Fig. 1
Birdseye view of Xinghua Duotian agrosystem. Source: China-Xinghua Duotian Agrosystem - GIAHS.

Feeding Waters

Emerging Perspectives on Traditional Agricultural Landscapes

Catalina Rey-Hernández[1], Naeema Ali[2], Rapa Surajara[3], Yuan Yuan[4]

This essay examines four traditional agricultural landscapes: the Chinampas in Mexico, the Kayalnilams in India, the Xinghua Duotian Agrosystem, and the Honghe Hani Rice Terraces in China, to draw lessons for sustainable, climate-resilient food production. With agriculture consuming 70% of global freshwater and food demand projected to rise by over 50% by 2050, these centuries-old agricultural systems demonstrate how working with natural water cycles, local resources, and ecological processes can sustain food security, livelihoods and biodiversity. A comparative framework reveals that their longevity stems not from fixed practices but from a capacity to adapt production, technologies and livelihoods to shifting environmental and socio-economic conditions. Four lessons emerge: circularity in water and nutrient flows, resilience to climate extremes, the interdependence of food, ecology and society, and the advantages of nature-based production over extensive monoculture. However, these systems face mounting pressures from ageing farming populations and urban expansion, which can fragment the relationships sustaining them. The chapter argues that contemporary agro-landscape planning should foster adaptive frameworks rather than rigid master plans, enabling water systems, production capacities, and local livelihoods to evolve together while preserving their ecological foundations.

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Water is at the heart of agriculture, weaving together the threads of our food systems and sustaining our global population. As we strive to feed a growing population, the relationship between water and food production becomes more crucial. Strikingly, agriculture consumes 70 per cent of the global freshwater resources, a figure set to skyrocket, as the demand for food production is projected to increase by over 50 per cent by 2050 (Kumar et al., 2022). To navigate this future, we must deeply understand the role of water in our food systems and provide a more water-efficient and resilient approach.

In this light, we can examine the past for inspiration. Traditional agricultural practices have evolved sustainably and are closely tied to water systems that support water management, supply, flood and drought protection, irrigation, and drainage infrastructures. By examining these traditional practices, we can better understand the global food security challenges and their links to water. Despite their resilience, traditional agrosystems have experienced several changes owing to overarching impacts. Therefore, it is crucial to explore these transformation strategies.

Four representative cases were selected: Chinampas Agrosystem, Xochimilco in Mexico (Figure 2), Kuttanad Kayalnilam Agrosystem (Figure 3), Xinghua Duotian Agrosystem (Figure 4), and Honghe Hani Rice Terraces (Figures 1 and 5). Whether nestled in the high mountain valleys where Chinampas flourish, the below-sea-level expanses of Kuttanad Kayalnilam, the low-lying fields of Xinghua Duotian, or the densely forested alpine terraces of the Honghe Hani Rice fields, inhabitants have mastered their natural surroundings to produce food with minimal resources. These cases have been examined through two lenses: 1) how nature acts as the foundation for the functioning of these systems and 2) the complex interactions between these systems and their surrounding environments.

The goal is to show how these systems have provided not only food for many communities around the world, but also livelihoods and resilience to extreme weather events. Water is an indispensable element in this achievement. Through a detailed analysis of these four cases, we present a comparative review to visualise the collected information and reflect on four core lessons for the future of food production: 1) circular practices in modern food systems; 2) resilient food systems towards climate change and natural disasters; 3) interdependence of food, ecology, and society; and 4) nature-based food production versus extensive food production.

UNDERSTANDING TRADITIONAL AGRICULTURAL LANDSCAPES

Floating Gardens of Wetland Agriculture—Chinampas in the Valley of Mexico

Chinampas is a system of human-made islands for agriculture and land expansion in the Valley of Mexico (Figures 6, 7, and 8), enabling practical agriculture and sustainable water management since approximately 200 BC. Tenochca civilization (also known as Mexica or Aztec) built Tenochtitlán, the capital of their empire, in the middle of the shallow waters of what is now Lake Texcoco, strategically protecting the city from external threats (Alcántara, 2007). To expand their capital, they developed the Chinampas Agrosystem to enlarge their territory, where the water was sufficiently shallow to reclaim land for settlement and agriculture (Gibson and Campos, 1978). Currently, the Chinampas have partly survived in the southern part of the Valley of Mexico, in the areas of Xochimilco and Tlahuac, which have



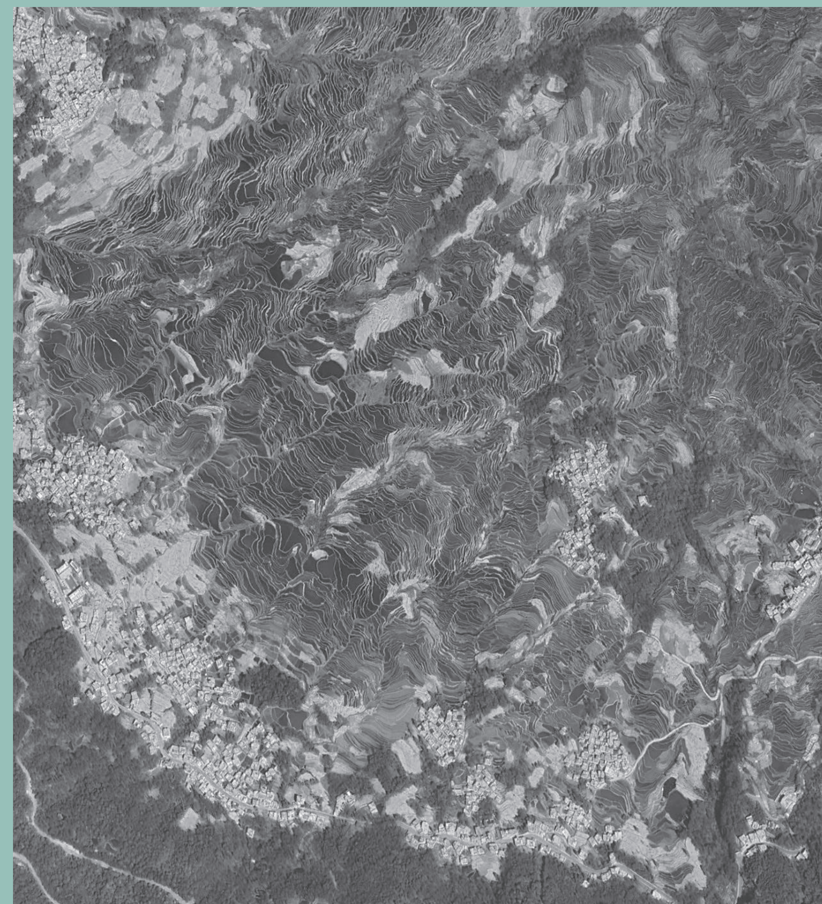



Fig. 2
(top left) Satellite view of the Chinampas Agrosystem. Adapted from Google (2020-a).

Fig. 3
(top right) Satellite view of the Kuttanad Kayalnilam Agrosystem. Adapted from Google (2020-b).

Fig. 4
(bottom left) Satellite view of the Xinghua Duotian Agrosystem. Adapted from Google (2020-c).

Fig. 5
(bottom right) Satellite view of the Honghe Hani Rice Agrosystem. Adapted from Google (2020-d).

become extensive islands of traditional urban agriculture for vegetables and ornamental flowers in the middle of densely populated Mexico City (Rey-Hernández & Bobbink, 2022).

Nature as a starting point

The Chinampas were initially developed in a high-mountain lacustrine valley with a wetland ecosystem of now-extinct interconnected lakes. Owing to the confined nature of the water system, mineralized sediments from the mountains accumulated at the bottom of the lakes, creating incredibly fertile soil (Scarborough, 2003). However, without a natural outlet for water, this area is prone to periodic flooding (Parque Ecológico Lago Texcoco, 2009). The inundations led the Tenochcas to modify their territory to 'reclaim land' and create safe grounds for the expansion of their city and agricultural areas (Surajaras & Rey-Hernández, 2021).

The Chinampas were built using existing resources to create cultivable land above the water's surface. To create these 'floating islands,' Tenochcas built reed rafts and enclosed them in rectangular wattle enclosures. The raft was then layered with mud, lake sediments, and topsoil composed of grass, leaves, and husks. Once the 'island' was stable enough, they stabilised the Chinampas by planting trees such as Salix bonplandiana in the raft's corners to secure it to the lakebed. (Rojas-Rabiela, 1993)

Relationship with the Environment

The Chinampa's 'floating gardens' have been built and used in close relationship to its landscape and environment, using the site conditions and natural resources to achieve maximum food production and profitability with minimum materials and infrastructure by taking advantage of the natural wetlands, which provide the ideal conditions for efficient crops without using external energy sources. At the same time, the materials used in the construction and maintenance of China come from the surrounding areas, enabling sustainable resource use and, combined with cyclical crop harvests, creating a circular food-production process. Furthermore, the system is deeply intertwined with its lacustrine landscape using natural irrigation and water filtration to maintain constant humidity throughout its structure and return it to the biological cycle. (Rojas-Rabiela, 1993)

Fig. 6
Canoers in a boat at the entrance to a chinampa. Adapted from a photograph by Catalina Rey-Hernández.

Fig. 7
(left) Fenced chinampa with Salix bonplandiana trees securing it to the lakebed. Adapted from a photograph by Catalina Rey-Hernández.

Fig. 8
(right) Chinampa worker on a boat in the Xochimilco Canal. Adapted from a photograph by Catalina Rey-Hernández.

Harvesting under the Sea-level—Kayalnilams in Kuttanad, Kerala

In southern India, adjoining the Vembanad backwaters, the longest lake in India, is a cluster of emerald-green islands fringed by coconut trees, called Kuttanad. Beyond this picturesque beauty, this area of Kerala unfolds an agricultural legacy that has been growing rice two metres below sea level for more than a century (Sreeja et al., 2015). They do this by constructing 'Kayalnilams,' where 'Kayal' means backwaters and 'Nilam' means land, implying that they are reclaimed from the backwaters (Chandran & Purkayastha, 2018).

Kerala's inhabitants developed techniques for constructing and operating Kayalnilams in the late 1800s (Figures 9, 10, and 11). They constructed dikes at least two metres above sea level, which acted as barriers separating water inside and outside the system. With a set of canals, inlets, and motor-powered outlets, the water levels within Kayalnilam are controlled to optimize agriculture. Kayalnilams grow food under various natural conditions, such as waterlogging, flooding, and sea salt intrusion, contributing to the dynamic site conditions of backwaters and the five rivers that flow through the system (Swaminathan, 2007).

Nature as a Starting Point

The reclamation process started by setting the boundaries of the identified shallow areas in the Vembanad backwaters. Then, an array of coconut poles is hammered deep enough into the lakebed in two rows, enveloping the area. The poles were fenced with bamboo mats on either side to form a skeleton for the dyke. Subsequently, the dyke channels were filled to the desired height with sand, twigs, and sedges mixed with high-quality clay dug from the bottom of the lake. The entire construction process uses organic, locally sourced materials, and the dykes and canals are sufficiently porous to create an excellent habitat for aquatic species.[1]

Relationship with the Environment

In this system, paddy farming works well with seasonal flooding and salt intrusion from the Arabian Sea but can be supplemented by fish farming and duck rearing for a few months. During summer, river water levels drop below sea level, and saltwater flows inland (Sreejith, 2013). The increased salinity

Fig. 9
(top) Aerial view of flooded Kayalnilams. Adapted from a photograph by Prasanth.

Fig. 10
(middle) Women agricultural labourers harvesting paddy by hand. Adapted from a photograph by Redz Photography.

Fig. 11
(bottom) Kuttanad Kayalnilam when the paddy crop is ready for harvest. Adapted from a photograph by Redz Photography.

renders the soil unsuitable for paddy farming, so the fields are deliberately flooded to harvest fish that migrate from the sea. Even the life cycles of local fish vary, adapting to this salt cycle; during certain growth phases, some fish and prawn species become intolerant of saltwater. At the same time, for the rest of their lifespan, they need a salty environment that naturally occurs during salt intrusion periods (Ali, 2020).

Additionally, paddy roots provide shelter for these species, and aerating movements of the fish improve soil fertility. Hence, aquaculture becomes the primary source of livelihood when rice is not cultivated and continues through the peak monsoon season, when the fields make room for excess water in the system, making the Kayalnilams resilient to flooding. Post-monsoon, when the water level recedes, this is a freshwater system that shifts back to growing rice. During this period, the soil was also enriched by sediments carried by upstream rivers into these low-lying areas during the monsoon season.

Instead of fighting salt and water, which are seen as threats in coastal areas, the rotation between agriculture and aquaculture aligns well with the natural water cycle and local ecology of the area. Thus, Kayalnilams are components of ecological infrastructure with multifunctional values that grow food, provide coastal protection, and serve as breeding and nesting habitats for fish and birds.

However, in the late 1900s, the industrial revolution began to reshape indigenous Kayalnilams. The construction of salt dams and expansion of industrial salt production have disrupted the traditional balance between agriculture and aquaculture. As a result, these landscapes have become less ecologically diverse, with reduced habitat availability for fish and birds. While salt production brings economic benefits, it also alters the natural water cycle, limiting the multifunctionality that once sustained both local livelihoods and biodiversity.

Rising above the Surface—Xinghua Duotian Agrosystem

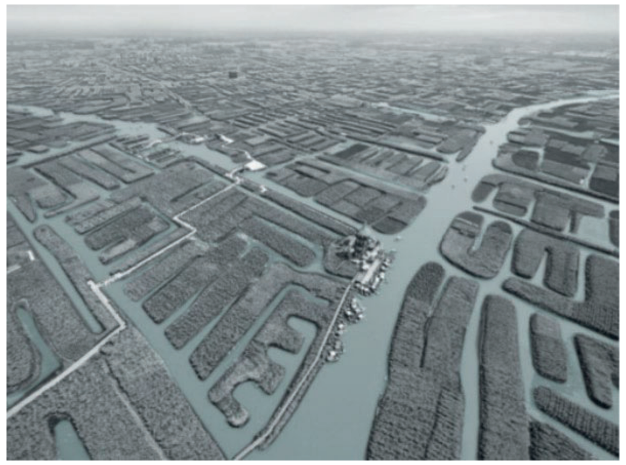
On the eastern side of China, Jiangsu Province lies in a vast open landscape featuring thousands of floating islands. These islands vary in shape, size, and color, creating a unique pattern that extends to the horizon. This waterscape is known as the Xinghua Duotian Agrosystem, a traditional water-land utilization technique developed over a thousand years ago to combat frequent flooding in the low-lying Lixiahe Plain. By constructing wooden structures to support fields and raising mud into small stacks, early agriculturalists transformed waterlogged areas into cultivable lands. This innovative approach has been in practice since the Tang Dynasty (AD 618–907), highlighting the ingenuity of early Chinese agricultural practices (Science and Technology Daily, 2022). (Figures 12 and 13).

This water-land management technique consists of a raised-field agricultural pattern, distinctive from other raised fields because of its thousand-year history and sustainable cultivation approach. The Xinghua Duotian was the region's primary food production source in the past, and it has gradually evolved into a combination of agriculture, forestry, and aquaculture. (Bai et al., 2014)

Nature as a Starting Point

The Duotian Agrosystem was initially established because of the area's natural condition: low-lying land surrounded by higher ground. This flat plain is significantly influenced by its surrounding riverine landscape, the Huai,

Fig. 13
Overview of the Xinghua Duotian Agrosystem. Adapted from a photograph courtesy of GIAHS—Xinghua Duotian Agrosystem, China (2020).



Yellow, and Yangtze rivers. People have suffered frequent floods. Tracing back 4200 years, the area was originally a lagoon fed by sedimentation from rivers, transforming it into a freshwater wetland landscape with numerous lakes. During this period, the Xinghua population grew due to its strategic location as a commercial hub (Bai et al., 2014). This led to massive food demand and challenged the Xinghua ancestors, who began using the area's fertile conditions, digging soil from rivers, and creating earthen platforms suitable for farming.

The raised fields were initially composed of a layer of piled wood as a base, followed by wetland soil, fertile soil from the rivers, lotus roots, and finally, a vegetation layer on top. They floated on the surface of the water, rising during flooding and falling when the water was released. After 1949, the frequency of floods decreased significantly because of dam construction. This made it possible to lower the field height. The soil was then used to widen and narrow the waterways. Thus, more land has been gained and used for various purposes and for urban development.

Relationship with the Environment

Currently, the area is mainly used to grow vegetables, with Longxiang taro, Xinghua chive, and Xinghua oilseed rape as the three most important farm products (Surajaras & Rey-Hernández, 2021) Other vegetation types are rotated according to season, changing the colors and textures of the fields throughout the year. Farmers plant crops under trees, breed fish and shrimp, and raise ducks and geese in the water to increase income and maximise land utilisation. Thus, the entire system provides food for the local population and exemplifies highly efficient agriculture within a unique wetland landscape.

Cultivating through Slopes—Honghe Hani Rice Terraces

Hani Rice Terraces have existed since 720 A.D. They are located in Yuanyang County, Yunnan Province, China, where terraced farming is central to the material production and national culture of the Hani people (Figure 14). For 1300 years, the Hani people have developed farming techniques, such as terrace management and ecological cultivation, in long-term farming. However, in the second half of the 20th century, with the transformation of Chinese society and the development of a market economy, the country blindly pursued food production and cut down forests to reclaim land without considering water sources. In 2012, scientists introduced the 'Rice-Fish-Duck Symbiosis System' production mode in the terraced fields to improve efficiency. Just one year later, the Hani Rice Terraces were declared 'World Agricultural Cultural Heritage' by the United Nations. (Hua & Zhou, 2015)

Nature as a Starting Point

After the Hani ancestors migrated to the Ailao Mountains and settled, they chose to live on sunny gentle hillsides. Later, they opened canals and ditches for drinking water and irrigation, and built terraced fields. The water source for the Hani people is rainfall and groundwater. Water is stored in forests on mountaintops. By utilising the topography when excavating canals, the Hani people developed the 'flowing water ditching method' to transport water from the mountain's summit into the village. In other words, the mountain's height was first visually gauged, followed by the terrain's direction. When excavating canals, a small amount of water is added to determine whether it can flow through existing ditches to the intended location. In this manner, the Hani gradually constructed canals and ditches from the mountain summit to the village. The Hani people developed the 'wood carving water-dividing method' simultaneously to guarantee equitable water use for residents upstream and downstream. This method involves determining the amount of water each terrace needs based on its area, then placing a horizontal beam at the terrace-ditch intersection and carving a specific width into it to restrict the amount of water entering the terrace.

The terraced fields were excavated and built from low to high, with the field width and length planned to fit the dimensions of the slope. After exposure to the sun and rain, the platform's natural settlement forms a stable foundation for building terrace ridges and irrigation systems. After this step-by-step process, the hillslope is reclaimed upward. Terraced fields of different lengths, widths, and layers were formed according to topography.

Relationship with the Environment

Regarding food production, the Hani people have shaped the ground to suit the local terrain and climate, recognising that forests on hills are essential for water storage and preventing landslides. Moreover, they deliver wood to build houses in the villages. The Yuanyang Terraced Fields store water for food production and daily use year-round.

Currently, the Hani Terraces only grow one crop rotation per year—red rice—and the land is left empty after the autumn harvest until the following year's planting. Farmers begin plowing and sowing the fields in April, and the rice fields grow lushly throughout the summer. In mid-September, water was drained from the fields to harvest the rice. The rice harvest was completed in November and the terraces were refilled with water to await the farming cycle of the new year.

Fig. 14
Subsistent farming in Yunnan Province. Adapted from a photograph by Jialiang Gao (2008).

TRADITIONAL AGRICULTURAL LANDSCAPES SIDE BY SIDE

Based on the knowledge collected from the four cases and analysis of the water systems (Figures 15, 16, 17, and 18), a framework was developed to compare the cases. This comparison aims to discuss the values embedded in these traditional agricultural landscapes that are relevant to today's food production challenges. By placing the cases side by side, it becomes possible to understand how different combinations of water, landforms, productive activities, labor, and maintenance have enabled them to remain viable over time. Preliminary conclusions were drawn from the comparison framework. (Figure 19)

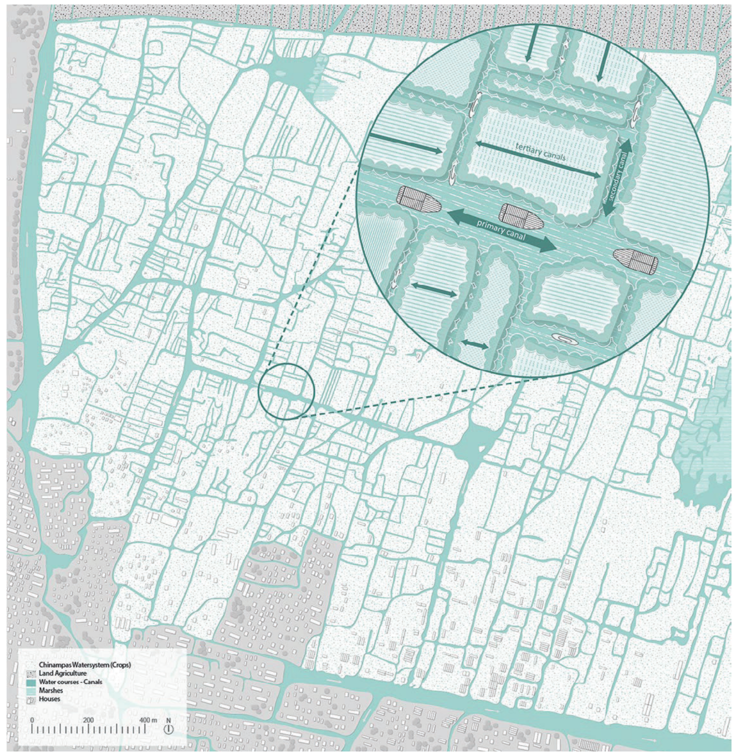
First, although the four cases are situated in very different weather conditions and landscapes, they all work with existing environmental processes to optimize food production using locally available resources. The Kayalnilams, Chinampas, and Xinghua Duotian cases are based on comparable landscape types and water conditions: wetlands with fresh-to-brackish water quality. These conditions support a greater variety of crops; however, because of the dynamic nature of wetlands, they also require continuous human intervention to maintain fields, waterways, and water levels. The Honghe Hani terraces, situated on the slopes of a mountainous region, are irrigated with freshwater and primarily produce rice. Human-made ponds require minimal maintenance, because they rely on gravity-fed irrigation systems. Therefore, their productivity is dependent on the continued relationships among forests, settlements, water channels, and terraces.

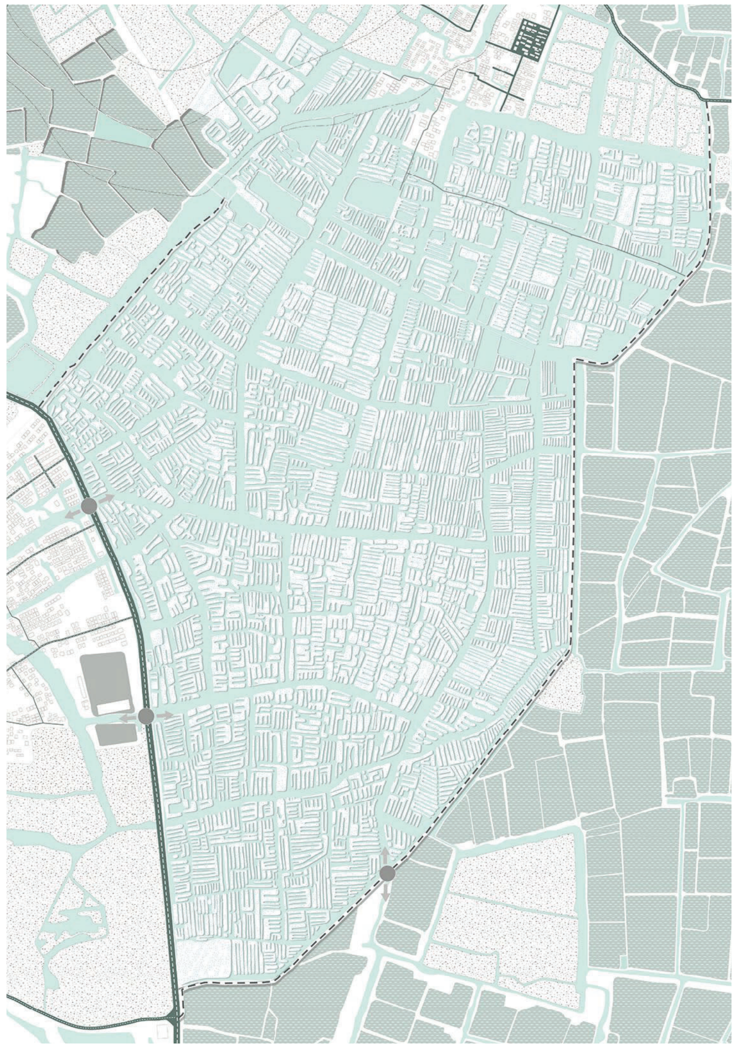
At the same time, all four systems extend beyond agriculture by combining food production with activities such as fish and duck breeding, horticulture, tourism, and Chinese cattle farming. This multifunctionality allows water, nutrients, labor, and productive space to be used across several interconnected activities. Therefore, the systems demonstrate different forms of circularity in water supply, irrigation, nutrient cycling, and self-sufficient local food production. Through these relationships, they support their livelihoods, biodiversity, and continued access to locally produced food.

The comparison also shows that their continuity depends on adaptation rather than preservation of historical agricultural practices. Crops, water control methods, field dimensions, technologies, and livelihood-related activities have evolved in response to changing environmental and socioeconomic conditions. The capacity to reorganise production around local water cycles and ecological processes has endured. The four cases, therefore, represent neither fixed traditions nor models to be copied directly but living agricultural landscapes whose survival depends on their ability to change without losing the underlying relationships that sustain them.

LESSONS FOR MODERN AGRO-LANDSCAPES

Building on the previous analysis and comparison, this section considers how these food production systems have sustained communities, supported livelihoods, and responded to climate shocks and extremes. Their longevity should not be viewed as evidence that they have remained unchanged or are inherently sustainable. Rather, it reflects their capacity to adapt while maintaining the relationships among water management, food production, ecological processes, labor, and local knowledge. Four lessons were drawn that show the indispensable role of water in addressing today's challenges to food production: circularity; resilience; the interdependence of food, ecology, and society; and nature-based food production.





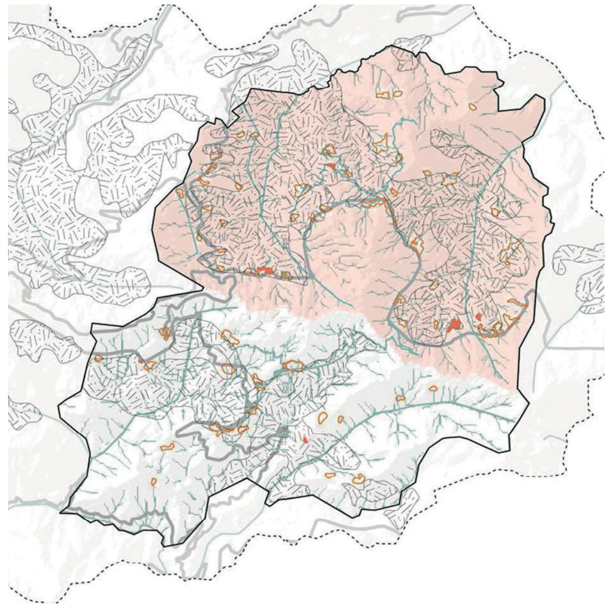


Fig. 15
(top left) Catchment area of the Chinampas Farming System. Adapted from Bobbink and Rey-Hernández (2022).

Fig. 16
(top right) Catchment area of the Kuttanad Kayalnilam Agrosystem. Adapted from Ali (2020).

Fig. 17
(bottom left) Catchment area of the Xinghua Duotian Agrosystem. Adapted from Surajaras (2019).

Fig. 18
(bottom right) Catchment area of the Honghe Hani Rice Agrosystem. Adapted from Yuan (2022).

	Chinampas	Kayalnilams	Xinghua Duotian	Honghe Hani
General context Location Climate Rainfall Area	Mexico City, Mexico Tropical wet and dry 700mm per year 150,000 ha (currently 7500 ha)	Kerala, India Tropical monsoon 3250mm per year 50,000 ha	Xinghua city, China Humid sub-tropical (Warm temperate) 1100mm per year 31,200 ha	Yunnan Province, China Humid sub-tropical (Warm temperate) 1400mm per year 16,600 ha
Historical Values	more than 2000 years	more than 100 years	more than 1000 years	more than 1000 years
Landscape Conditions Landscape type Water Quality Natural processes	Lake with wetlands Fresh and Brackish Lacustrine landscape transformed into a dry mountain valley	Low lying wetland (1-2m below sea level) Fresh and Brackish Seasonal mixing of saline and freshwater, tidal	Low-lying wetland Fresh and Brackish Riverine	Mountainous Freshwater Forest converted into cropland
Water System Function Initial Purpose Final Purpose	Land reclamation, Hunting, Irrigation Irrigation, Tourism	Land reclamation, Irrigation Irrigation, Flood protection, Tourism	Land reclamation, Irrigation Irrigation, Tourism	Irrigation, Water supply, Fish cultivation Irrigation, Water supply, Fish cultivation
Types of food produced	Maize is the main crop Other crops like beans, squash, tomatoes, peppers etc. Poultry and cattle farming also predominant Flowers	Rice and fish predominantly in the low lying areas Duck, shrimp Fruits are grown on higher grounds all through the year Toddy alcoholic beverage drink, locally produced from coconut trees	36 traditional varieties of rice Other grains like bean, millet, sorghum, corn Vegetables and fruits like Chinese yam, taro, lettuce, leek, Chinese chive, spring onion, etc. Fish, shrimp, duck and goose Flowers	Predominantly rice, fish and duck production
Maintenance Strategy	Labor intensive, Regular dredging and soil refilling	Labor intensive, Annually repaired	Labor intensive, Regular dredging and soil refilling	Ponds need minimal maintenance
Landscape Values	Secures livelihoods, Food self-sufficiency, Flood mitigation, Cleaning Water, Air purification, Biodiversity	Secures livelihoods, Food self-sufficiency, Flood mitigation, Coastal Protection, Salt intrusion regulation, Cleaning Water, Biodiversity	Secures livelihoods, Food self-sufficiency, Cleaning Water, Air purification, Biodiversity	Secures livelihoods, Food self-sufficiency, Water supply, Landslide regulation, Air purification, Biodiversity

Fig. 19
Comparative overview of the agrosystems, including their contexts, conditions and key characteristics. By the authors.

CIRCULAR PRACTICES IN MODERN FOOD SYSTEMS

Farmers in these four agrosystems have embraced traditional agricultural techniques and knowledge passed down through generations, although the extent to which these practices remain active varies across cases. They have developed ingenious ways of living with nature, protecting local biodiversity, securing livelihoods, and generating income from landscapes. The economy in these areas is closely connected to the ecosystem services for food production. Farmers continue traditional agricultural techniques (re)using local resources and, at the same time, the construction of these water systems facilitates natural water irrigation.

The crops produced and harvested in these systems allow inhabitants easy access to food from their surroundings. Self-sufficiency is an adaptation strategy that bolsters food security against climate change, closes nutrient cycles, and reduces dependence on global markets. Additionally, the circular use of water in these examples helps to restore the ecological quality of water, naturally cleaning it as part of its cycle.

Furthermore, there is a mutualistic symbiotic relationship among agriculture, non-human species, and other productive activities such as fish, shrimp, and duck breeding, where different crops provide protection and shelter to these species, which enhances land fertility and creates suitable environments for the crops to thrive. At the same time, the rotation between crop cultivation and aquaculture, for example, is intertwined with the life cycle of different endemic species, such as fish and shrimp. By combining these productive activities with others, such as tourism and, in some cases, horticulture, farmers have shifted their focus from food production alone to the production and maintenance of heritage landscapes. (Figures 20, 21, 22 and 23)

RESILIENT FOOD SYSTEMS TOWARDS CLIMATE CHANGE AND NATURAL DISASTERS

Beyond adaptation and mitigation, which are usually considered the pillars of global climate discourse, these systems are resilient to the impacts of climate change because of their ability to quickly recover from extreme events such as floods, while also preventing hazards such as landslides and foreshore erosion.

Amid climate change, these agrosystems have diversified their productive activities, creating conditions for local economic development and providing goods and services to urban areas. By rotating between agriculture, aquaculture, horticulture, and associated productive activities, the analysed systems can grow food while adapting to daily tides and seasonal flooding and avoiding land erosion, which is generally seen as a threat to life associated with climate change.

Furthermore, these water systems exhibit remarkable resilience as they have been designed to accommodate changing site conditions. Consequently, they transform themselves according to season, flowering time, migration, and breeding pattern. In this way, local inhabitants also adjust their livelihoods accordingly: when seasonal conditions change, farmers shift among different productive activities, making intelligent use of local resources and improving field efficiency.

INTERDEPENDENCE OF FOOD, ECOLOGY AND SOCIETY

In terms of the societal aspect of these systems, an important insight is the close eco-social relationship and symbiosis among humans, water management, and agriculture. As they are not automated, food landscapes require constant maintenance and care from the inhabitants of each place, fostering an embedded sense of place and a close relationship between humans and their environment.

Furthermore, when locally administered, maintained, and managed, these agrosystems become more democratic and climate-just because of the involvement of their inhabitants in decision-making processes regarding food production and distribution.

Regarding health and well-being, the analysed systems have a direct impact on people's diet; in the current global scenario, for every undernourished person, there are two obese or overweight people. These agrosystems show us how to rely on a balanced diet. By relying on the local food supply, inhabitants derive their nutrition from their surroundings. Simultaneously, people are naturally physically active, as they must work and manage the systems on their own.

NATURE-BASED FOOD PRODUCTION VERSUS EXTENSIVE FOOD PRODUCTION

As discussed in the chapter, these systems were created based on the natural conditions of the landscapes in which they were developed. Therefore, these systems have a special respect for the natural processes inherent in the landscape, allowing them to (partially) survive for thousands of years. The discussed circularity and resilience characteristics of these food production systems can be important lessons towards the current scenario of agriculture, where extensive areas of monoculture or greenhouses are not responsive

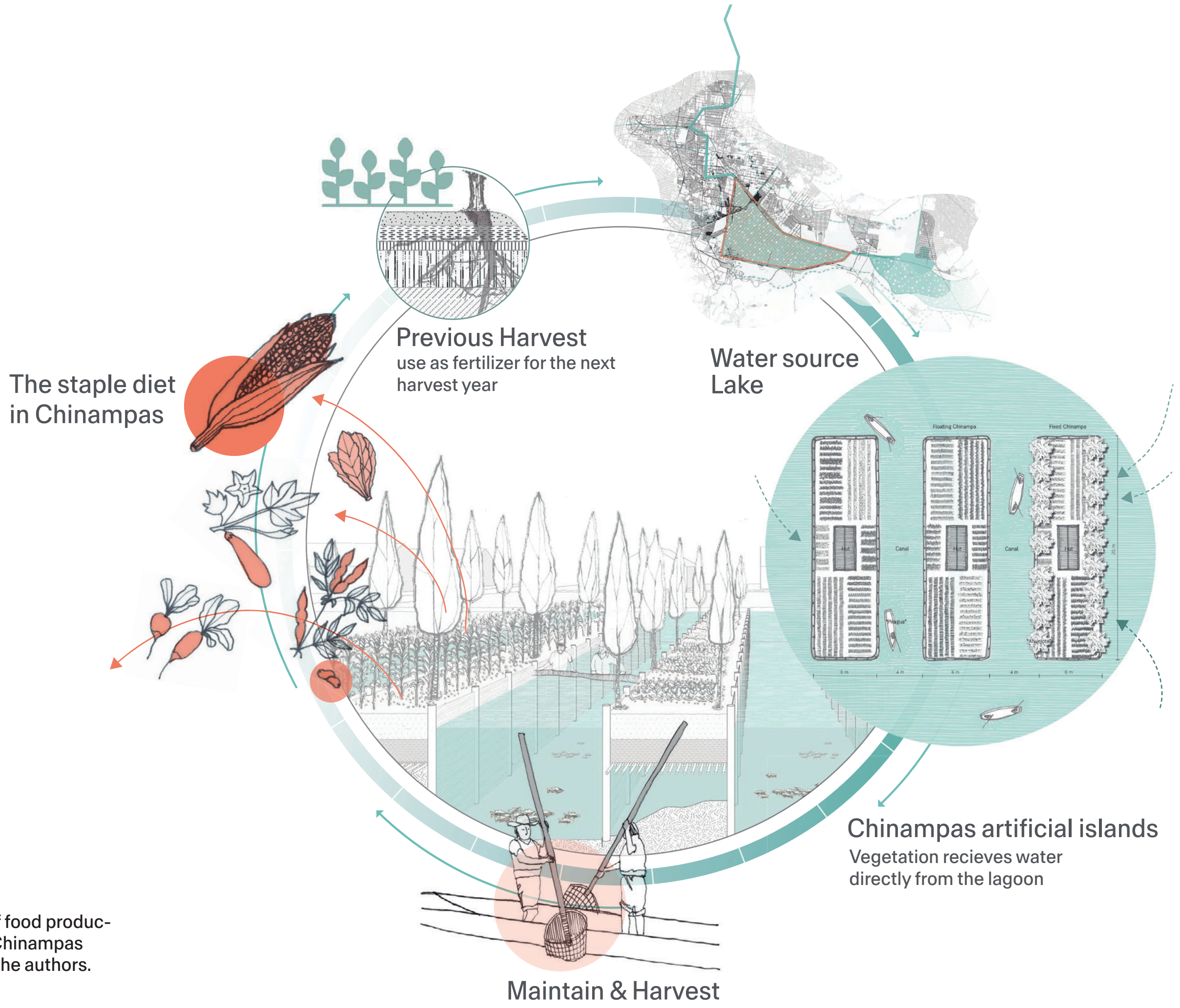


Fig. 20
The cycle of food production at the Chinampas islands. By the authors.

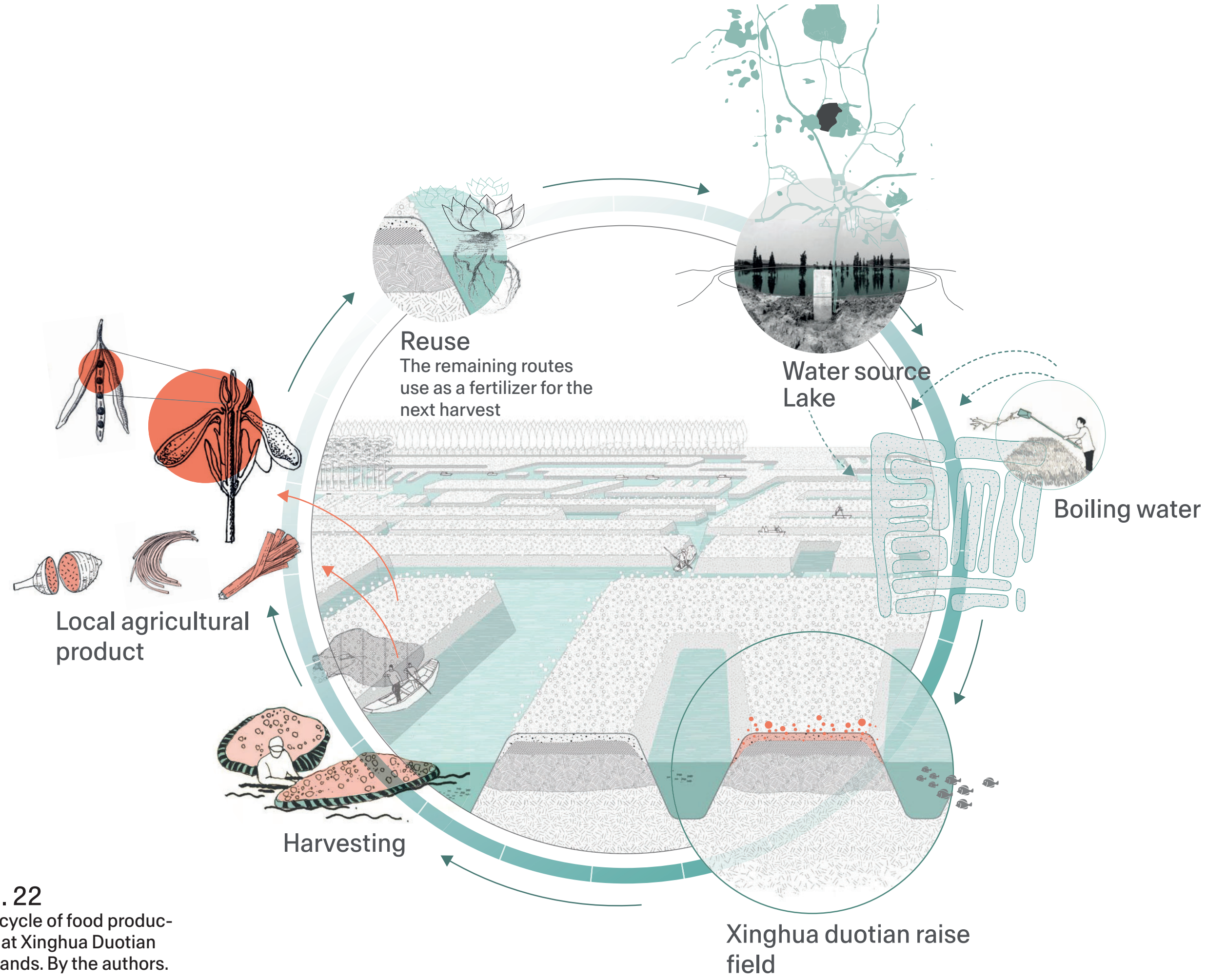


Fig. 22
The cycle of food production at Xinghua Duotian lowlands. By the authors.

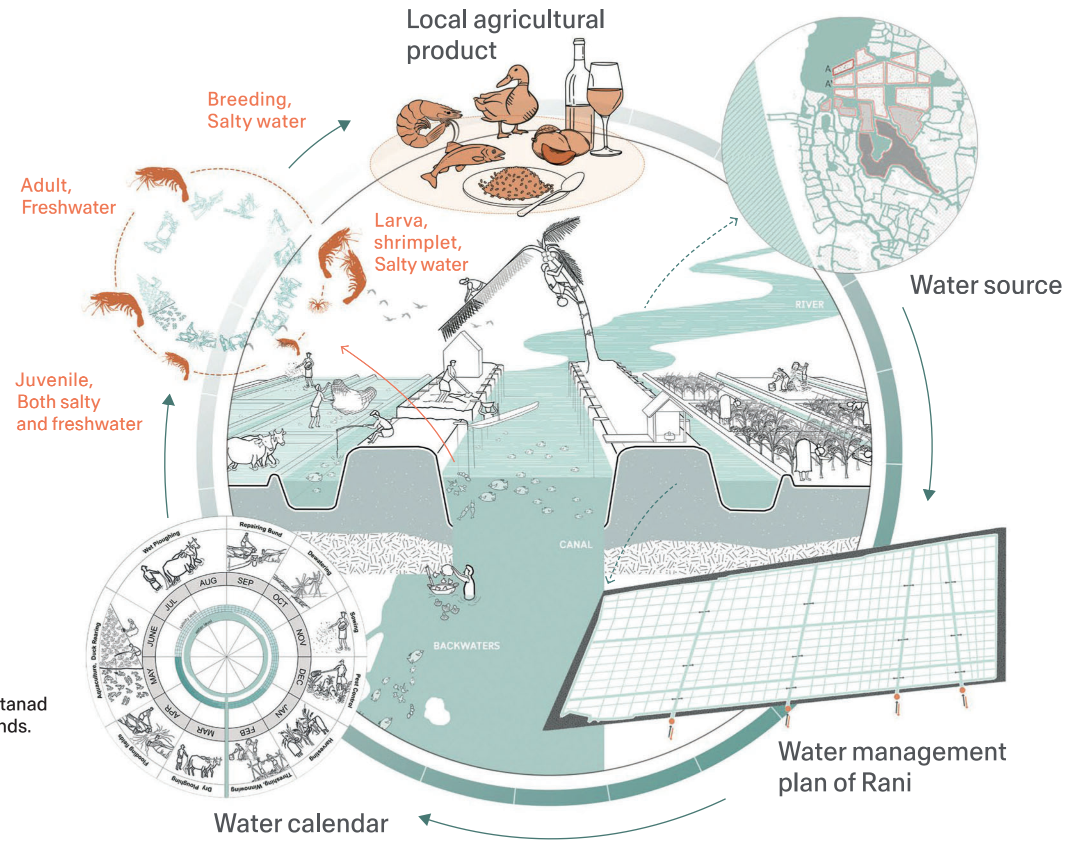


Fig. 21
The cycle of food production at Kuttanad Kayalnilam lowlands.
By the authors.

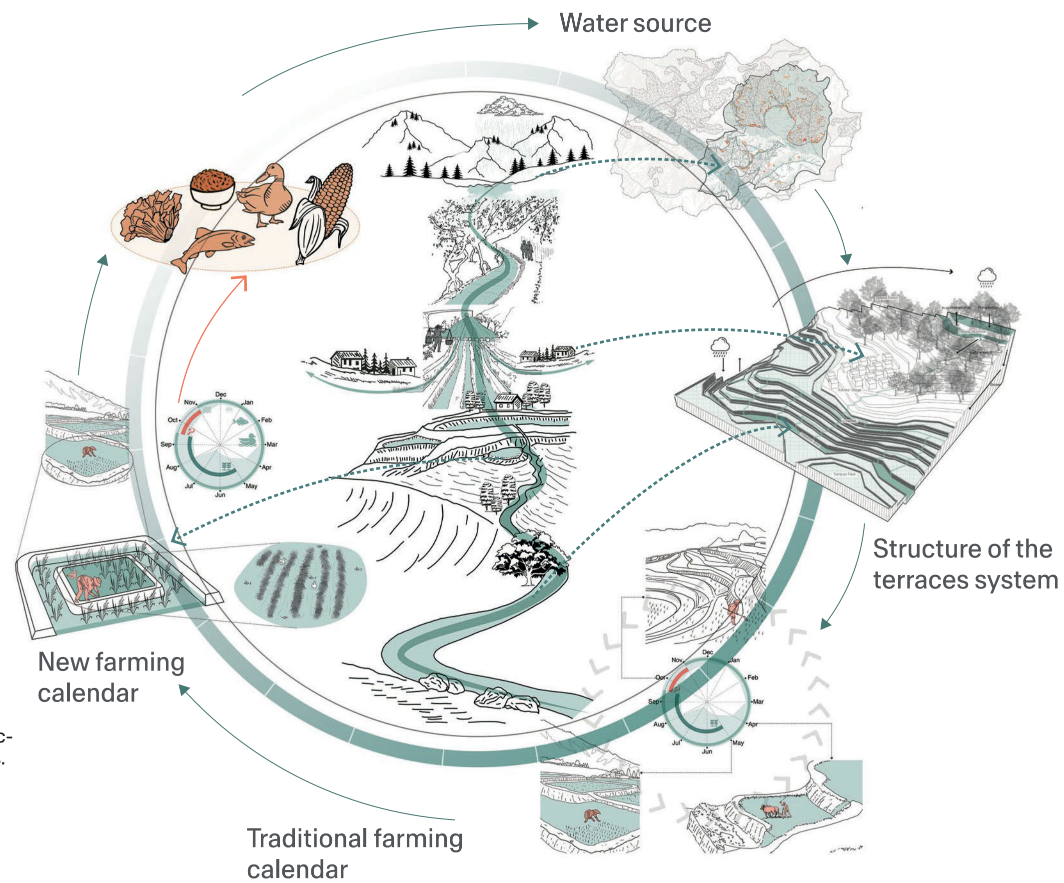


Fig. 23
The cycle of food production in the Hani Terraces.
By the authors.

to the natural context, overuse sensitive resources, such as water, and contribute to the acceleration of climate change through carbon emissions, water scarcity, and excessive pollutants.

CONTINUITY THROUGH ADAPTATION

The traditional agricultural systems discussed in this section demonstrate the central role of water in sustaining food production. By circulating water and nutrients within the landscape, they support irrigation, food security, and multiple livelihood activities during different seasons. Even with changing seasons, local food production is not affected, but is instead adapted. This language of adaptation translates into a unique relationship between ecology and communities, whereby people adapt to the rhythm of the seasons, changing their livelihoods to work both within and beyond agriculture, and to earn money from other ecosystem services, keeping the ecosystem and the local socioeconomic system healthy and alive. All decisions and interventions, ranging from the individual to society level, align with nature, giving rise to nature-based food production systems. With nature and the water cycle as the starting points, these systems have also shown remarkable resilience to climate change and natural disasters, proving that flourishing communities adapt by working with, not against, the natural world.

The central question in analyzing the cases was not only how they functioned, but also why they remained viable. A comparative framework showed that the degree and form of adaptation differ across the Chinese, Kayalnilams, Xinghua Duotian Agrosystem, and Hani terraces. Therefore, their longevity cannot be attributed to any single quality, such as circularity or multifunctionality. What has sustained them is their capacity to adjust production, technologies, and livelihoods to changing environmental and socioeconomic conditions.

Some of these conditions are under pressure, and we identified two main threats common to all four cases. First, although to different degrees, many farmers who have mastered the required agricultural techniques are relatively old, while younger generations tend to leave their hometowns to seek better work opportunities in cities. This weakens both the knowledge transfer and the human power needed to maintain fields, canals, dikes, terraces, and other waterworks. This has resulted in abandoned or collapsed fields that have affected local food production. Second, urban expansion and infrastructure development have converted agricultural land into roads, housing, factories, and other uses, thereby significantly reducing the extent and continuity of several systems. These pressures do more than remove farmland; they fragment the relationships among water management, food production, biodiversity, and local livelihoods on which the systems depend.

However, these landscapes did not survive by resisting all the changes. They have incorporated new technologies, diversified productive activities, and, in some cases, drawn on aquaculture, tourism, heritage recognition, and ecological conservation to remain viable. Such adaptations can support continuity, but can also weaken food production or local control when driven primarily by external markets and development priorities. Therefore, the challenge is not to preserve these systems as static heritage but to enable them to continue changing without losing the ecological functions, knowledge, and livelihood relationships that sustain them. In contemporary agro-landscape planning, the key lesson is to foster adaptive frameworks rather than fixed master plans, allowing water systems, production capacities, and livelihoods to evolve together.

NOTES Feeding Waters

1. Rupeshkumar, personal communication, January 2023.