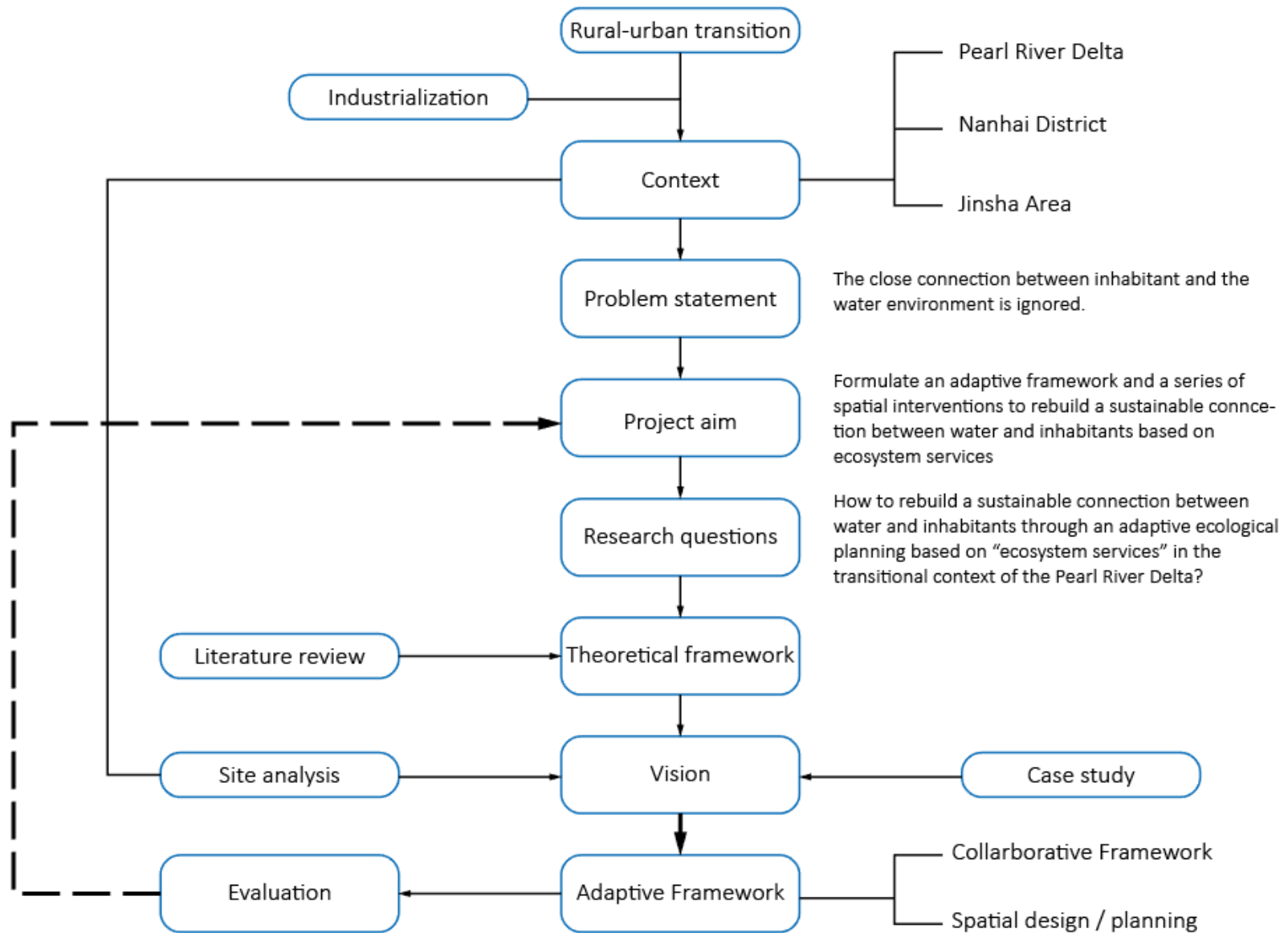
Considering the probable challenges in the future, scenario study is a useful tool to estimate the impact and possible effect of uncertainty. In this case, scenario study mainly used in defining different possibilities of climate change and urbanization in the Pearl River Delta. The proposed adaptive framework as an end product should reflect on the scenarios.

Sketching

Sketching has been proved to an effective skill to express designer/planner's thought in a fast and straightforward way. Moreover, sketching indicates uncertainty and fuzziness which better represent the reality and helps to trigger new ideas. This method will mainly be used in illustration and design process.

Modeling

Mapping and sketching did contribute to showing the analysis and design. As for a more precise and variable way, modeling is suitable method for perceptive recognition. Both model in substance and digital model could directly present the design products and proposed space.



<i>Research questions</i>	<i>Methods and data to be used</i>	<i>Expected result</i>
<p>Q1</p> <p><i>How does the delta function as an ecosystem before the emergence of rural industrialization?</i></p>	<p>Literature review</p> <p>Layer approach</p> <p>Mapping</p>	<p>Theoretical understanding of ecosystem and ecosystem service</p> <p>The complexity of interrelation between layers in the context</p>
<p>Q2</p> <p><i>What is the impact of rural industrialization on the on the traditionally dyke-pond system dominated region?</i></p>	<p>Literature review</p> <p>Site visit</p> <p>Layer approach</p> <p>Mapping</p>	<p>The complexity of interrelation between layers in the context</p> <p>An summary of leeso</p>
<p>Q3</p> <p><i>What ecosystem services should be highlighted for the human well-being and economic prosperity?</i></p>	<p>Literature review</p> <p>Case study</p> <p>Mapping</p>	<p>A set up of the assessment and value system</p> <p>Development principles and guidelines</p> <p>Summary of lessons learned</p>
<p>Q4</p> <p><i>How to develop an adaptive design/planning framework to support a robust urban ecosystem?</i></p>	<p>Literature review</p> <p>Scenario study</p> <p>Sketching</p> <p>Modeling</p>	<p>Theoretical understanding of the role of ecosystem service in planning and design</p> <p>Alternatives of possible pathways</p>

7. Theoretical Framework

In this thesis, two main theories are applied to understand the context of the Pearl River Delta, identify the existing problems, evaluate the performance and achieve the designated goal.

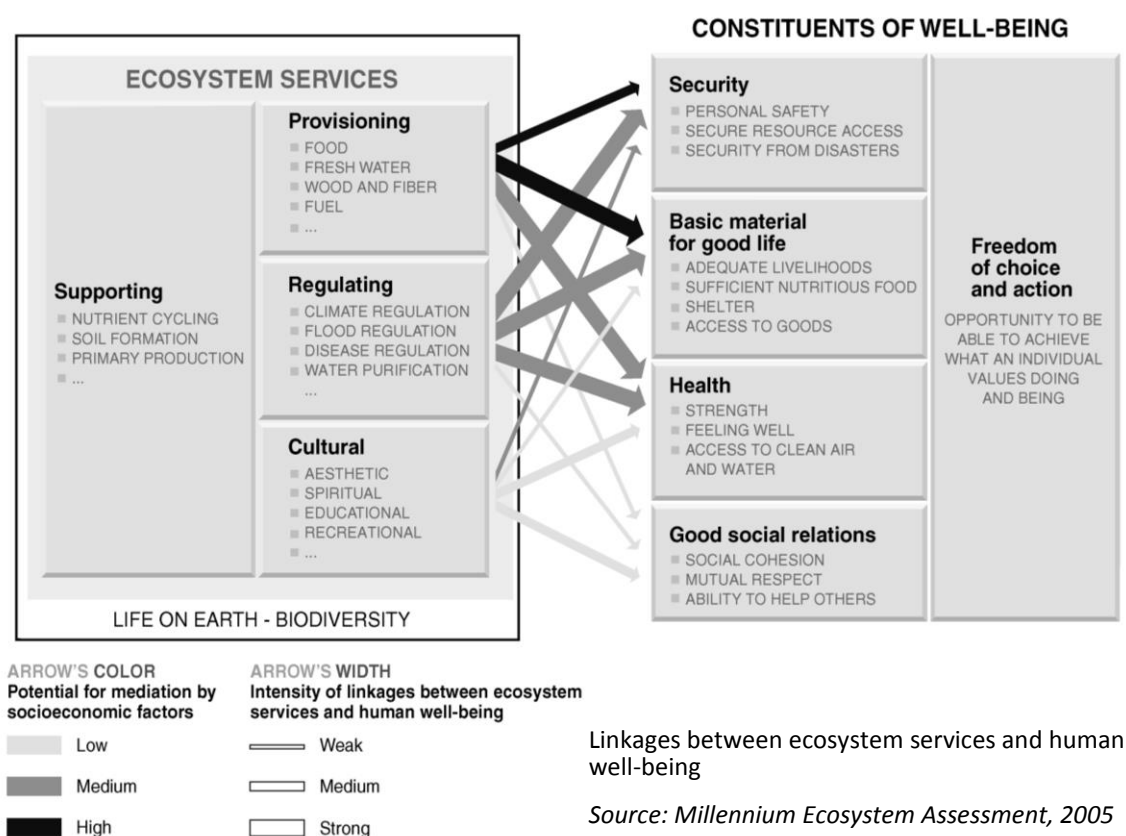
7.1. Ecosystem and ecosystem service

An ecosystem is defined as the totality of interrelated organisms inhabiting an area, together with their abiotic environment (Kronenberg, 2012). In the context of this study, the inhabitants including human and other organism in the Pearl River Delta and the environment of the delta as a whole construct an ecosystem.

“Ecosystem services” is a concept increasingly used to refer to the benefits that people derive from the functioning of ecosystems (Hubacek &

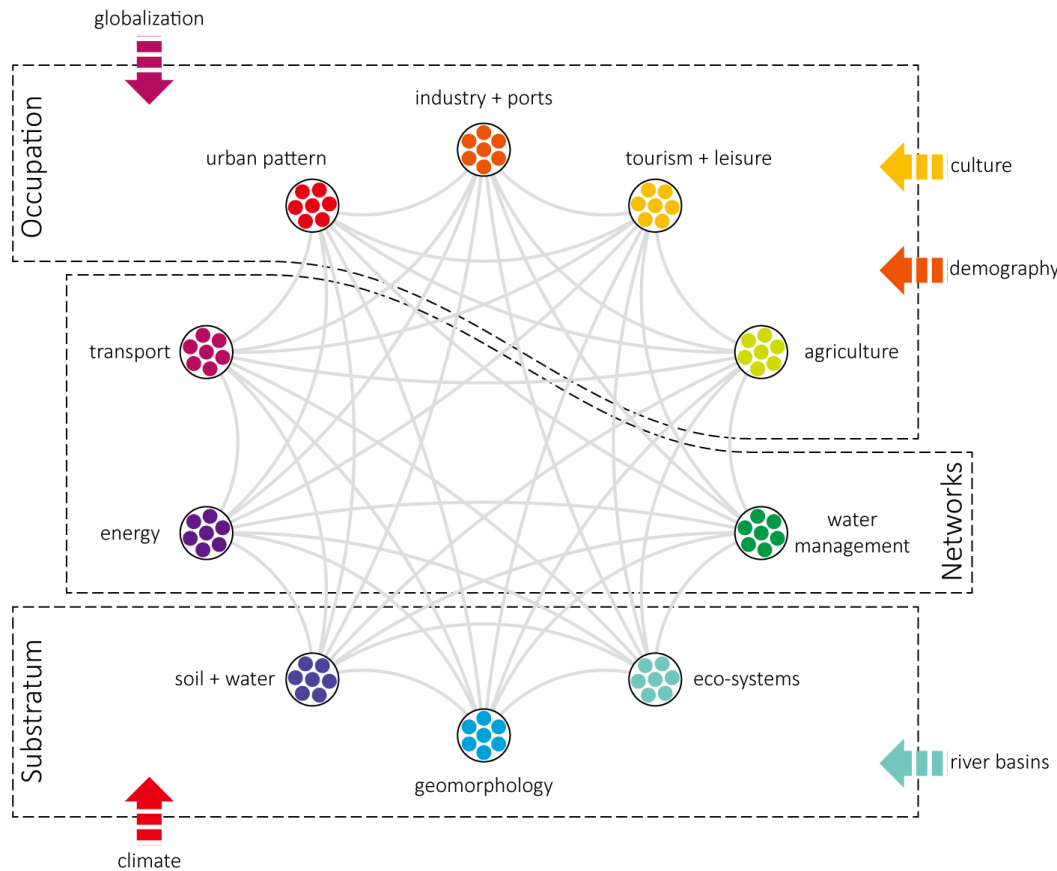
Kronenberg, 2013). The most widely used classification of ecosystem services was proposed in the Millennium Ecosystem Assessment (MEA), a global research project report published in 2005 that comprised a summary of the current knowledge on the state of the global environment.

There is a linkage between ecosystem services and human well-being. Human well-being is affected by changes in the composition and functioning of ecosystems and the resultant flow of ecosystem services. Human transformation of ecosystem and the choices about the way in which their services are used can either amplify or reduce the benefits to society. Changes to ecosystem, and thus to human well-being, can occur at global, regional, sub-regional, national, and local scales, and often at several scales simultaneously. (Millennium Ecosystem Assessment, 2005)



The process of cultural evolution, occurring over centuries but substantially accelerated in the industrial era, has entailed a progressive dissociation of daily needs and activities from the services of the natural world. Both the awareness of human dependency on nature, and the rapidity and spatial immediacy with which ecosystem changes affect human well-being vary hugely among contemporary human societies, spread across the spectrum from pre-agrarian to post-industrial (Millennium Ecosystem Assessment, 2005). Thus when temporally comparing ecosystems in a same location, the needs of human well-being for ecosystem services may be varied.

7.2. Adaptive complex system and layer approach



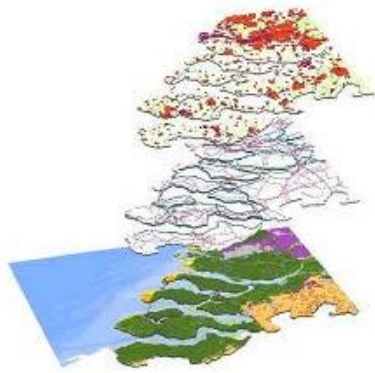
System, subsystem and the environment of CAS

Source: Modified from Dammers et al., 2014

A complex system is defined by a large number of subsystems, each with its own characteristics and dynamics, influencing each other and influenced by external conditions, which have their own dynamics as well (Mitchell, 2009). A complex adaptive system (CAS) can be regarded as being in a relatively stable equilibrium when it is able to adapt to sudden change of one subsystem or with a structural change of the context (Meyer, 2014).

A delta can be considered as a complex and dynamic whole, consisting of various social, ecological, and physical components which constantly change and interact with one another and which are continuously influenced by physical and socioeconomic trends in different and often unpredictable ways (Dammers et al., 2014). Thus, defining the Pearl River Delta as a complex adaptive system is helpful in understanding the relations between subsystems and dealing with the uncertainty.

Subsystems in complex adaptive systems can be characterized by its own dynamics and speed of change although each of them will be influenced by changes in other subsystems (Meyer & Nijhuis,

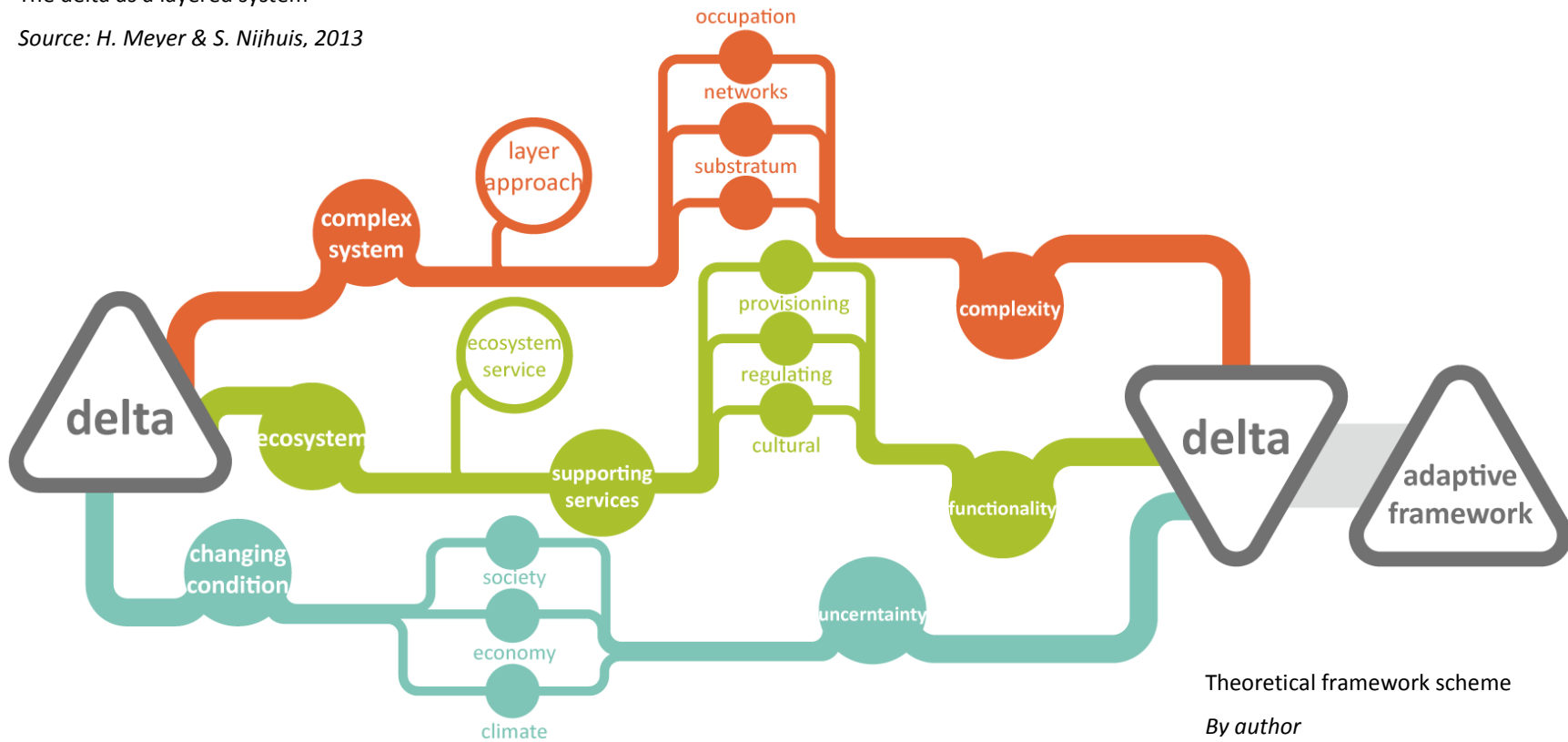


The delta as a layered system

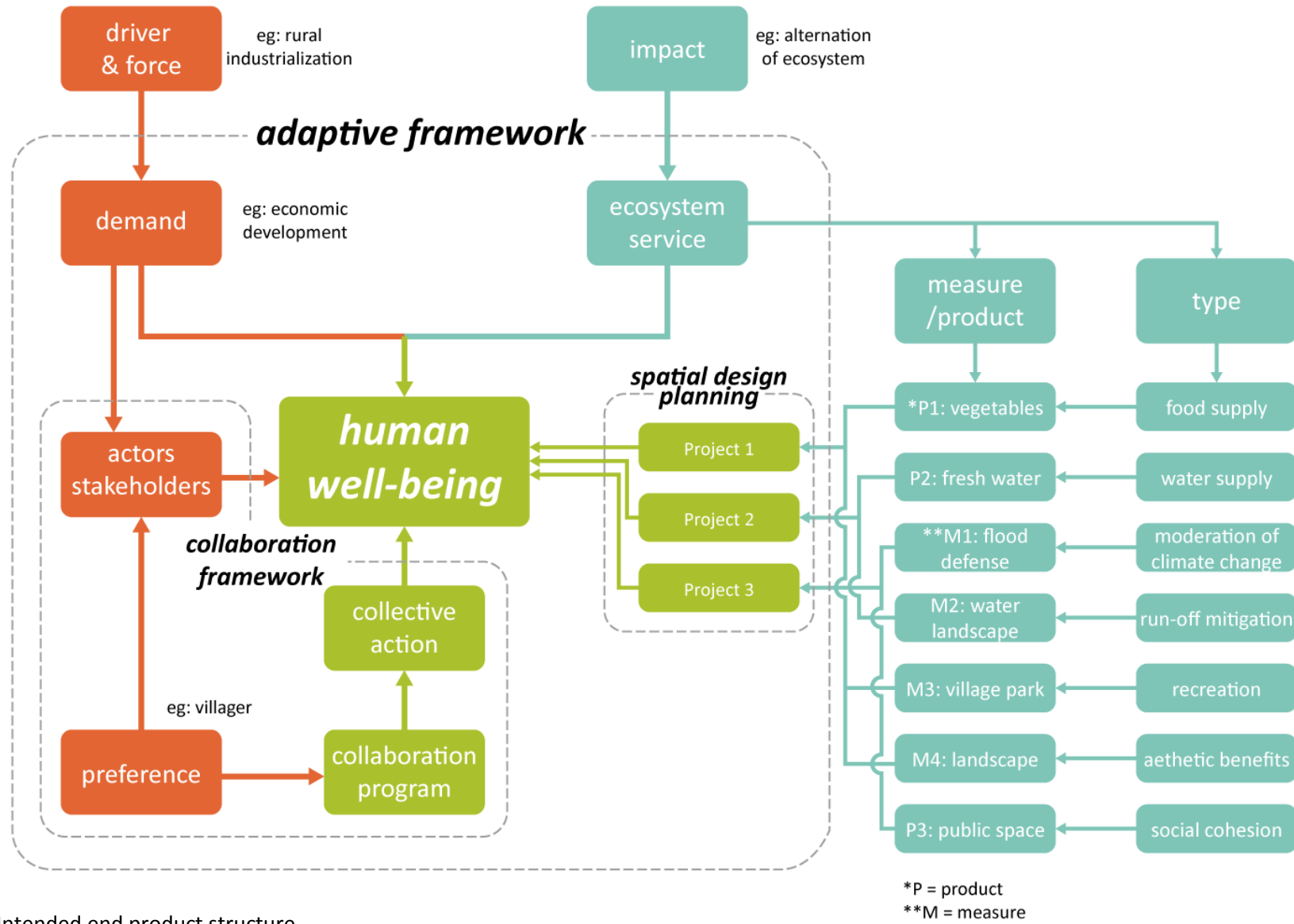
Source: H. Meyer & S. Nijhuis, 2013

2016). The necessity of finding a method that enables us to understand the complexity and the relationship among subsystems has resulted in the development of the “layer cake model” (Meyer et al., 2010). Ian Mcharg considered urbanized landscape as layered systems which include natural substratum, infrastructural networks and urban land-use patterns. This layer approach became a leading approach in professional planning practices from the 1990s (Meyer & Nijhuis, 2016).

E. Dammers et al. also raise the idea of the particular behaviors of complex adaptive systems which are adapting, synchronizing and mobilizing. The complex adaptive system theory and layer approach offers a reflective and integrative framework for planning activities. According to that, planners and other actors to make a critical assessment of their activities, to reflect on them and to generate new ways of thinking, communicating and acting (Dammers et al., 2014).



8. Intended end products



Intended end product structure

By author

8.1. Vision



Vision
By author

8.2. Product structure

A: An **adaptive framework** for rural-urban transition in Nanhai which includes preferences of actors and underlying ecosystem services

B: A **collaboration framework** for collective action program

C: Several **spatial design & planning project** as a tool to test the strategies applied within the framework

8.3. Proposed projects

Corresponding to the ecosystem services mentioned above and the potentiality of the site, several projects and programs are proposed as experiments.

Water Landscape Park:

Wetland Park

Ecological corridor

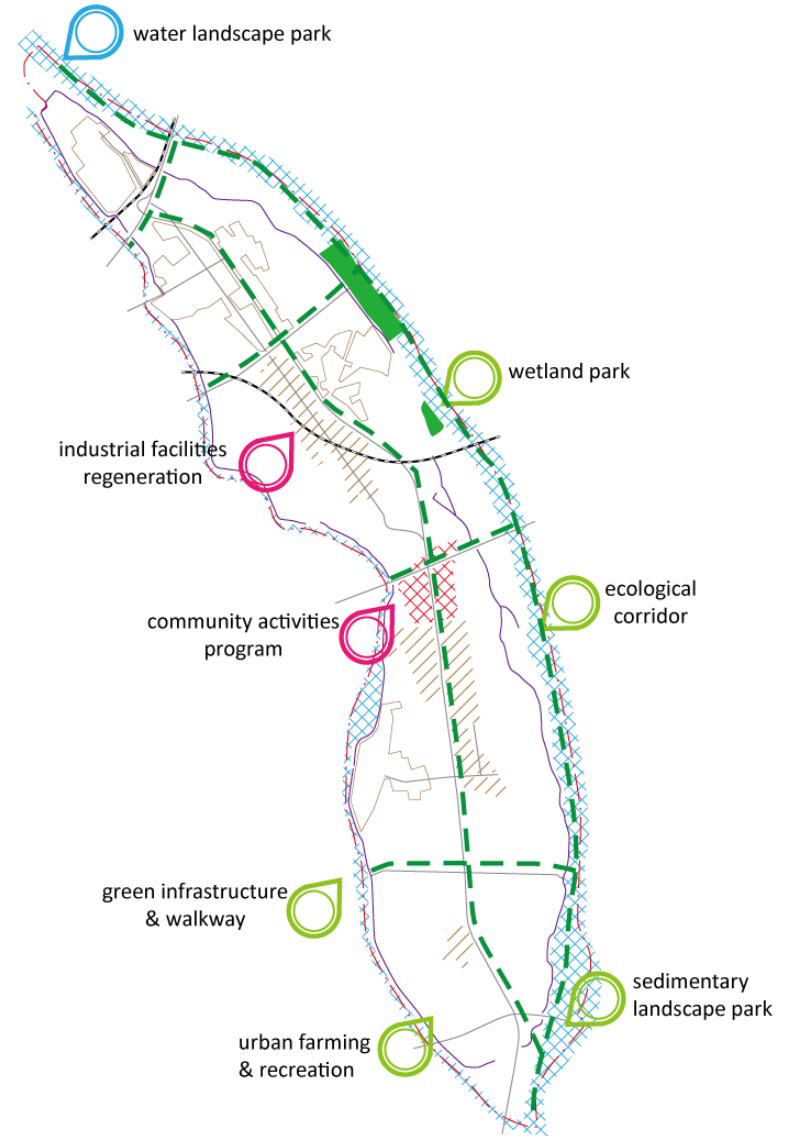
Sedimentary Landscape Park

Urban farming & recreation

Green infrastructure & walkway

Community activities space

Industrial facilities regeneration



Propose projects and programs

By author

9. Case study

Thousand Lantern Lake Park System

Project owner: Nanhai District Government

Designer: SWA Group et al.

Size: 116 ha

Formerly known as the South Sea Welcome Plaza, the Thousand Lantern Lake Park System represents a defining infrastructural success that has been integral to Nanhai's strategic plan for urban transformation over the past 15 years. Nanhai District exemplifies a people-oriented approach to urban development and provides creative solutions for attracting people to its newly constructed Guangdong Financial High-tech Industrial Zone. (UOSA, 2015)



Signature lighting design of Thousand Lantern Park

Source: UOSA, 2015



Thousand lantern park system

Source: UOSA, 2015



Historical elements are integrated

Source: UOSA, 2015

The master planning and urban design consists of a commercial precinct, public parks, and civic buildings arranged around a series of lakes and waterways. The waterways act as the connecting element between the larger site, providing transportation networks that run through the entire park. The centerpiece of the park, Citizen's Plaza on Thousand-Lantern Lake, provides an active public gathering space that transitions from day to night with unique streetscape and lighting elements. The relatively blank canvas allowed the master plan that will be able to grow over time and inspire and connect the city of Nanhai well into the future. (SWA Group)

The development solves one of the greatest challenges that similar third-tier Chinese cities face: how to retain a community's vitality while the city upgrades its industrial structure to modern functionality, including a redefined spatial layout. As the core piece of this public open space, Thousand Lantern Lake has become the primary destination for recreation, events, and retail in the region, displaying the lively energy that contributes a significant competitive edge to the city's growth and value generation.

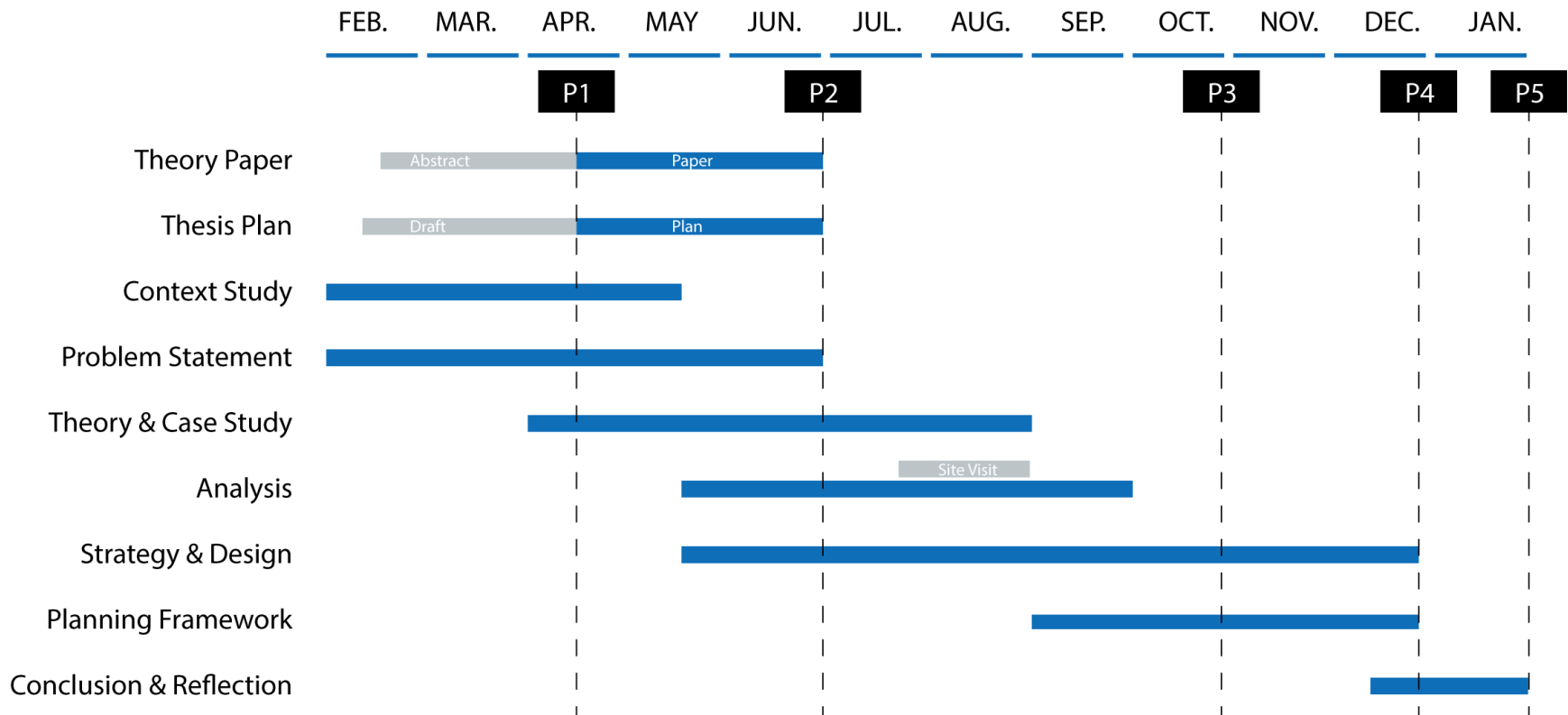


Thousand Lantern Park

Source: SWA Group



10. Time schedule



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12. Appendix

Theory paper

Toward a Sustainable Delta Urbanism: Implications for Urban Planning and Design in the Pearl River Delta from a System Perspective

Abstract - During Ming and Qing dynasty (14th century – 19th century) when Pearl River Delta achieved its prosperity in agricultural society, the urban landscape has been largely shaped by intensifying human activities as well as natural process. Since late 1970s, a forty-year period of rapid urbanization has taken place in the Pearl River Delta. The ongoing processes and evolving patterns of “urban-rural integration” in Pearl River Delta demonstrates the complexity of relationship between industrialization and urbanization (Lin, 2000) in which political, economic, societal and ecological factors interact. Thus the Pearl River Delta can be considered as a complex and dynamic whole, consisting of various social, ecological, and physical components which constantly change and interact with one another and which are continuously influenced by physical and socioeconomic trends in different and often unpredictable ways (Giacomoni et al., 2013). This paper reviews the complexity of the interaction between natural processes and human interventions in the Pearl River Delta as a complex system and the functioning of the services provided by the delta as an ecosystem. Different processes are analyzed using a “layer approach” – where substratum, network and occupation are regarded as different layers with different speeds of change (Meyer & Nijhuis, 2016). On the basis of it, it discusses the main challenges that the delta is facing at present and attempts to formulate recommendations for planners and actors to establish an adaptive framework toward a sustainable urbanism.

Keywords - urbanization Pearl River Delta climate change rural industrialization complex system adaptive planning

Introduction

Deltas, generally refer to territories characterized by the terminus of one or more river basins, providing sediment loads into an ocean, gulf, lagoon, estuary, or lake (Meyer and Nijhuis, 2014). Close access to fertile ground, abundant natural primitive resource such as water, wildlife and forest which provided by the unique ecosystem of deltas has identified the natural landscape. Agriculture and urban development occurs largely in delta areas as people capitalize on the natural advantages the areas provide (Dammers et al., 2014). No wonder, many great prosperous cities such as Rotterdam, New Orleans, Guangzhou and Shanghai has developed as hot spots of culture, economic activities, and knowledge. Meanwhile, as usually a transitional zone of natural landscapes and human activities, delta areas often face a complex and variable situation. For instance, flooding and storm surges from the nature, over-concentrated population and polluted water source make delta areas more fragile to incoming changes from both inside and outside. Considering the complexity of the delta areas, system theory may be helpful in defining the challenges and understanding the interrelation between subsystems and layers under a water-centric context in the Pearl River Delta.

This paper explores a possible answer to the question: when the demand for proper functionality of ecosystems and the complex relations between different processes in the delta region is taken into account, how to develop an approach to planning which is flexible to changing conditions. The paper focus on the Pearl River Delta, through which the discussed theories will be applied. In the next section an overview of the transformation and development of the delta analyzed by “layer model” will be presented to illustrate the complexity of the delta system. The third section reviews the

functionality of the delta as an ecosystem and the services provided. The fourth section discusses the incoming challenges and the uncertain future of the delta. The fifth section provides some insights by briefly comparing the situation of the Pearl River Delta and the Dutch delta. After those, some remarks and recommendations will be proposed.

Delta as a complex system

Delta regions can be considered as complex systems which characterized by their climate, geographical, economic, ecological conditions. According to complexity theories, a complex system is

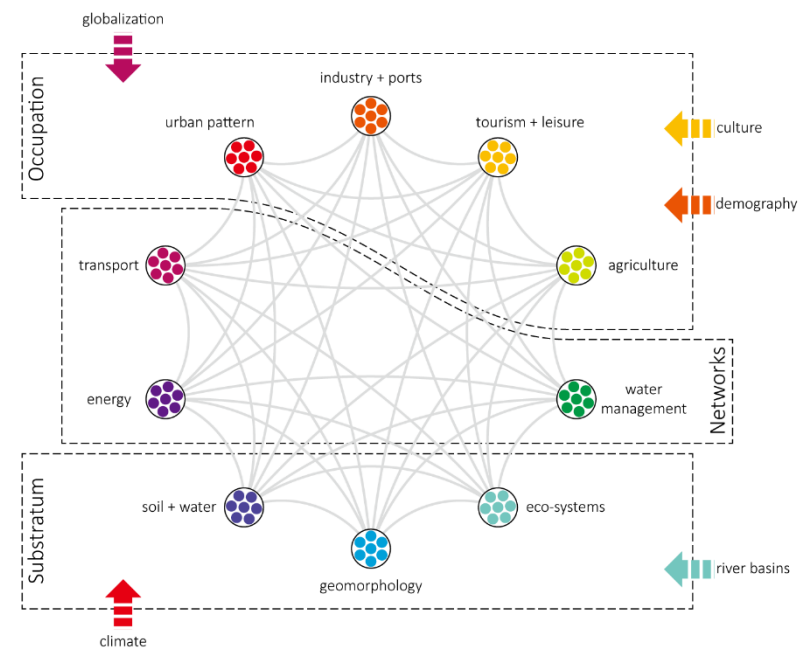


Figure 1: System, subsystem, the environment and the external conditions of complex system

Source: Modified from Dammers et al., 2014

defined by a large number of subsystems, each with its own characteristics and dynamics, influencing each other and influenced by external conditions, which have their own dynamics as well. The evolution of a complex system is the result of the continuous interaction of subsystems and of the continuous interaction with the dynamics of the external conditions (Meyer and Nijhuis, 2014).

In 1960s and 1970s, Ian McHarg, who considered urbanized landscape as layered systems proposed a “layer cake” which presented a causal or probabilistic explanation of regions under study: each layer was dependent upon the underlying ones, each augmented the explanation (Mcharg, 1992). Thus this method provides a way to identify and represent the dynamics and characteristics of each subsystem and the relation between them, though layers are not exhaustive and some of them may be more important than others, often varying at different periods in time. The layer approach has developed over time. The subsystems can be divided into three categories. The base layer (substratum) consists of the coherent whole of water, soil and creatures living in them (Bucx, 2010). The network layer consists of the physical infrastructure, such as dams, airports, motorways, railways and waterways, and invisible networks such as flyways and satellite connections. The occupation layer is formed by spatial patterns that emerge from the use of the base layer and the network layer such as urbanization, agriculture and recreation. (Dammers et al., 2014)

The forming of natural landscape in the Pearl River Delta

Fed by three major rivers near its head, the Pearl River Delta is building into the Pearl River estuary, which interfaces with the South China Sea. Together with their distributary networks, a very complicated deltaic morphology has developed. The distributaries of these rivers are separated by a large and rather circular mountainous

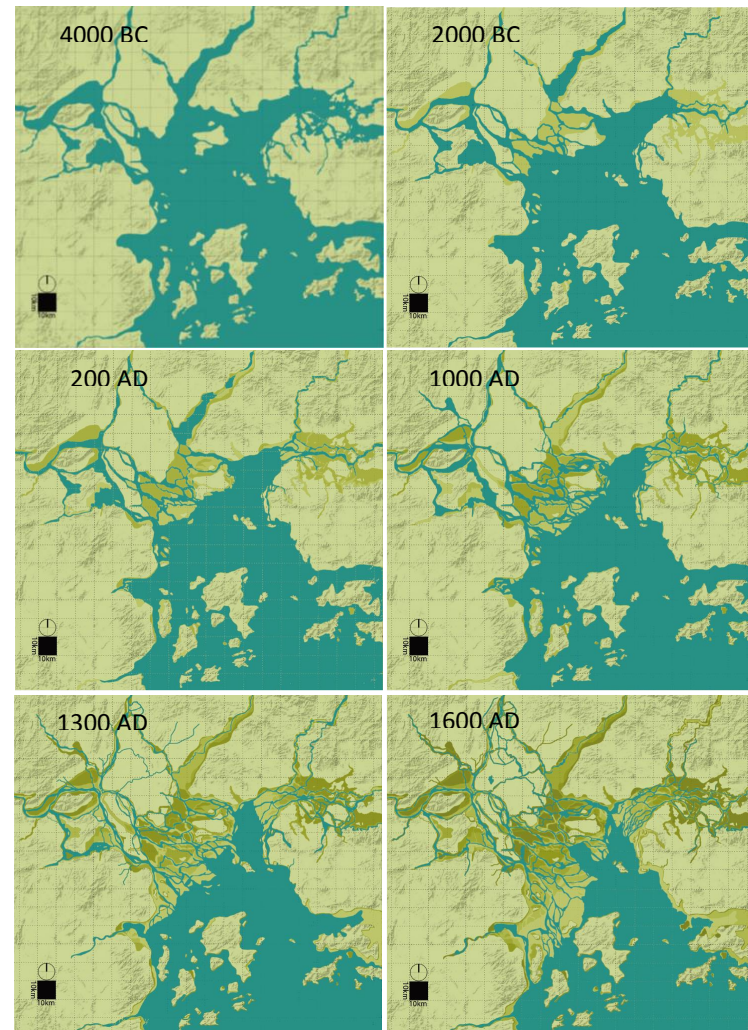


Figure 2: The forming of the Pearl River Delta
Source: maps by Liang Xiong

block (now Zhongshan), around which sediments are being deposited as the deltaic plain progrades to the southeast. Eight major channels and numerous smaller ones debouch sediment-laden fresh water into the water body, causing rapid seaward progradation of subaqueous shoals and the deltaic plain. During the summer peak-flow months, approximately 95 percent of the annual suspended load (72.5 million tons) is discharged through the delta. However, compared to the Yangtze River, though their total discharges are similar, the sediment load of the Pearl River Delta is only about one tenth of that carried by the Yangtze. The rivers flow through the delta has constructed a delta over 100 km long during the past 4000 to 5000 years. (Short et al., 1986)

Human activities and manmade landscape

Historical record suggest that man has been cultivating the deltaic lands of the Pearl River Delta for over 1000 years. Not only did man expand his agricultural territory as a consequence of natural advancement of the delta, but he learned to build new land by constructing dykes to accelerate reclamation. Many of the dykes are constructed so that the structure is submerged at high tide. This produces a new increment of sedimentation to the diked areas with each tidal cycle (Short et al., 1986). Although natural processes constantly contribute sediment, wave energy and other conditions to the formation of substratum, the present delta actually represents the interaction of natural processes and human activities. Over the past several hundreds of years, safety of settlement and agricultural production augmentation was the major force of land reclamation and engineering manipulation.

Stepping into the industrial era, the increasing need of urban development and infrastructure has led to a more powerful and overall transformation of natural landscape. This trend became more

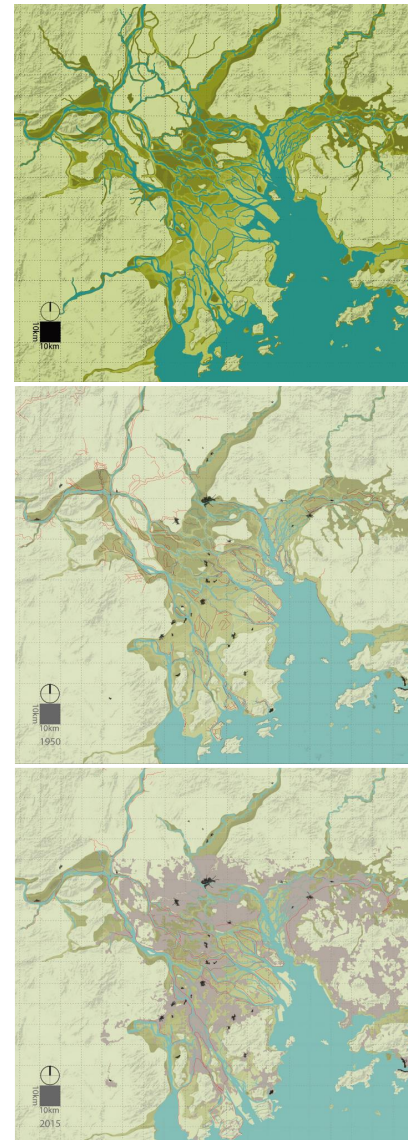


Figure 3: The expanding occupation of built-up areas
Source: maps by Liang Xiong

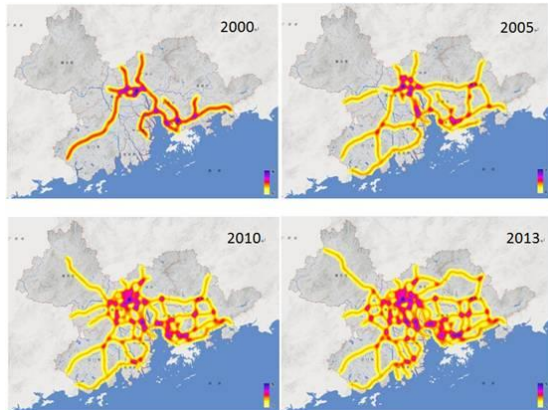


Figure 4: The evolution of highway network in the Pearl River Delta
 Source: *The Pearl River Delta Region Planning, 2014*

significantly visible in the past decades. In terms of built-up area growth, the Pearl River Delta is the fastest urbanizing delta in the last thirty years. In 1979, around 250 km² land was occupied by built-up area which took up only 0.5% of the whole delta. Until 2009, the number increased to 5845 km² and the share was 10.8% (Liu and Huang, 2015). Along with the economic and demographical growth, the occupation of human activities greatly expanded in the delta.

The infrastructure pattern has also been changed in the delta while undergoing the shift from traditional agrarian society to industrial society. Before 1970s, water as a forming force of the delta, was made use as an important means of transportation. At the river network era, the meeting points of water courses were the premier location of settlements. Economic, cultural and productive activities were inseparably connected to water system. However, the road network has taken over water network as the most important means of transportation since 1980s. The massive growth of industrial products and rapid-access demand stimulated the explosive extension of road network. Ever since the highway system development and the growth of private cars in mid 1990s, the highway network became a new attraction of extensive industrial

land use. The occupation of human activities can be seen attached more closely to the infrastructure network.

Delta under an ecological perspective

Deltas as ecosystems

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems (Millennium Ecosystem Assessment, 2005). In the context of this paper, the inhabitants including human and other organism in the Pearl River Delta and the environment of the delta as a whole constitute an ecosystem, which could also correspond to the complex system theory.

The ecosystem theory is highly relevant to urbanized and/or urbanizing delta study. The concept of an ecosystem provides a valuable framework for analyzing and acting on the linkages between people and the environment. For analysis and assessment, it is important to adopt a pragmatic view of ecosystem boundaries, depending on the questions being asked (MEA, 2005). However defining clear boundaries for ecosystems often proves difficult because many of the relevant fluxes and interactions necessary to understand the functioning of ecosystems extend far beyond the boundaries defined by political or biophysical reasons (Gómez-Baggethun et al., 2013).

Within the delta, ecosystems can be categorized in different themes, depending on the aim of the study. They also share a suite of biological, climatic, and social factors that tend to differ across categories (MEA, 2005). Those factors constitute the analytical foundation of the delta.

A bridge between the environment and human well-being

Ecosystem services are the benefits that people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on earth (MEA, 2005). Deltas as one the most active habitats in the biosphere, constantly provides different ecosystem services to their inhabitants. For instance, the dyke-pond system is considered an integrated sustainable ecosystem intervened by human for agricultural production. It provides the habitat for fish, mulberry tree, silk and human themselves. Through water retention and dyke construction, the impact of flooding is mitigated. Beyond

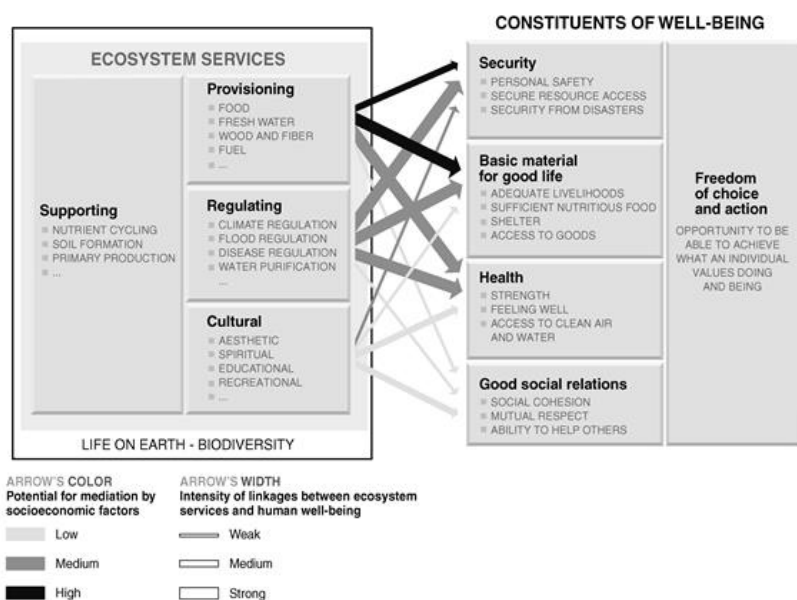


Figure 5: Linkages between ecosystem services and human well-being

Source: Millennium Ecosystem Assessment, 2005

the unique landscape constructed in the delta, different kinds of culture related to water and agriculture are bred.

It is important to recognize the multidimensional web of ecological and social interactions humans depend on for their well-being which is complex and may change over time. The term “well-being” not only refer to personal and social functioning but also needs to be understood at the supra-individual level, since some aspects of it are primarily a collective experience or the property of a community (MEA, 2005). The sustainable well-being of a community at large depends on the continued flow of ecosystem services, and on the distribution of benefits and costs. A further important criterion of well-being is the capacity to adapt in situation of change and to do so without compromising the well-being of others, either now or in the future (MEA, 2005).

In the context of urban planning, urban ecosystems are often portrayed as embedding both the built infrastructure and the ecological infrastructure. The concept of ecological infrastructure captures the role that water and vegetation in or near the built environment play in delivering ecosystem services at different spatial scales. It includes all green and blue spaces that may be found in urban and peri-urban areas (Gómez-Baggethun et al., 2013). Compared to natural ecosystem, ecosystems related to urban development are to meet urban ecosystem service demands in particular, which has its own preferences.

Unpredictable future: the changing conditions

To be more aware of the environment and its complexity and uncertainty is important for the vitality of the system and its subsystems. The adaptation of the delta to developments and events with an impact on the area can be improved by exploring uncertainty

more systematically (Dammers et al., 2014). In the Pearl River Delta, uncertainty of several aspects may have key impacts on the direction in which the delta will change. Those uncertainties may be opportunities but dealing with them is an inevitable challenge.

Climate change

The widely used term, “climate change” may refer to a change in average weather condition or in the time variation of weather around longer-term average conditions and often linked to global warming as well as sea level rise. Though climate change is now a proved fact, the change on specific area is relatively quite different.

The impact of climate change on the Pearl River Delta concerning weather, coastal erosion, flooding etc. has been studied by many scholars (Gu and Yang, 2008; Sun et al., 2015). As confirmed, high temperature, increased change rate of precipitation, warmer winter and more disruptive weather events is predicted. As a result, urban development, agriculture and water management is confronting more stress.

Economic restructuring and urban development

In the past thirty years, labor-intensive manufacturing industries driven by direct foreign investment and rural industrialization supported by local forces have greatly influence the economic, demographical and land use structure in the Pearl River Delta. However, the loss of attractiveness due to the rise of cost on labor and land has put those conventional manufacturing industries into a bottleneck (Chen, 2008). A new wave of economic restructuring has been advocated and the mode of extensive exploitation of water and land resource will come to an end. As a result, new conditions of water management and urban development are expected to be seen in the near future.

Preferences and value shift

As the economic values once dominated in the mode of urban development which left environment polluted and the ignorance of spatial quality, the rising awareness of ecological values has gradually led to a value shift. In a period of time, economic values were considered the primary aim. The accumulation of manufactured capital was achieved at the cost of natural capital and the cost of social capital. However, in the longer term, those neglected ecological, cultural and social values are proved to be at least as important as economic values. Thus the way to utilize water and land resource and mode to develop will be challenged by multidimensional values. Ecological value, as it closely connected to the well-being of inhabitants, will be more emphasized.

Towards an adaptive and sustainable delta urbanism

In this chapter the transitional ideas about dealing with the interrelationship between natural processes and human activities will be discussed. After that some recommendations will be presented for developing an adaptive framework which help designers, planners and actors to make assessment of their activities, to reflect on them and to generate new ways of thinking and acting (Dammers et al., 2014).

Comparative pathways on ideas shift

As for the rising awareness that the world we are living in is experiencing a process of some significant changes such as climate change, urban spatial reconfiguration, caused by both natural processes and human activities, the ideas about how to cope with the surrounding systems and deal with the complexity of different agencies are evolving over time.

For example, the key issue, water in delta areas has drawn much more concern than ever before. Measures coping with water taken by human are always being examined by practice since the first settlements appeared in delta areas. In the Netherlands, the Dutch has long understood that living in the deltas means living with water.

The Netherlands sits at the northwest corner of the great European plain, and two-thirds of the country is at or below sea level. The Dutch landscape was constantly shaped by water, wind-driven wave energy, sand dispersion, and sedimentation. The Delta Project implemented after the North Sea storm surge of 1953 is an example of rational comprehensive planning which indicates a change from trial and error to probabilistic approach in hydraulic engineering in the recent past. Though the objective that taming the water and enhancing the water safety was achieved, the project had serious impacts on water systems, ecology and the economy (Meyer, 2009). In recent years, developing and adopting an approach that works with nature in an interdisciplinary way has become a major challenge (Stive and Vrijling, 2010). Nowadays, a paradigm shift from “building in nature” to “building with nature” implies designing infrastructure is aligned with natural processes rather than working against them, and that is adaptable to cope with changing conditions such as sea level rise and climate change (Ecoshape, 2012).

The Pearl River Delta in China has walked through a similar pathway. For agricultural cultivation and fertile land reclamation, dykes and sluices were built to enclose the flood plains along the rivers since 10th century. A unique artificial landscape which spread over the central delta area was formed by building dykes and ponds in low-lying land. As the economy grew strong, a larger scale of water management construction which mainly consist of dyke rings were built to ensure irrigation and safety of settlement through trial and error. Limited by technologies and incongruous execution, the dykes

were often breached by high-peak discharges. Since 1949, a holistic approach that taking measures to reinforce existing dykes and enlarge the capacities of reservoirs in upstream by building dams has been adopted, benefited from technical advancement and economic growth. However, the disruptive floods in the past 50 years seemingly remind us that water and the power of nature is an invincible enemy. The devastating flood in 1994 breached 1502 km dykes and 2060 sluices. Causing 371 casualties and affecting 13 million people in the area, the flood plagued 1.25 million hm² farmland (Guangdong Provincial Bureau of Beijiang River Basin Administration, 2007). In 2016, as the wet season is coming, it is predicted that the Pearl River Delta will face a severe test from excessive discharges affected by El Niño (Pearl River Flood Control and Drought Headquarters, 2016). Conventional engineering-oriented approach can no longer perfectly cope with the rapidly changing circumstance.

Many scholars who focuses on the interrelation between human activities and water infrastructure have realized that it is not realistic to solely heighten or strengthen the dyke to resist water from threatening urban development. Restoring the fill-up courses and stuffed ponds as well as other technical solutions may be possible measures to take. But moreover a new approach which balance the sustainable functioning of ecosystems with the demand for their development should be adopted. It is rather an interdisciplinary challenge than a single-perspective one. The shift of ideas about working with nature has occurred.

Recommendations for adaptive frameworks

In general, an adaptive framework can be used as a basis for sustainable development in delta regions. But for proper use of the framework, there are some recommendation when developing an

adaptive framework. Considering the complexity of the systems and subsystems, there should be a consensus of the boundary of the system.

Determine the agencies and actors which characterized the system/ecosystem in the delta area.

When building up a framework or making a plan, the issues that need to be tackled should be clear and well-informed. The current conditions and the incoming conditions are equally important to define the problems.

Identify the challenges the framework aims to deal with and the opportunities that could be utilized.

To achieve adaptive and sustainable development in urban delta regions, measures must be taken to protect the ecosystems from negative effects to prevent deterioration of ecosystem services demanded in delta regions. The adaptive framework does not provide a must-achieve objectives. The actors and planners can propose their preferences within the extent of the framework. The ecosystem service concept can be used as an indication in respect of the goals to achieve. The concept can also be used to demonstrate the potential benefits and the goods/services ecosystem provides.

Set up the criteria or assessment of the new equilibrium to be achieved.

There will always be gaps between different actors which vary on knowledge, preference and benefit. It is necessary to develop a common understanding among actors in order to form stable cooperation between them.

Develop a common level of knowledge and a regular means of communication.

Adaptive frameworks are not result-oriented but rather process-oriented. Instead of creating a comprehensive execution plan, adaptive frameworks are always ready to be fixed and updated. Actors and planners should constantly respond to the changing conditions and adding new preferences.

Regularly monitor the progress made by the framework, reflect on them and timely respond to and update the framework.

Adaptive frameworks should be able to adapt to not only moderate changes over time but also disruptive events at an unpredictable time.

Make preparation of immediate reacting measures in case of disruptive events or emergency.

Conclusion

The objective of this paper is to build up a theoretical framework for an adaptive framework which may be applied in the Pearl River Delta. This paper attempt to integrate available knowledge from systematic perspective. The delta is regarded as a complex system in which different actors and subsystem interact with each other that properly represents the current situation of the delta. This approach helps to

understand the complexity and of the delta as a system. It also indicates the uncertainty the delta may be confronted as a complex system. To better evaluate the functionality of the delta system, the ecosystem service concept is introduced to provide insight on the relevance of inhabitant well-being. In this paper, the changing conditions of the Pearl River Delta as examples are discussed. Based on the theories mentioned above, some recommendations for formulating an adaptive framework are presented.

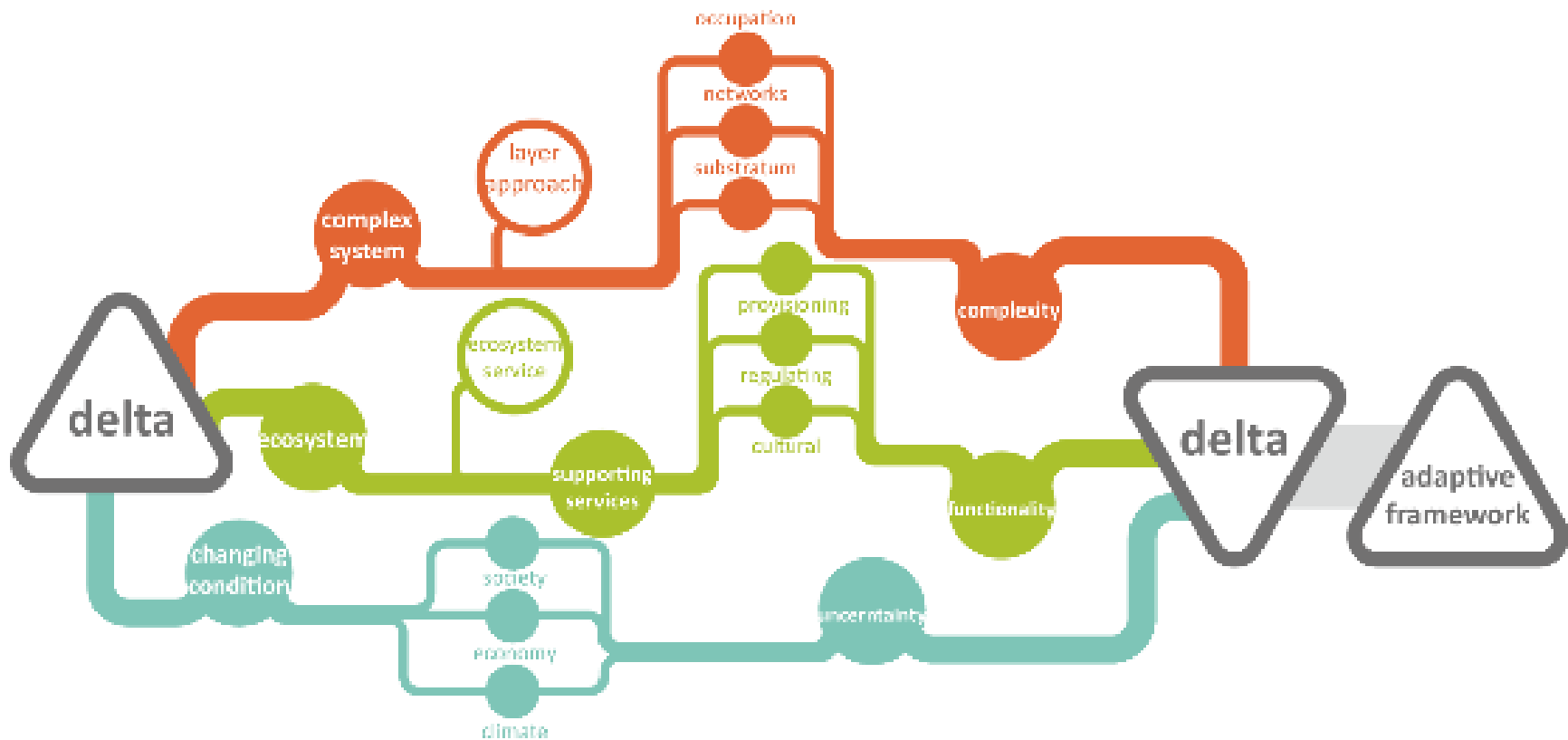


Figure 6: Theoretical framework

Source: by author

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