Constructing community circular economy:

A solution to address landscape simplification in the traditional aquaculture area of the Pearl River Delta

Project Statement:

In the context of global specialized production, market demand for aquaculture has driven traditional dike-pond areas to shift from multifunctional aquaculture systems to monoculture modes, leading to decreased biodiversity and reduced landscape heterogeneity, resulting in landscape simplification. Taking the dike-pond system in the Pearl River Delta as an example, the project aims to re-establish a community-based circular economy while maintaining the current production level of the system, to provide comprehensive solutions for traditional dike-pond areas worldwide threatened by landscape simplification.

Firstly, by assessing production suitability, we divide the area into intensive aquaculture areas, arable cultivation areas, and artificial wetland areas. These three functional zones aim to reduce resource waste and demand through new material cycles and minimize waste generation, while maintaining local community economic income.

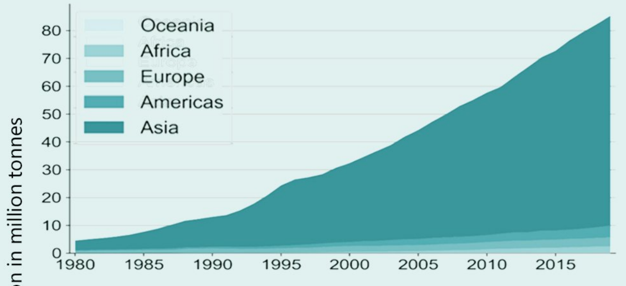
Secondly, the project proposes new governance schemes for the dike-pond areas to ensure smooth operation of material cycles within the community, including regular pond mud transportation and wastewater purification.

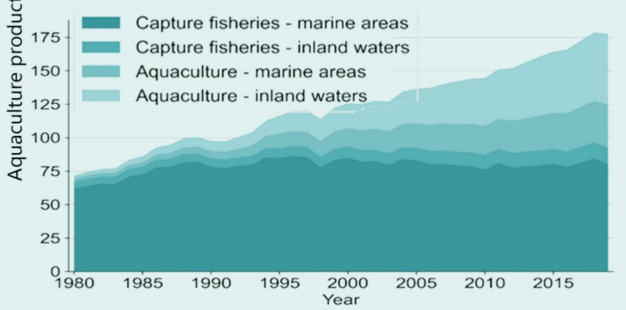
By establishing an ecological material circulation system and community governance system, this project offers practical nature-based solutions to mitigate the negative impacts of landscape simplification on traditional agricultural areas, improving the ecological environment and enhancing the overall value of ecosystem services.

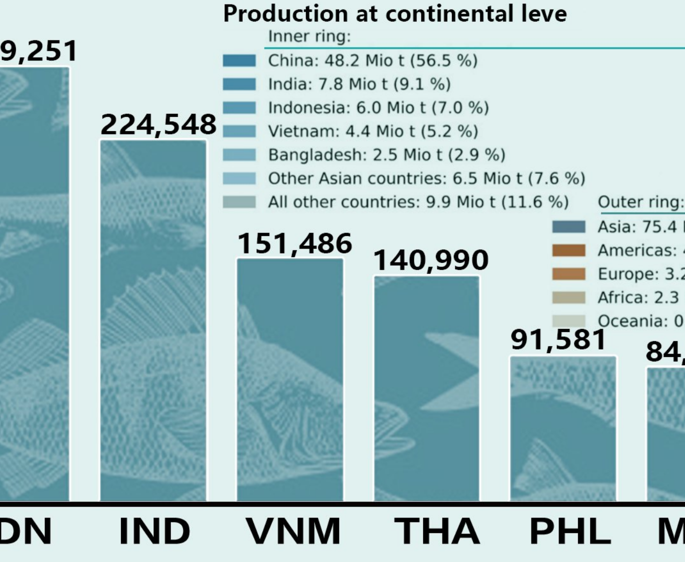
BACKGROUND & SITES ANALYSIS

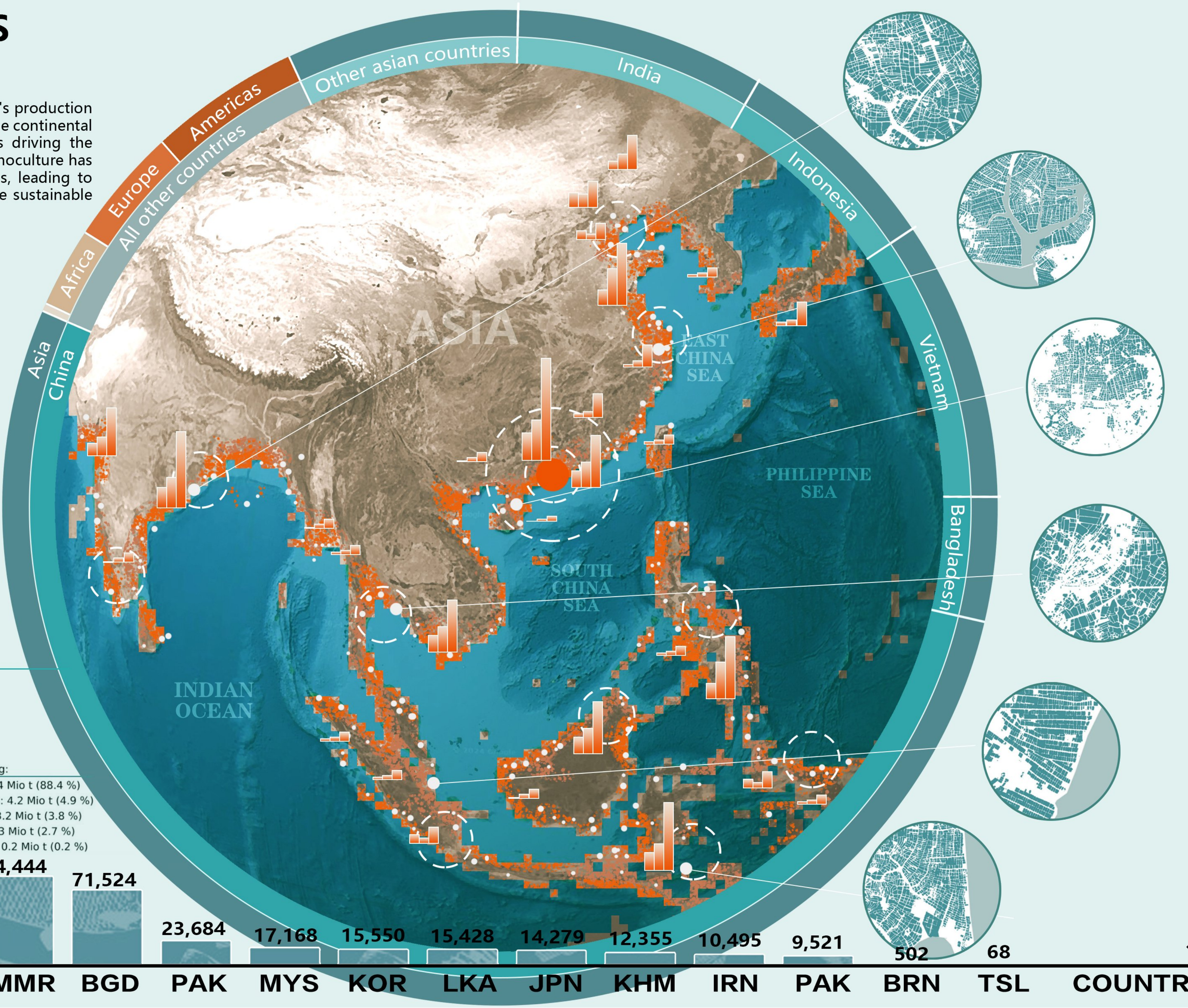
Background

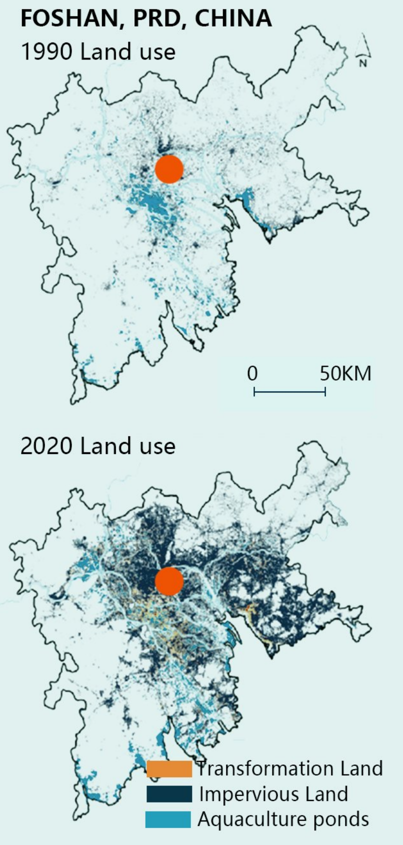
Aquaculture has expanded globally, with 88.4% of the world's production concentrated in Asia, where China accounts for over half of the continental output. Increasing demand for fish, especially in Asia, is driving the growth of aquaculture landscapes. Over recent decades, monoculture has replaced traditional multifunctional systems to boost yields, leading to landscape simplification that poses significant threats to the sustainable development of traditional aquaculture regions.



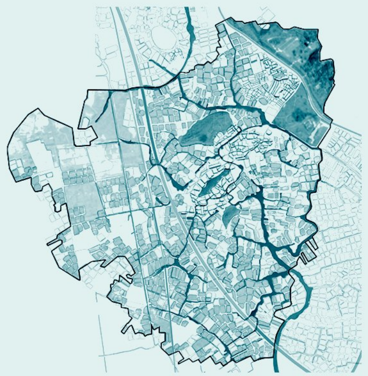








SITE-RUXI VILLAGE

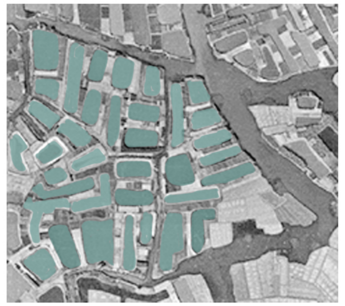


Data & Chart Source:
Tian, P., Liu, Y., Li, J., Pu, R., Cao, L., Zhang, H., ... & Yang, Y. (2022). Mapping coastal aquaculture ponds of China using sentinel SAR images in 2020 and google earth engine. Remote Sensing, 14(21), 5372.

Aquaculture landscapes are expanding due to the demand for fish products, especially in Asia. Affected by global markets, the multifunctional aquaculture systems have been replaced by the monoculture modes to increase yields. As a result, landscape simplification is becoming the main issue threating the sustainable development of the traditional aquaculture areas, one of which is the Pearl River Delta in South China. As one of the high-density aquaculture regions globally, aquaculture brings economic benefit as well as severe environmental problems.

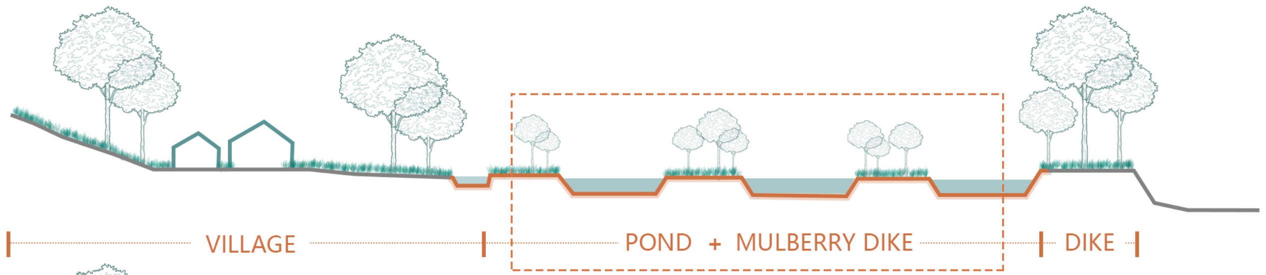
LANDSCAPE SIMPLIFICATION OF THE TRADITIONAL DIKE-POND SYSTEM

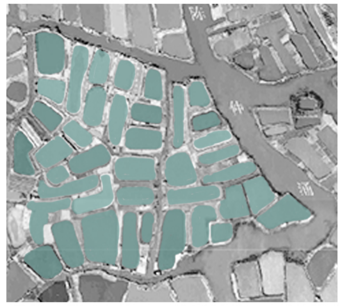
PROCESS OF LANDSCAPE SIMPLIFICATION



1989

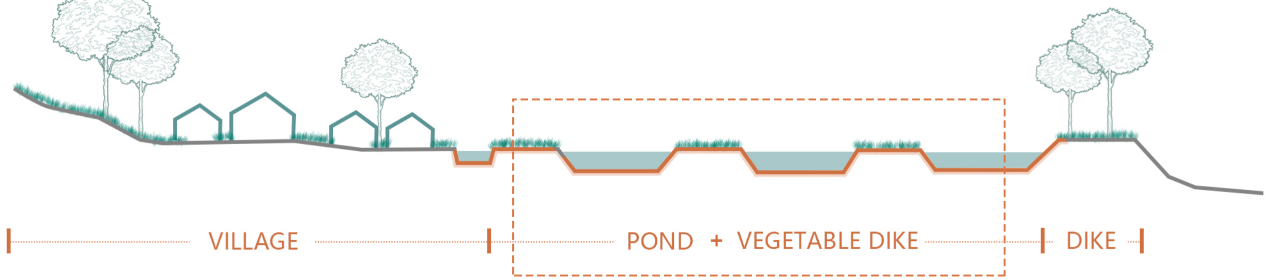
The system is combined with ponds and arable lands.

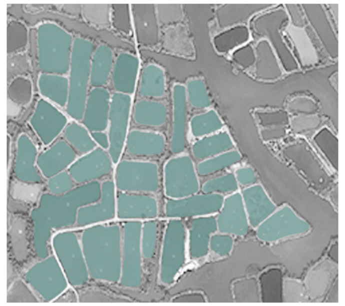




1999

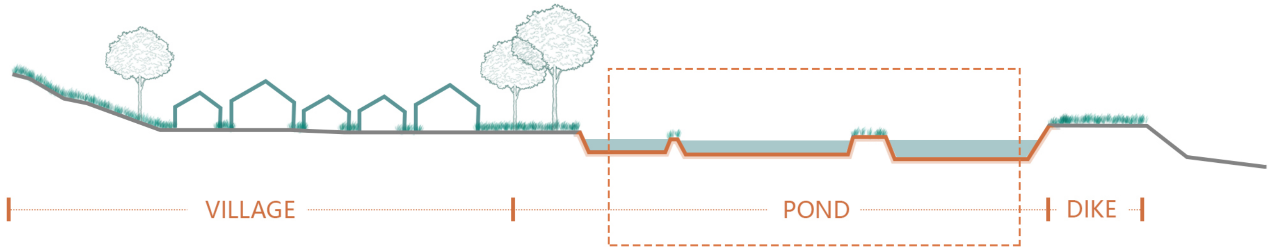
Ponds were expanded for aquaculture, arable lands shrunk.





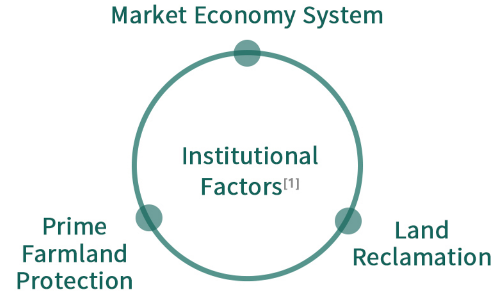
2016

Almost all of the arable lands were transformed into intensive ponds.

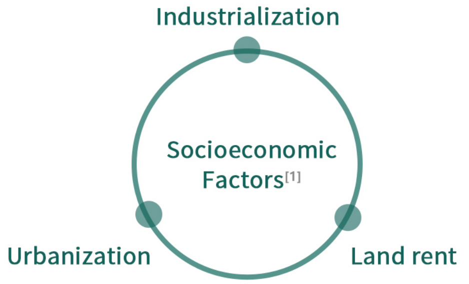


DRIVERS OF SIMPLIFICATION

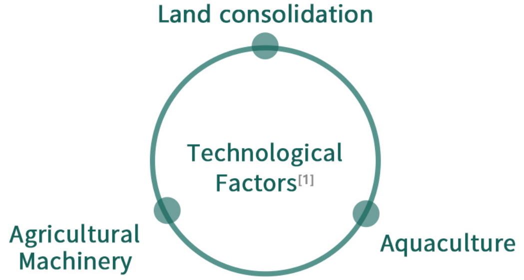
With the capitalization of land, the transition from production cooperation to economic relations has occurred both at the community level and among farmers, marking a shift in the institutional environment.



After the reform and opening up, the development of the market economy led to the rise of commodity fish production and aquaculture market.

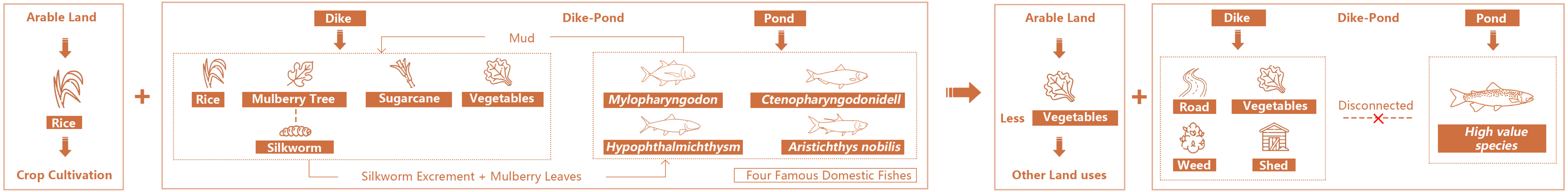


Technological advancements include the development of oxygenation equipment, artificial feeds, and seedling improvement.



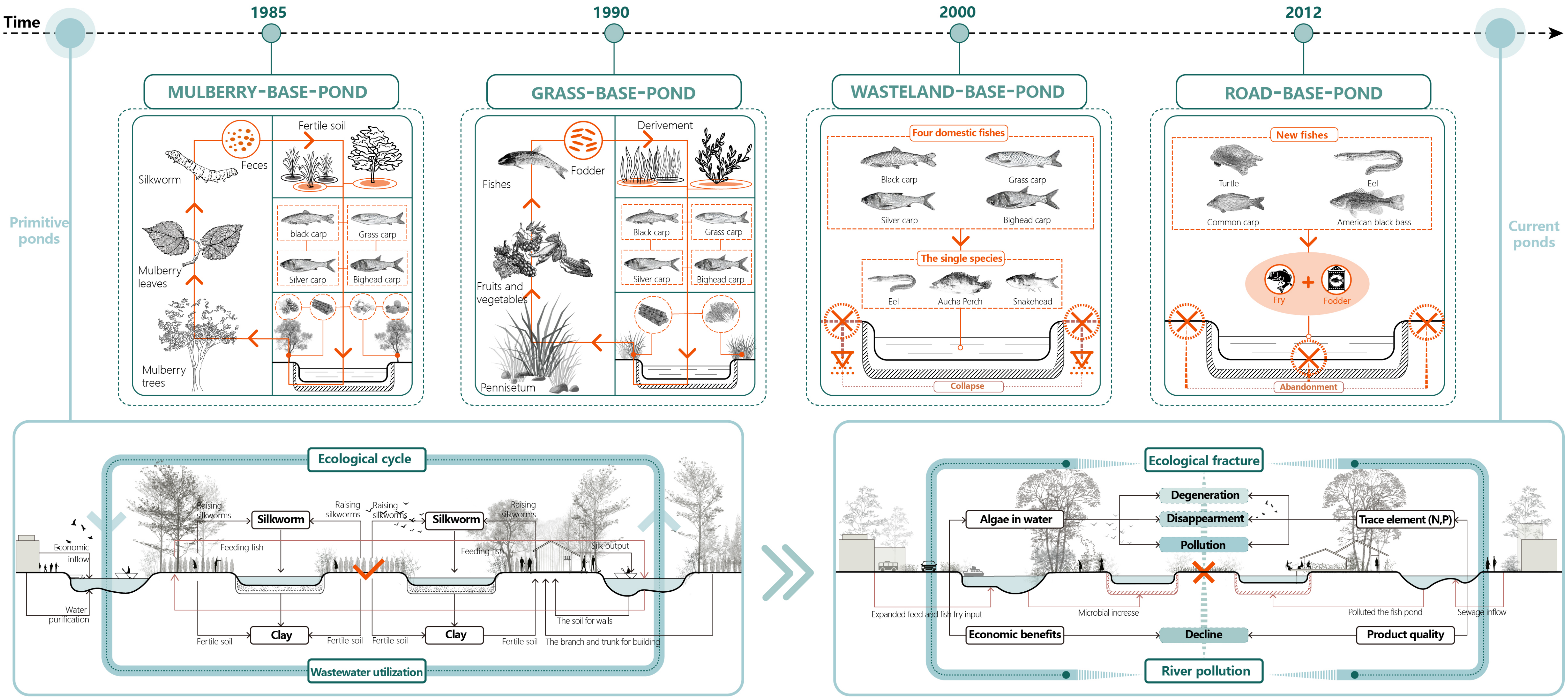
[1]Chen CX,Huang GQ, Ye YY, et al. (2021). Change and ecological restoration of the dike-pond system in the Pearl River Delta: Acase study of four villages in Foshan City. Resources Science. 43(2): 328-340.

THE SHIFT IN PRODUCTION MODE OF THE SYSTEM



Due to institutional, socioeconomic, and technological factors, the landscape structure of the dike-pond system has changed, resulting in landscape simplification. Firstly, extensive farmlands and dikes have been converted into water bodies, resulting in the reduction of the proportion of arable dikes and the transformation of the original landscape patterns. Secondly, crop cultivation activities on the dikes have been abandoned, causing the decline in the landscape elements.

SPECIFIC ANALYSIS OF SIMPLIFIED LANDSCAPE WITHIN THE SITE

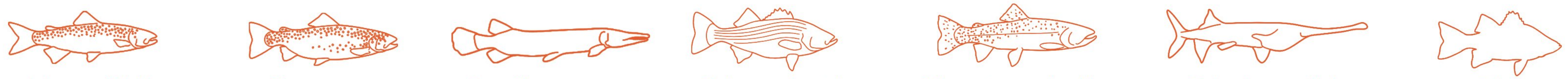


We believe the key site issue is the disruption of the previous cycle model. This led to a linear production model characterized by high input, unstable yields, inadequate waste utilization, and water eutrophication.

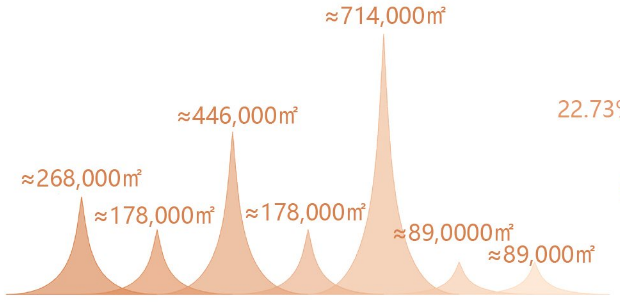
NEGATIVE IMPACTS OF LANDSCAPE SIMPLIFICATION

CONDITIONS OF INTENSIVE AQUACULTURE: The new aquaculture mode broke the original cycle and brought negative impacts.

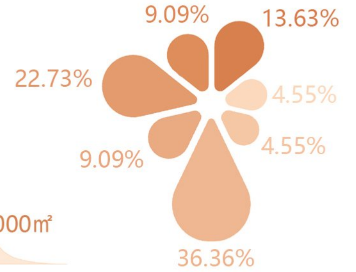
Main species



Pseudobagras fulvidrace	*Channa argus*	*Anguilla marmorata*	*Siniperca chuatsi*	*Micropterus salmoides*	*Polyodon spathula*	Others
Breeding Cycle: 1 year	Breeding Cycle: 1.5 years	Breeding Cycle: 2 years	Breeding Cycle: 1 years	Breeding Cycle: 8 months	Breeding Cycle: 1 year	



Farming Area of Different Species



Proportion

WATER EUTROPHICATION

Source

- EXCESS FEED
- FISH FECES
- AQUACULTURE DRUGS

Components

- AMMONIA
- NITROGEN
- PHOSPHORUS

Negative Impacts

WATER EUTROPHICATION

Ineffective monitoring by regulatory authorities on water discharge results in deteriorating water quality in rivers and streams.

POND MUD ACCUMULATION

Source

- EXCESS FEED
- FISH FECES
- FISH CARCASS

Components

- SUSPENDED SOLIDS
- SETTLED SOLIDS

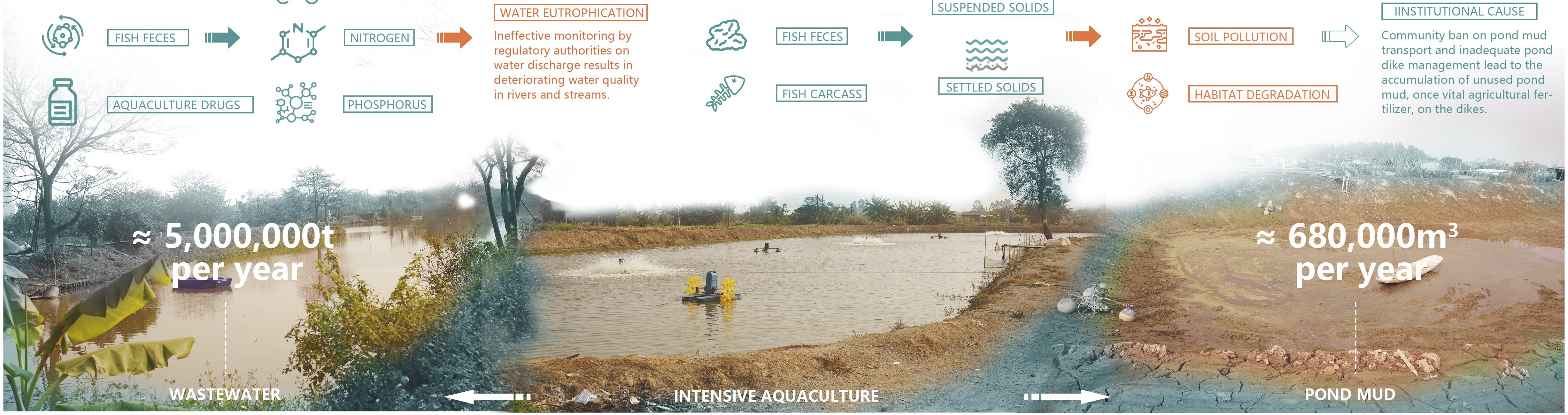
Negative Impact

- DIFFICULT TO REMOVE
- SOIL POLLUTION
- HABITAT DEGRADATION

Further analysis

IINSTITUTIONAL CAUSE

Community ban on pond mud transport and inadequate pond dike management lead to the accumulation of unused pond mud, once vital agricultural fer-tilizer, on the dikes.

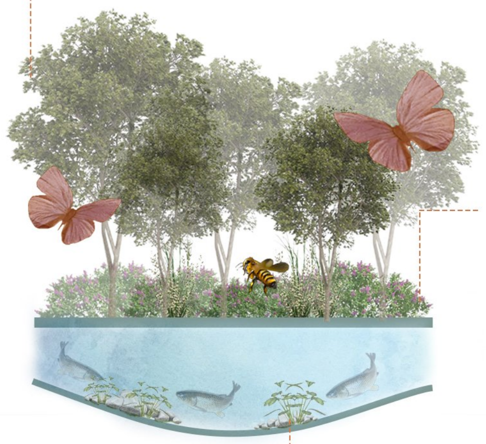


The intensive aquaculture system relies heavily on feed and drugs, and generates about 5 million tons of wastewater and 680,000 m3 of pond mud annually. Due to the lack of community regulation, pond mud accumulates on the dikes without decomposition, and wastewater discharge deteriorates the water quality of public rivers, resulting in water eutrophication and sediment accumulation.

NEGATIVE IMPACTS OF LANDSCAPE SIMPLIFICATION

REDUCTION IN BIODIVERSITY

Fruit Trees
Providing habitat for birds and other wildlife.



Flowers And Grass
Providing habitat for butterflies, bees, and other insects.

Aquatic Plants
Providing habitats for fish and amphibians.

Fruit Trees
Decreasing

Flowers And Grass
Decreasing

Species
The quantity of fish has increased, but the variety has decreased.

Aquatic Plants
Decreasing

INCREASED RISKS TO LIVELIHOODS

HIGH COSTS

Cost
For 1 ha

+ Lease
7,300 $

+ Seedling
62,800 $

+ Feed
52,000 $

+ Oxygen machine
18,000 $ per year

+ Fish medicine
900 $

140,000 $ per year

FISH DISEASES OUTBREAK

Intensive Aquaculture

Reduced Immunocompetence
Higher density weakens fish immune systems, leading to vulnerability to pathogens.

Disease Transmission
Pathogen spreading in high-density environments increase disease risks.

Deterioration of Water Quality
Accumulation of waste and pollutants in high-density aquaculture negatively affects fish health.

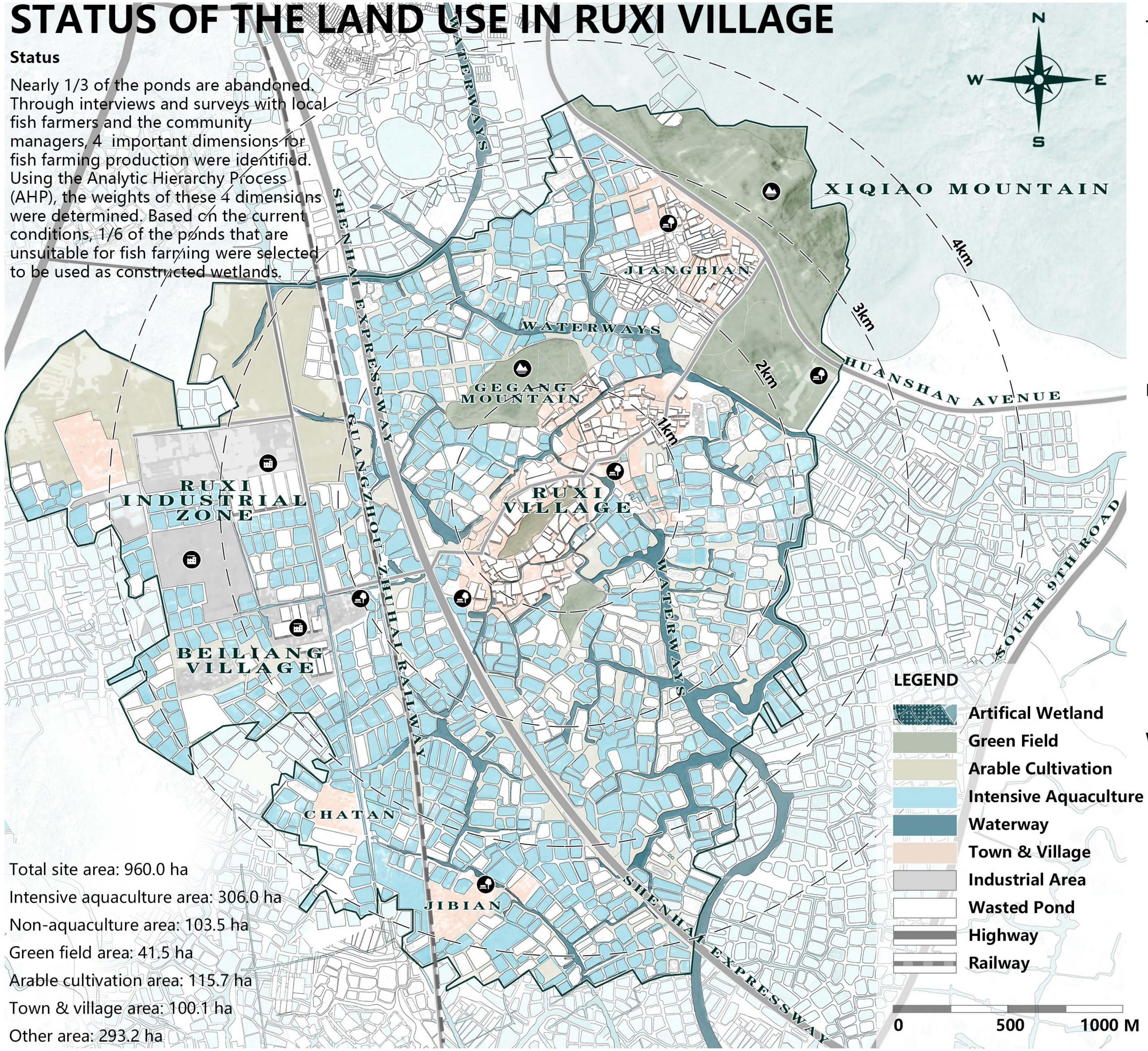
Outbreak of Fish Disease

Crop cultivation activities on the dikes have been abandoned, causing decline in biodiversity. Additionally, water eutrophication and sediment accumulation increase the risk of fish diseases, which ultimately pose a growing livelihood risk for farmers.

STATUS OF THE LAND USE IN RUXI VILLAGE

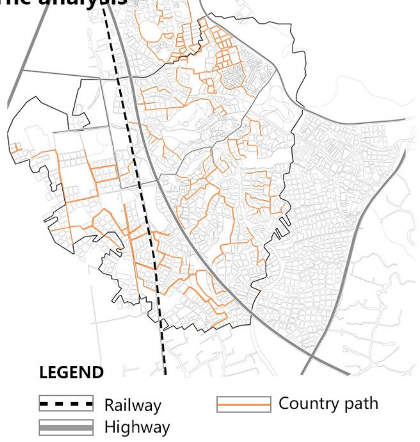
Status

Nearly 1/3 of the ponds are abandoned. Through interviews and surveys with local fish farmers and the community managers, 4 important dimensions for fish farming production were identified. Using the Analytic Hierarchy Process (AHP), the weights of these 4 dimensions were determined. Based on the current conditions, 1/6 of the ponds that are unsuitable for fish farming were selected to be used as constructed wetlands.

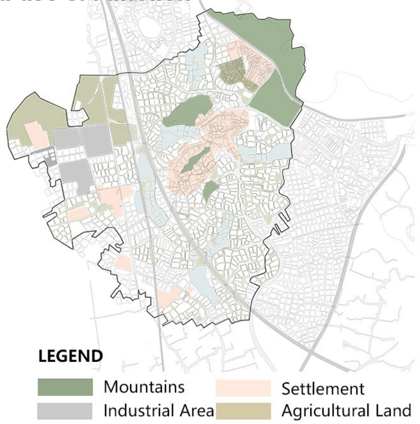


Total site area: 960.0 ha
Intensive aquaculture area: 306.0 ha
Non-aquaculture area: 103.5 ha
Green field area: 41.5 ha
Arable cultivation area: 115.7 ha
Town & village area: 100.1 ha
Other area: 293.2 ha

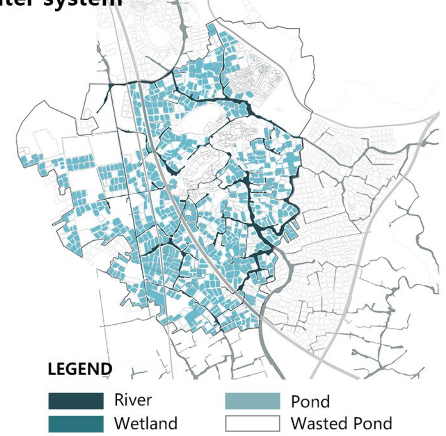
Traffic analysis



Land use & Function



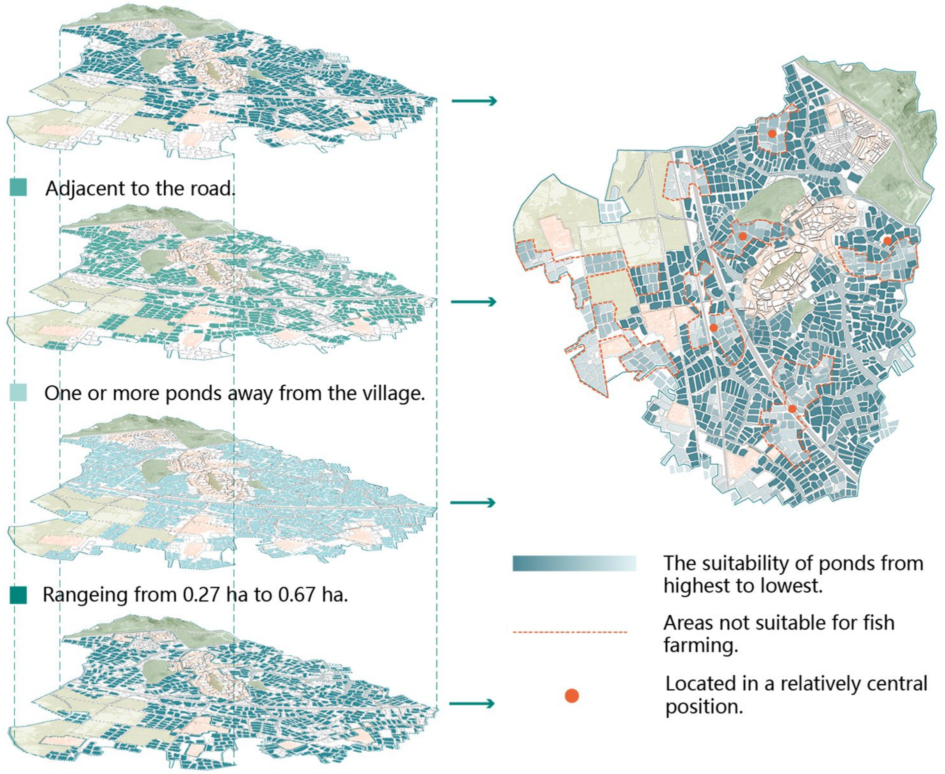
Water system



Analysis Framework for Production Suitability of Ponds

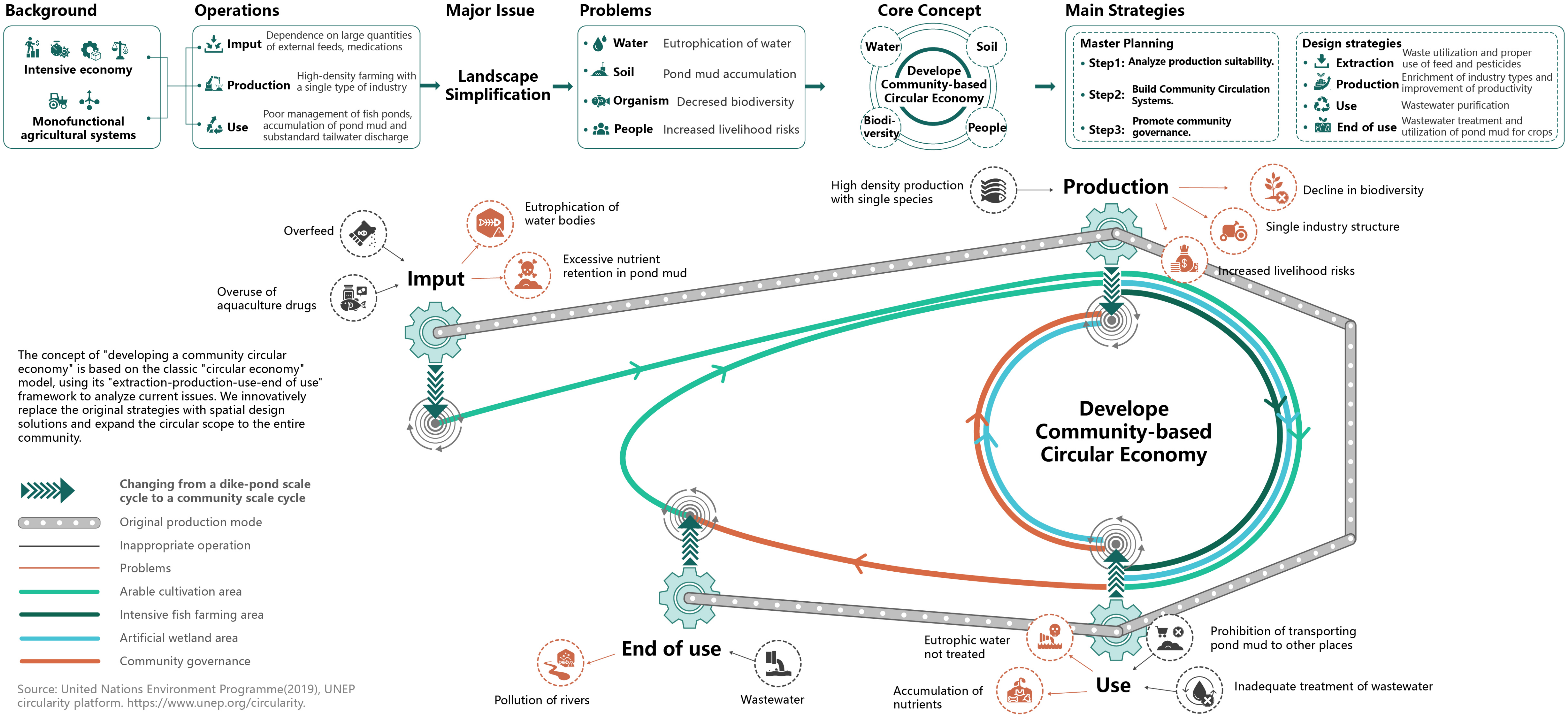
Indicator	Weight	Criterion Level	Score
Distance from river	0.54	Adjacent to the river or separated by only one pond.	1
		Two ponds or more away from the rivers.	0
Distance from roads	0.24	Adjacent to the road.	1
		One or more ponds away from the roads.	0
Distance from village	0.08	One or more ponds away from the village.	1
		Adjacent to the village (with domestic sewage).	0
Pond area	0.14	The area rangeing from 0.27 to 0.67 ha.	1
		Smaller than 0.27 ha or larger than 0.67 ha.	0

Results of Production Suitability Analysis



According to the survey, study area is 9,600,000 m², ponds area is 3,061,033 m², and 1/3 of the existing ponds were abandoned, the ponds were re-evaluated according to the production suitability. Through interviews and surveys with local fish farmers and the community managers, 4 important dimensions for fish farming production were identified. The weight of these 4 dimensions was determined using the Analytic Hierarchy Process (AHP). Based on the current conditions and considerations of distances, 1/6 of the ponds that are unsuitable for fish farming were selected to be used as constructed wetlands.

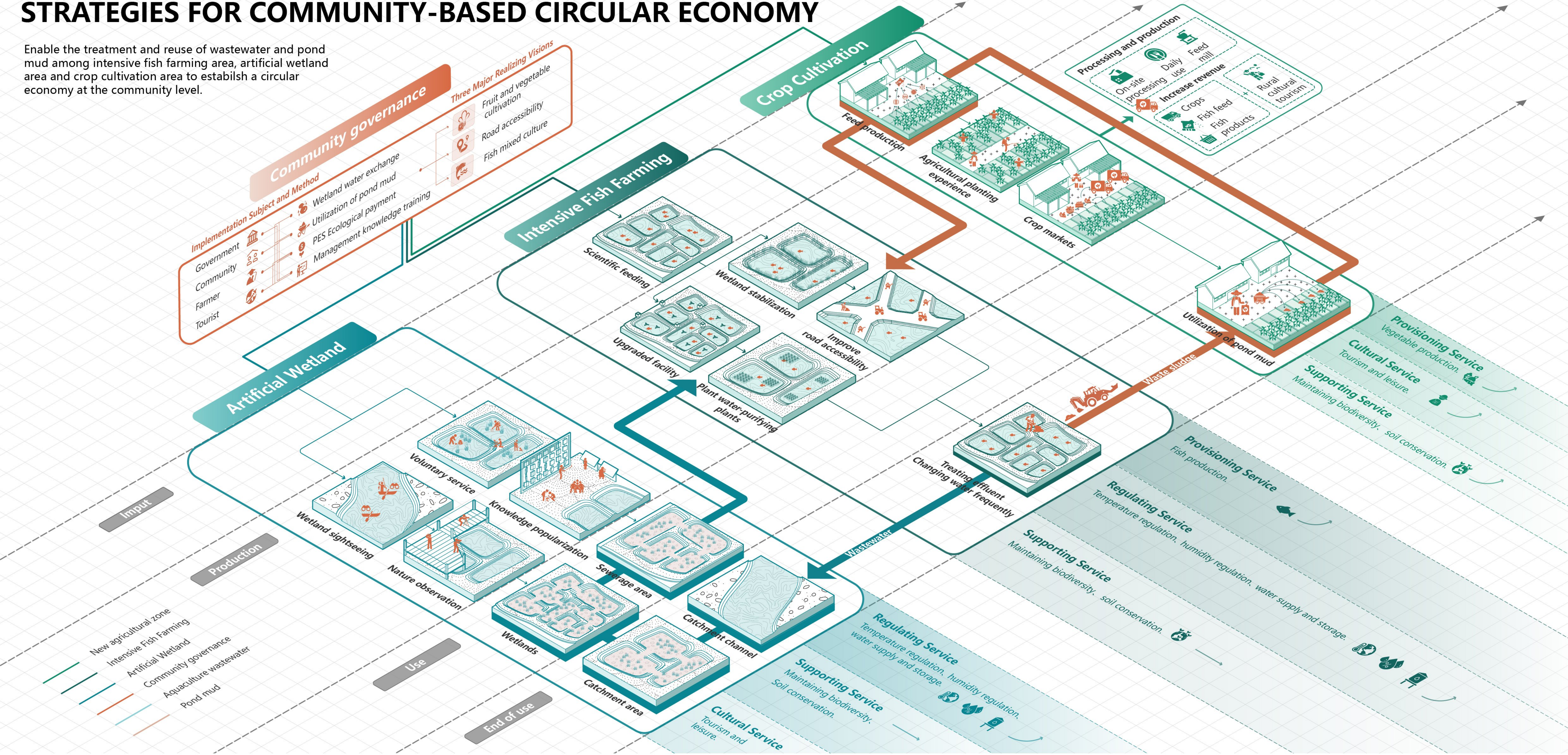
CONCEPT: COMMUNITY-BASED CIRCULAR ECONOMY



The concept of "developing a community circular economy" is based on the classic "circular economy" model. We applied the "extraction-production-use-end of use" framework to analyze current issues. We innovatively combined the original strategies with spatial design solutions and expanded the circular scope to the entire community.

STRATEGIES FOR COMMUNITY-BASED CIRCULAR ECONOMY

Enable the treatment and reuse of wastewater and pond mud among intensive fish farming area, artificial wetland area and crop cultivation area to estabilsh a circular economy at the community level.

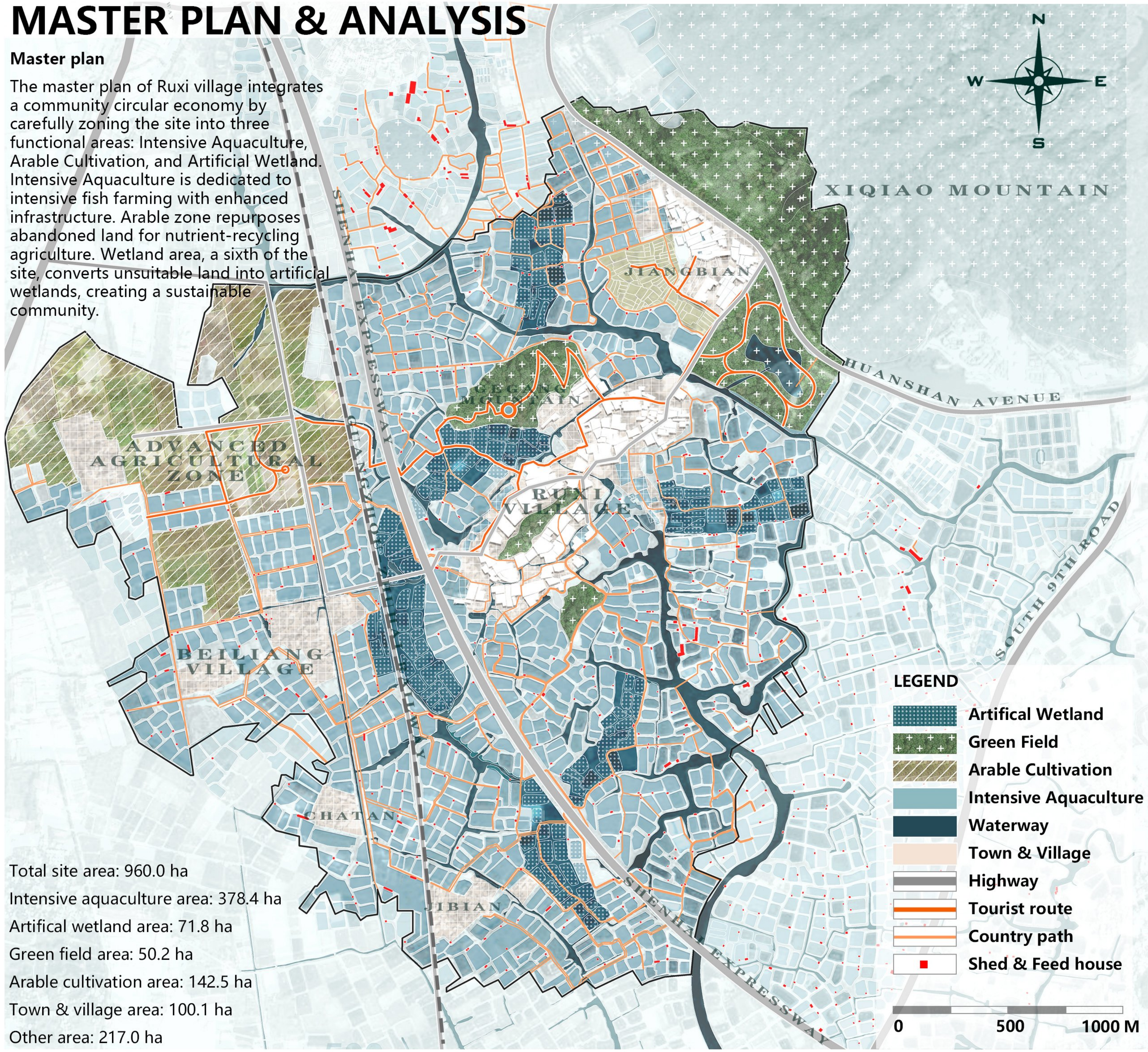


The community-based circular economy is established through the planning of intensive aquaculture area, artificial wetland area and arable cultivation area. Strategies have been adopted at each of the four stages of "extraction-production-use-end of use" in each of the three districts in order to reduce inputs at the source for the entire community, improve the efficiency of the production process, reduce the generation of waste during the production process, and enhance the purification of wastewater and the utilization of pond mud after use.

MASTER PLAN & ANALYSIS

Master plan

The master plan of Ruxi village integrates a community circular economy by carefully zoning the site into three functional areas: Intensive Aquaculture, Arable Cultivation, and Artificial Wetland. Intensive Aquaculture is dedicated to intensive fish farming with enhanced infrastructure. Arable zone repurposes abandoned land for nutrient-recycling agriculture. Wetland area, a sixth of the site, converts unsuitable land into artificial wetlands, creating a sustainable community.



Total site area: 960.0 ha

Intensive aquaculture area: 378.4 ha

Artifical wetland area: 71.8 ha

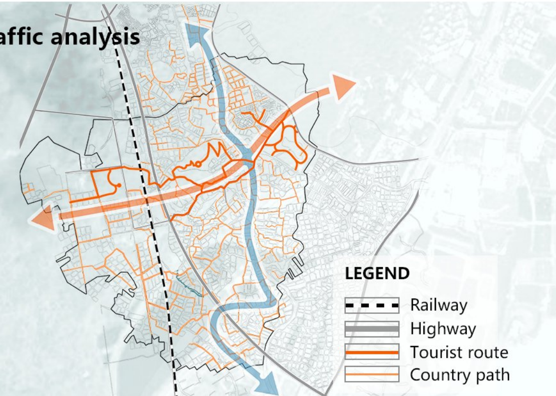
Green field area: 50.2 ha

Arable cultivation area: 142.5 ha

Town & village area: 100.1 ha

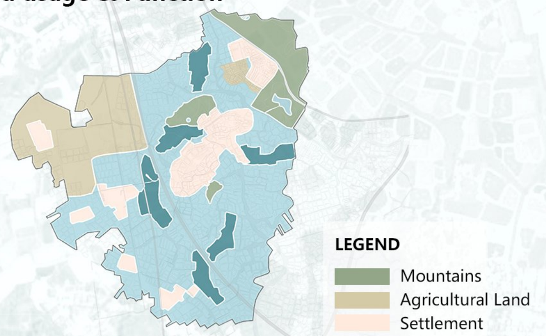
Other area: 217.0 ha

Traffic analysis



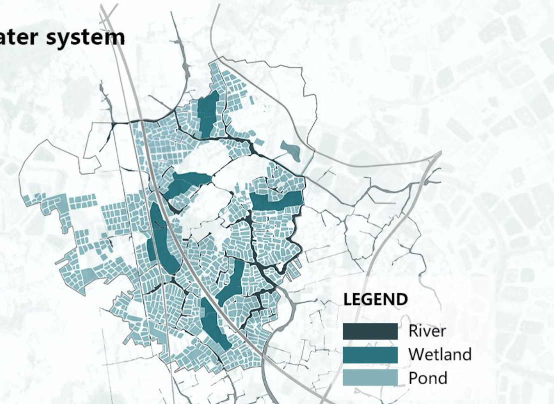
Tidying up of pond ridges and reshaping of paths to facilitate sightseeing, daily farming and mechanical transportation.

Land usage & Function



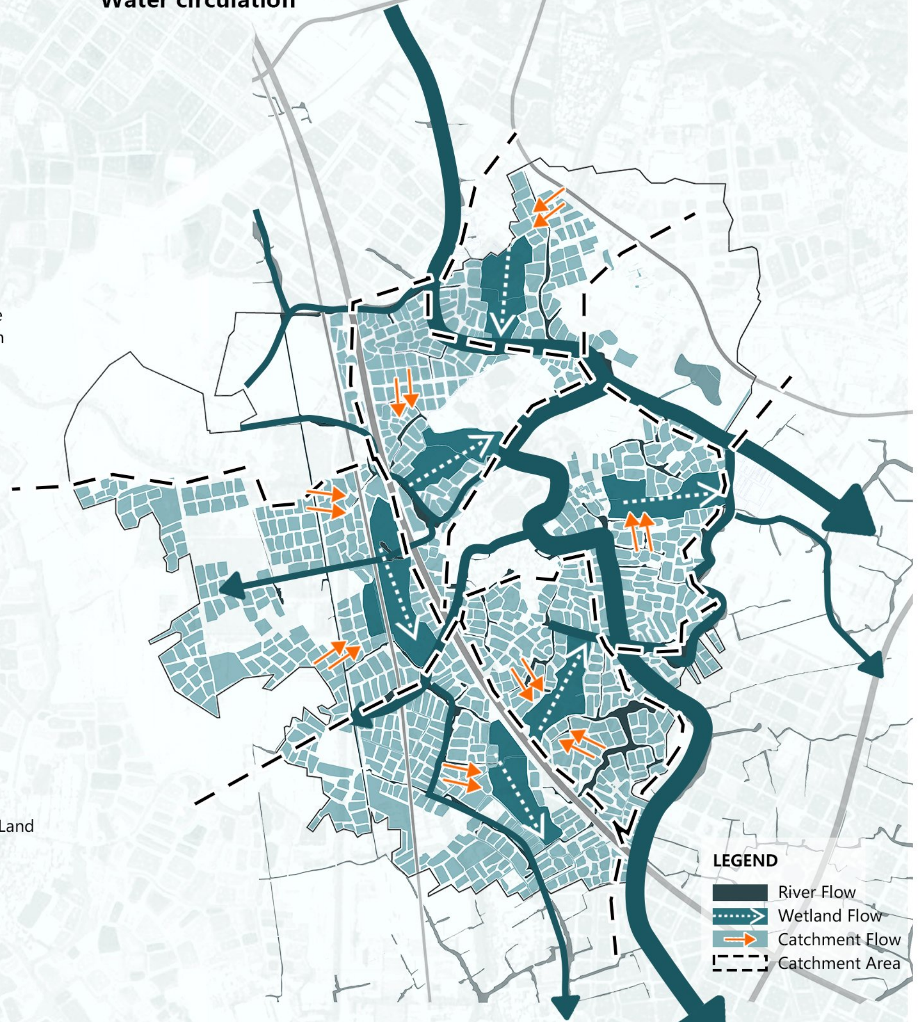
Consolidation of temporary industrial zones and development of new types of agriculture in conjunction with the tertiary sector.

Water system



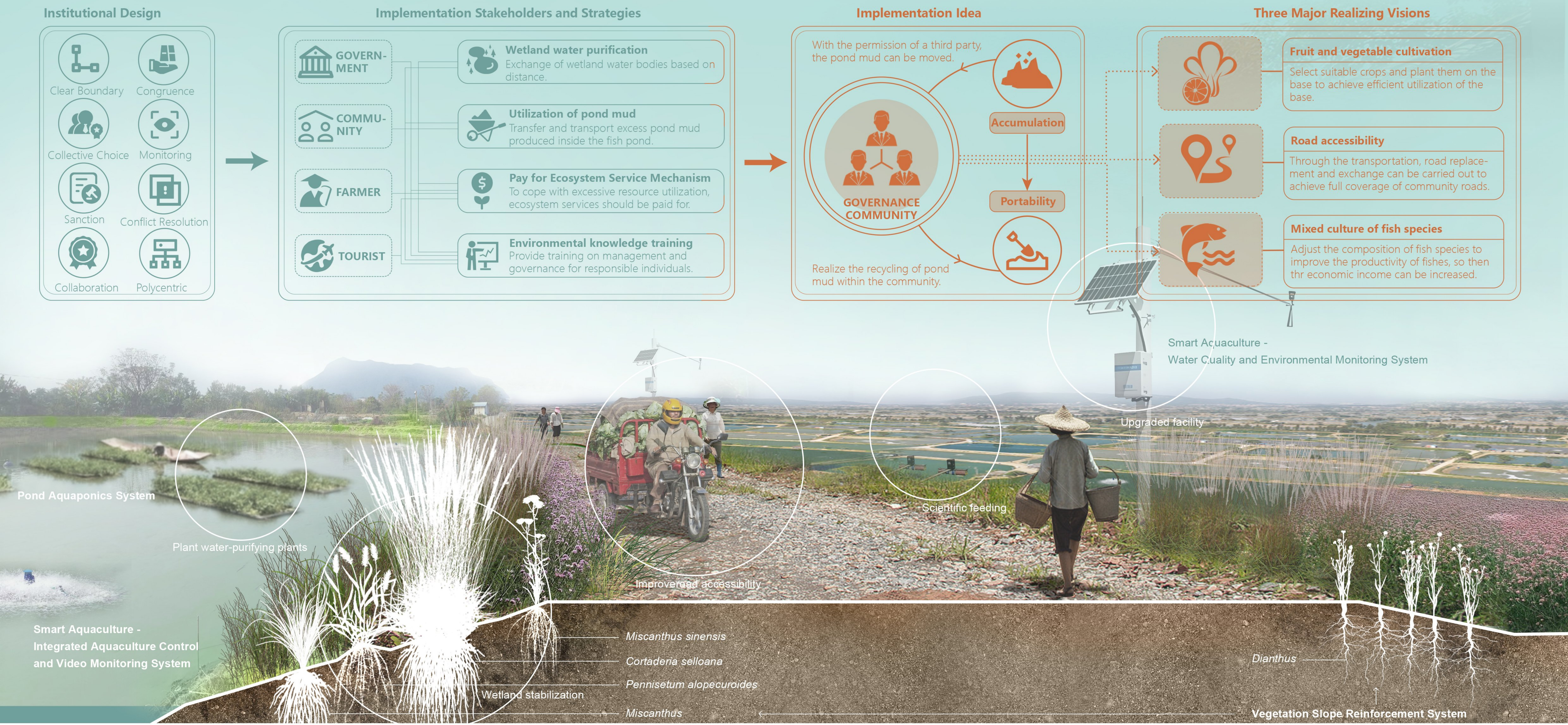
Reorganising derelict ponds, zoning and integrating artificial wetlands, and addressing the relationship with waterways.

Water circulation



The master plan of Ruxi village integrates a community circular economy by carefully zoning the site into three functional areas: Intensive Aquaculture, Arable Cultivation, and Artificial Wetland. Intensive Aquaculture is dedicated to intensive fish farming with enhanced infrastructure. Arable zone repurposes abandoned land for nutrient-recycling agriculture. Wetland area; a sixth of the site, converts unsuitable land into artifitial wetlands, creating a sustainable community.

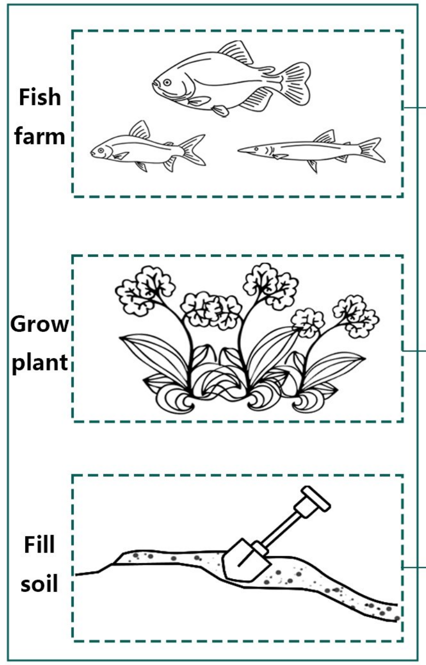
INTENSIVE FISH FARMING AREA



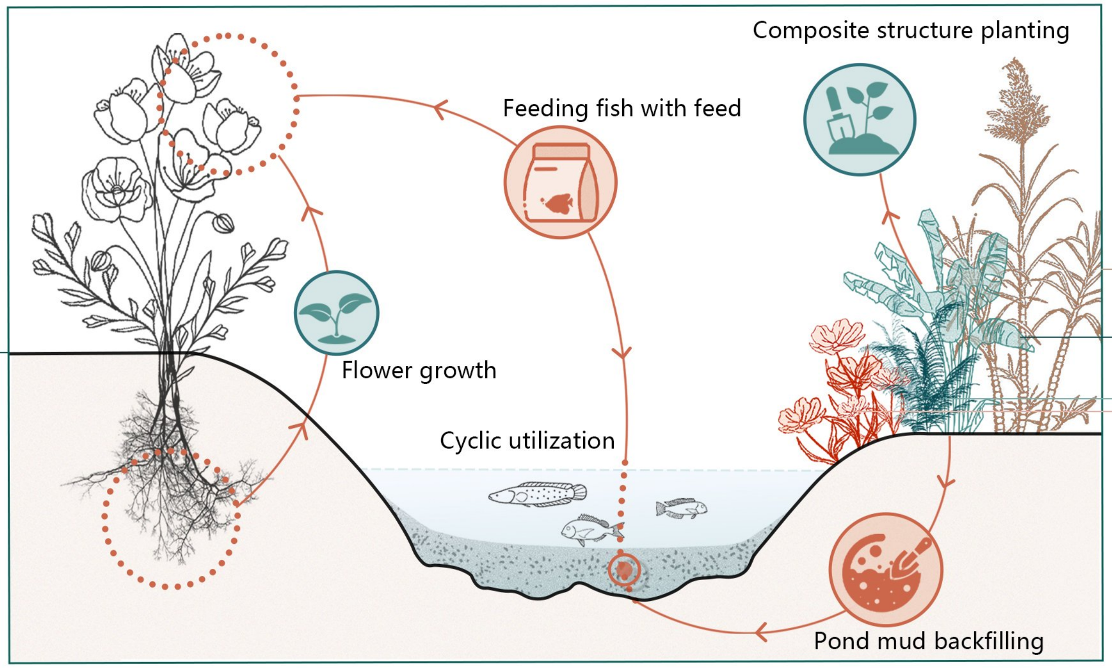
Intensive Aquaculture Area: The most suitable area for aquaculture (382 hectares) is reserved for intensive fish farming. By improving the production environment (e.g. infrastructure and water quality) and establishing community management regulations (e.g. scientific feeding methods and pond management), the aquaculture industry gets developed and farmers' livelihoods are ensured.

ARABLE CULTIVATION AREA

Consumption pathways



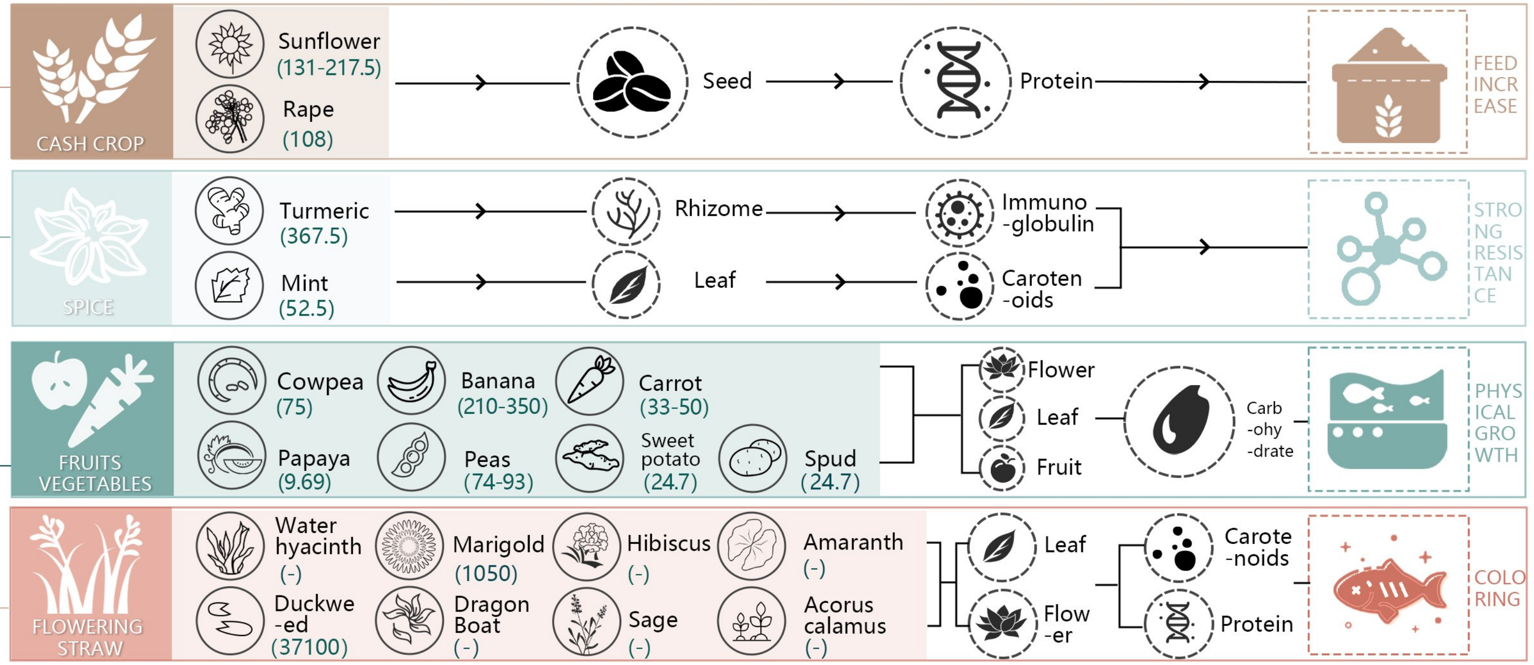
Transformation form



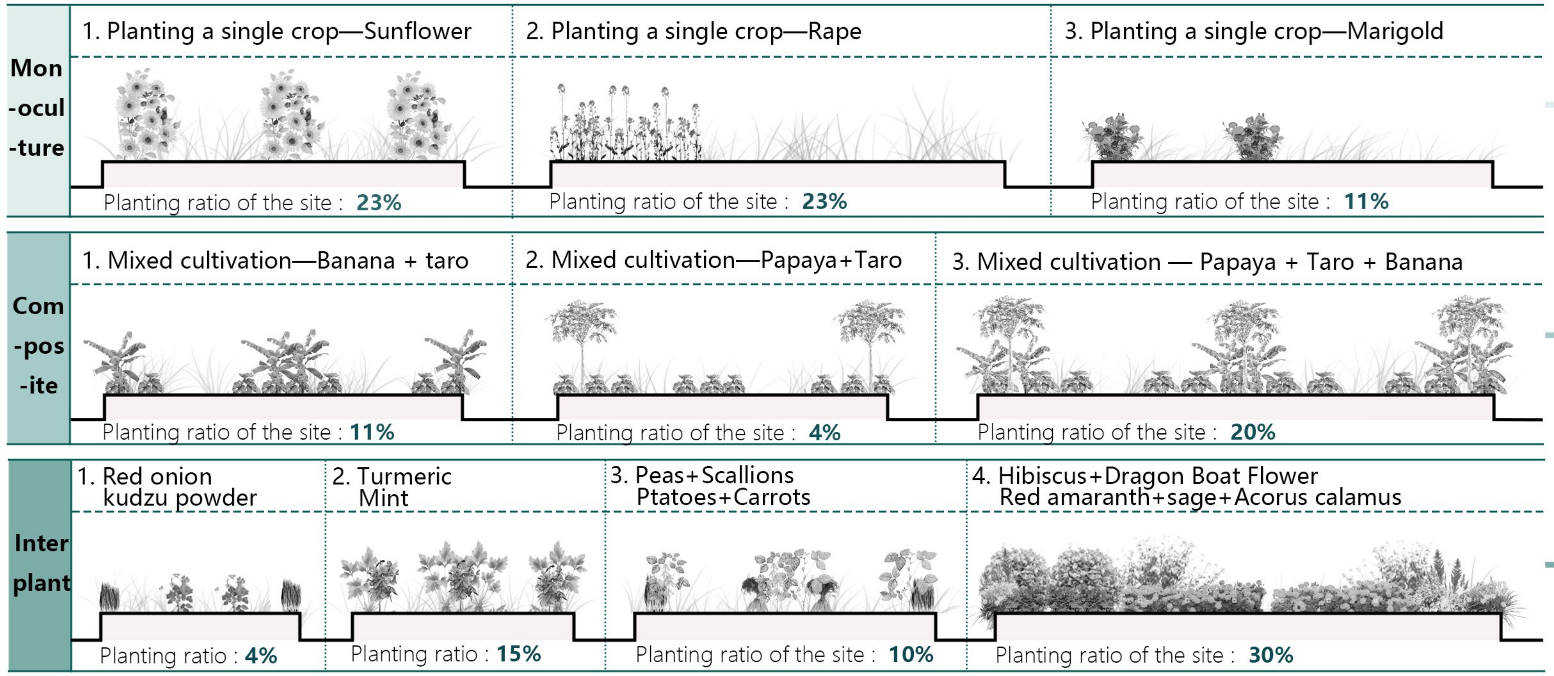
Crop selection and available processes

(x) the yield per mu of fish feed (the available part*0.35kg)

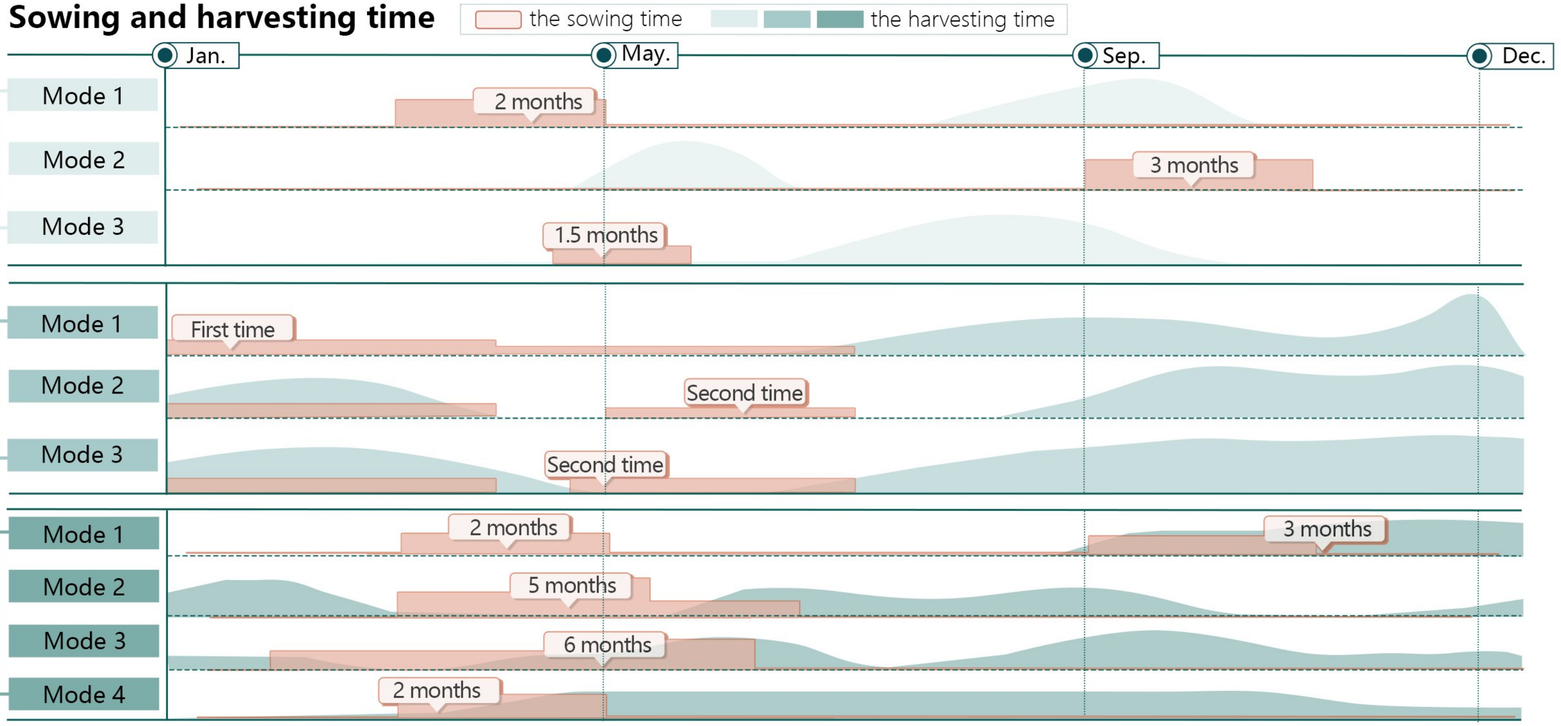
Benefit



Three types of combined structures

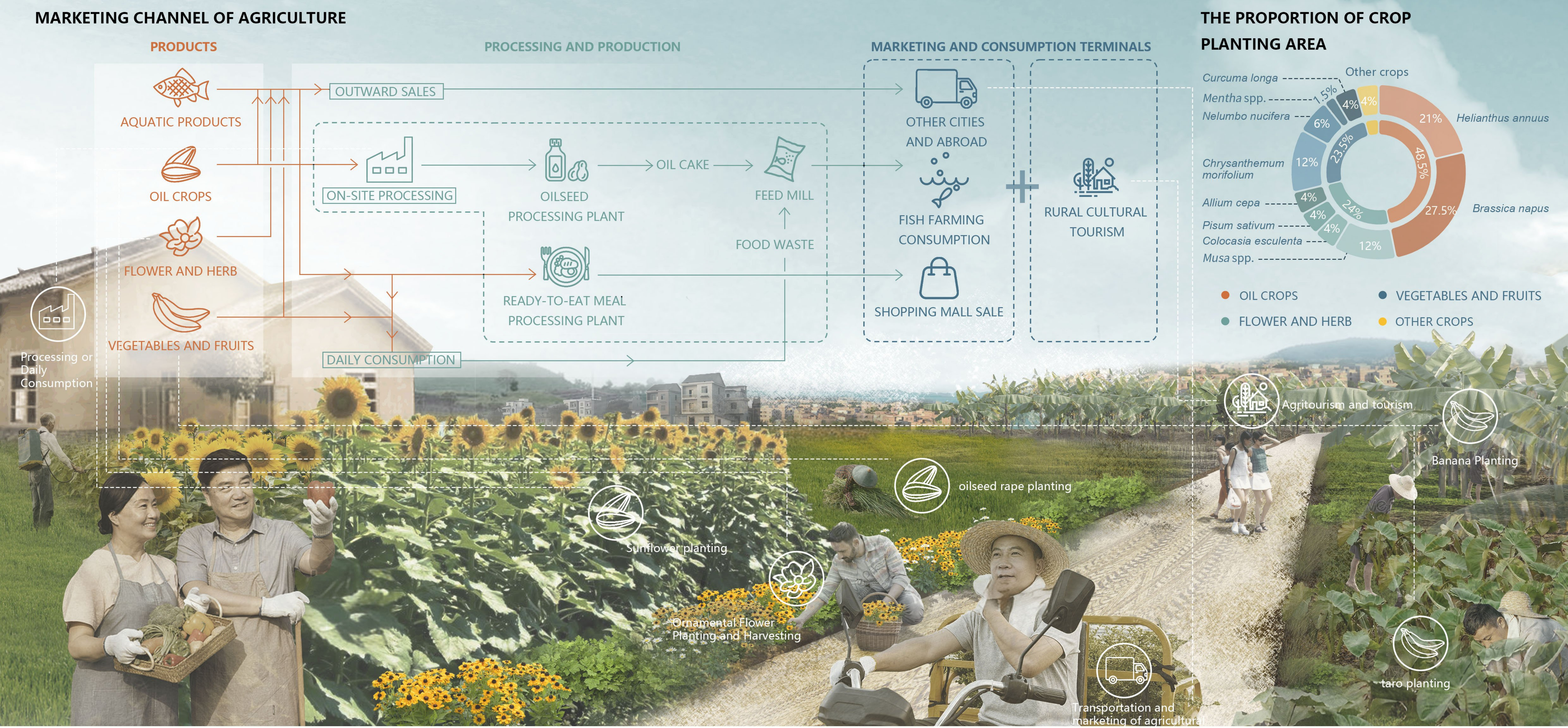


Sowing and harvesting time



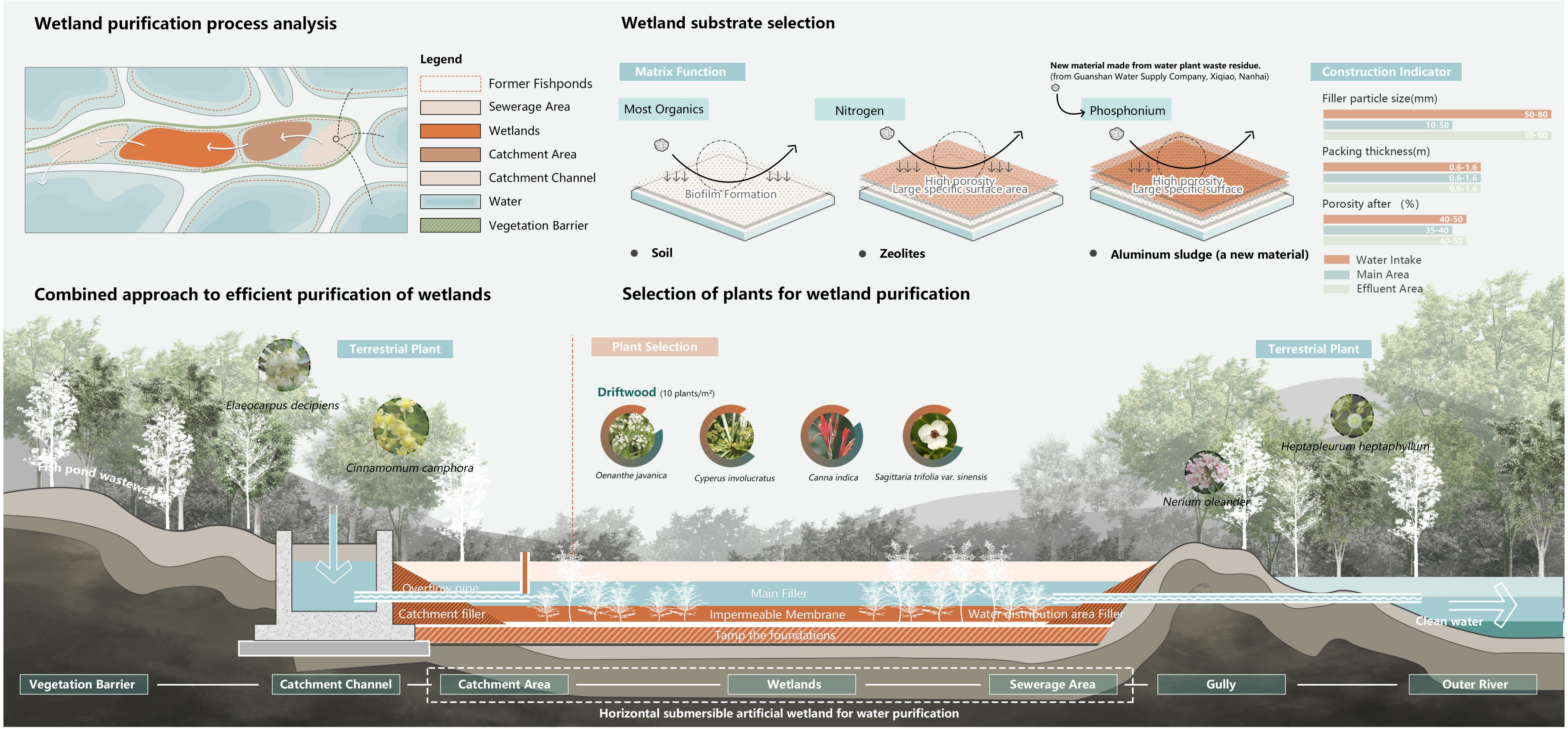
Arable cultivation Area: Abandoned farmland within the community (115.8 hectares) are planned for agricultural planting to enrich the community livelihoods. By planting flowers, fruits and vegetables that can be used for fish feed, the nutrients of 680,000m³ mud can be reused each year. Moreover, the organs of these plants are processed to partially replace the proteins and carbohydrates in the artificial feed, reducing the overall input of the system.

ARABLE CULTIVATION AREA



Crop cultivation can bring additional economic benefits to community and increases farmers' incomes. Crops mainly serve for the daily consumption of the community members. Besides, extra quotas are delivered to nearby markets. The flowers and crops also contribute to a practical, high-yield and beautiful agricultural landscape, and by using the existing water network of the dike-pond system, we plan a sightseeing waterway to foster the tourism economy.

ARTIFICIAL WETLAND AREA



Artificial Wetland Area: An area of 71.8 hectares, equivalent to 1/6 of the site, is converted into artificial wetlands. Within controllable economic costs, 6 wetland areas are planned based on pond drainage needs and water flow direction, with a purification cycle of 7 days, providing fresh water for the system.

ARTIFICIAL WETLAND AREA DESIGN

The wetlands can provide natural habitats for insects, fish, and birds, enhancing the ecological service value of the ecosystem. At the meanwhile, the wetland can also be used for science education and thus enhance the cultural service value of the dike-pond landscape.

SITE VISION AND VALUE ENHANCEMENT

Through the establishment of the community-based circular economy, farmers' incomes have been greatly increased and the ecosystem services have been enhanced.

PAST → **NOW** +VALUE BY 992.86%

SUPPLY SERVICE

VALUE OF PRODUCTION ($)

Increases in suitable aquaculture area (fish pond area increased to 84%), decrease in wastage rate (wastage reduced to 5%), increase in pre-prepared vegetable industry.

	BEFORE		AFTER
AQUACULTURE PRODUCTION	28.8M	486%	140M

Algorithm:
Market Value Method

Data source:
- Field interviews
- Foshan Statistical Yearbook

+

REGULATORY SERVICES

VALUE OF PRODUCTION ($)

One-third of the original abandoned ponds were transformed into a wetland.

	BEFORE		AFTER
ADJUSTMENT OF TEMPERATURE	13.88M	150%	20.82M
ADJUSTMENT OF HUMIDITY	84.89M	150%	127.34M
WATER SUPPLY STORAGE	550K	150%	830K

Algorithm:

$$V_{r1} = \frac{R \times P_d}{3600 \times K}$$

$$V_{r2} = Z \times D \times P_d$$

$$V_g = X \times P_k$$

Data source:
- Foshan Municipal Water Bureau
- Foshan Development and Reform Bureau

+

SUPPORT SERVICE

VALUE OF PRODUCTION ($)

Support services are related to the total area, which remains unchanged.

	BEFORE		AFTER
MAINTAINING BIODIVERSITY	85K	MAINTAIN	85K
CONSERVATION OF SOIL	190K	MAINTAIN	190K

Algorithm:
$V_w = T \times P_q$ $V_{s2} = T \times P_{s2}$

Data source:
- Qualitative Inorganic Analysis

+

CULTURAL SERVICE

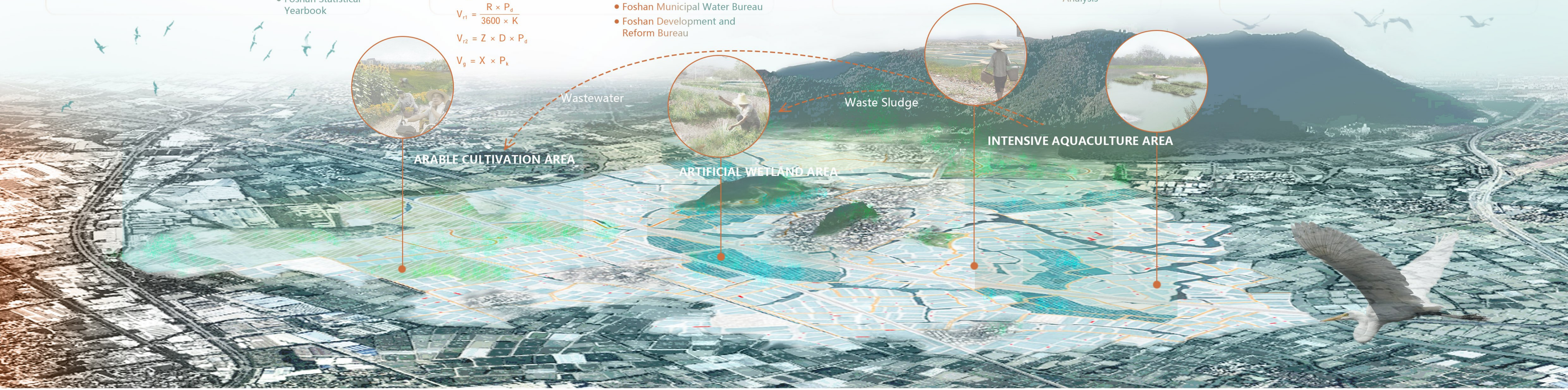
VALUE OF PRODUCTION (KUSD)

Calculated based on expected amount of visitors and per capita spending (the visitors are expected to increase from 5000 to 50000).

	BEFORE		AFTER
TOURISM AND LEISURE	35	1000%	3500

Algorithm:
$V = P \times C$

Data source:
- Ruxi Village Committee



By establishing a community-based circulation system, the program not only increases farmers' incomes, but also significantly enhances the ecological service value in the traditional dike-pond landscape, thus achieving the goal of a circular economy.

Project Narrative and Contents:

Project Background:

Asia dominates global aquaculture, accounting for almost 90% of total global production. The aquaculture industry generates income and employment, contributes to food security, and has become an important industry with socio-economic value amounting to billions of dollars. However, during the process of globalization and specialized production, market demands for aquaculture have driven the transformation of traditional multifunctional systems into intensive aquaculture systems, causing serious threats to social-ecological systems. This transformation has led to severe landscape simplification, which poses challenges to the biodiversity and sustainable development of agricultural landscapes in traditional dike-pond areas. Therefore, there is a need to reconstruct a circular economy within the community in the context of intensive economic development trends, providing comprehensive ecological, economic, social, and cultural solutions for traditional aquaculture areas in Asia affected by landscape simplification.

Site Survey and Issues:

As one of the high-density areas for global aquaculture, the Pearl River Delta in South China was once famous for its integrated dike-pond systems, characterized by mixed aquaculture, planting, and poultry raising, and a mosaic landscape pattern of fish ponds, dikes, and arable land, achieving efficient material utilization. Ruxi Village in Xiqiao Town, Nanhai District, Foshan City, Guangdong Province, is located in the dike-pond area of the Pearl River Delta, covering an area of 9.6 km^2. This area has a dense water network and a long history of dike-pond production, retaining the largest dike-pond landscape in the Pearl River Delta. However, under the intensive aquaculture production mode, the dike-pond landscape in this area has experienced simplification.

Through research, we concluded that the simplification of the dike-pond system was the result of human interventions and interactions with elements such as water, land, and organisms. Firstly, farmers have converted large amounts of arable land and dikes into fish ponds to develop aquaculture. Meanwhile, low-economic-yield planting activities were abandoned, leading to land system degradation and a further decline in biodiversity.

Project Narrative and Contents:

Under high-intensity production models, the system relies on substantial inputs of artificial feed and drugs, causing water eutrophication and the generation of fish pond sediments, with approximately 5 million tons of wastewater and 68,000 m3 of pond mud produced annually. However, due to the lack of community regulation, the pond mud, once an important fertilizer, accumulates on the dikes and remains unused, altering the original spatial structure of the land system. Simultaneously, untreated wastewater from fish ponds is directly discharged, leading to the deterioration of public river water quality, increasing the incidence of fish diseases, and ultimately resulting in higher livelihood risks for farmers.

Planning Goals:

We believe the key to the socio-ecological problems of the dike-pond system is the disruption of traditional material cycles. This has led to linear production model characterized by high input, unstable yields, inadequate waste utilization, and water eutrophication. In the context of globalized production, the core goal of this project is to rebuild the circular economy within the community based on the existing intensive aquaculture of the dike-pond system. By taking corresponding strategies in 4 stages, namely input, production, use, and post-use, we aim to mitigate the adverse effects of landscape simplification, achieve internal waste consumption, and restore the ecological environment.

Planning Strategies:

From the perspective of the community circular economy, we first introduce arable cultivation that can be used to feed fish, with the aim to reduce external feed inputs and the generation of waste. During the pond management and utilization process, pond mud is allowed to circulate between planting and farming areas as crop fertilizer, fully utilizing system resources. Besides, the wastewater generated by production is purified through constructed wetlands and reused for fish pond production and agricultural irrigation.

Design Strategies:

According to planning goals and strategies, the area is subdivided into three diverse areas to build a new material cycle and achieve a circular economy: intensive aquaculture areas, arable cultivation areas and artificial wetland areas,. The required areas and locations of the three zones are determined through production

Project Narrative and Contents:

suitability assessment with 4 environmental factors affecting fish pond production listed as important evaluation criteria.

The most suitable area for aquaculture is retained as the intensive aquaculture area (382 hectares). The goal of the region is to continue the intensive production of commercial fish to sustain farmers' livelihoods by improving the production environment and establishing community management regualtions. Firstly, intelligent production equipment and soil-stabilizing plants are introduced to improve the production environment and increase fish pond production efficiency. Secondly, scientific feeding methods are adopted by introducinga three-dimensional farming model of mixed fish farming based on fish habits to fully utilize water space and feed, purify water quality, reduce fish disease incidence, and increase yield. Finally, during farming, the community redefines the frequency and volume of fish pond wastewater discharge to ensure production quality.

Abandoned framland and forest land within the community are planned as arable cultivation area (115.8 hectares), aiming to promote the material cycle of pond mud and cultivate new industries to increase the diversity of community income. The arable cultivation area plants ornamental and edible flowers and vegetables, such as sunflowers (Helianthus annuus) and peas (Pisum sativum) based onthe climate conditions of the Pearl River Delta and fish feeding needs. On the one hand, these plant organs can be processed and incorporated into fish diets, partially replacing traditional feed proteins and carbohydrates and reducing overall system inputs. On the other hand, the flowers and vegetables can absorb nutrients from the transported pond mud, promoting community material recycling. The entire agricultural area, covering 115.8 hectares, can process approximately 68,000 m3 of pond mud, with the remaining mud used for flower seedling cultivation and sold along with the flowers. By planting flowers, the area forms a practical, high-yield, and aesthetically pleasing agricultural landscape, leveraging the crisscrossing dike-pond terrain to plan sightseeing water routes and develop tourism.

Based on the carrying capacity of artificial wetlands and the discharge volume of fish pond wastewater, 1/6 of the dike-pond area, which is not conducive to aquaculture， is transformed into

Project Narrative and Contents:

a artificial wetland area (71.8 hectares). The goal is to address aquaculture wastewater pollution within controllable economic costs and provide ecological recreational functions. By calculating wastewater volume and discharge cycles, soil, zeolite, and aluminium sludge are selected as the main substrates for horizontal subsurface flow artificial wetlands. Aluminium sludge, a waste product from a nearby water company, is used to reduce water purification costs. The wetlands are divided into 6 sections based on fish pond drainage needs and water flow directions, each with a service radius of approximately 500 meters. Based on the water purificationcapacity the wetland provides a water treatment cycle of 7 days. The large amount of eutrophic wastewater produced by aquaculture flows through the artificial wetlands and is purified before being discharged into rivers. When water is needed for aquaculture and agriculture, it can be directly drawn from the river. The wetlands are planted with emergent plants such as windmill grass (Clinopodium urticifolium), Chinese arrowhead (Sagittaria trifolia var. sinensis), water celery (Oenanthe javanica), and canna (Canna indica) to meet water purification needs. These plants provide natural habitats for pollinators, fish, birds, and other organisms, enhancing ecosystem services. Based on this, wetland classrooms and bird-watching houses are designed for educational purposes, creating an eco-tourism economy.

Project Benefits:

By establishing ecological recycling systems and community governance systems, we provide practical, nature-based solutions to mitigate the negative impacts of landscape simplification on dike-pond areas. The functional zoning of intensive aquaculture areas, arable cultivation areas, and artificial wetland areas reduces the aquaculture area's dependence on external resources, maintains farmers' existing livelihoods, promotes waste recycling, and improves ecosystem stability. These integrated measures not only enhance the ecological environment but also increase farmers' income, attract tourists and investments, promote sustainable community development, and thus achieve the goal of a circular economy.