Design by Radical Indigenism

Equitable Underwater & Intertidal Technologies of the Global South

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Abstract

This article considers the traditional water systems of indigenous cultures and explores their innovations as unique responses to the impacts of climate change in the global south. Local communities have been living with and developing water-responsive infrastructures for generations that engage and support the complex ecosystems they inhabit. Many of these innovations improve coastal resiliency, yet remain undocumented and unexplored in the evolution of contemporary solutions. Rooted in traditional ecological knowledge, or TEK, these technologies work symbiotically with, rather than against nature, and offer examples of a more comprehensive approach to underwater and intertidal design. These innovations are Lo–TEK, a term coined by designer and author Julia Watson, that is defined as resilient infrastructures developed by indigenous people through Traditional Ecological Knowledge (TEK) (Watson 2019). The movement to bring these innovations to the forefront of the design field counters the idea that Lo–TEK indigenous innovation is low-tech, a term often incorrectly applied to indigenous innovation that means unsophisticated, uncomplicated, and primitive. In actuality, Lo–TEK aligns to today's sustainable values of low-energy, low-impact and low-cost, while producing complex nature-based innovations that are inherently sustainable. Lo-TEK expands the definition of contemporary technology by rebuilding our understanding of climate resilient design using indigenous knowledge and practices that are sustainable, adaptable, and borne out of necessity. Indigenous people have learned to live symbiotically with their environments, especially water. This essay will explore the *Kuttanad Kayalnilam* Farming System by the Malayalis in India, the *Sangjiyutang* Mulberry Dyke and Fish Ponds in China, and the *Ramli* Lagoon farms in Ghar El Melh, Tunisia. These innovations are inherently resilient to the stresses of the climate and are multi-functional, symbiotic structures themselves. While not directly intended for protection from the new challenge of sea level rise, they can inform how we can build circular water systems that work with the environment, rather than disrupting it.

Keywords

Lo–TEK, climate adaptation, adaptation pathways, adapt, surrender

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Introduction

This article retells an ancient mythology—that humankind can and must live symbiotically with water. It is an indispensable part of life on earth, and essential to healthy ecosystems. In the past, civilizations and settlements were built on the availability of water resources. Today, this is reversed as humans manipulate the course of water bodies for their benefit. This has fractured our innate connection to the earth's water systems and we have become blind to the strain it is putting on the planet and our livelihoods. Climate change is forcing us to rethink this strained relationship with water and how it has led to disasters and a rising sea. Today, the existential risk of climate change is a global challenge, evidenced by universal metrics and approached with universal solutions. If we continue this generic approach of universality, we perpetuate the thinking that led to this climate crisis. We need to prepare ourselves to face the increasing climatic extremes by turning to complex solutions that have been in existence for centuries and acknowledge an adaptive relationship with the earth's water resources.

With wealthier nations causing climate change, poorer nations are suffering in a crisis that disproportionately affects people living in the global south, a term used for regions that are identified as lower wealth or undeveloped. An increasingly contentious term, however, the ideology behind identifying certain regions as less developed in the western sense is still maintained in discussions of technological progress and resilience. In specifically referring to regions that have been identified as part of 'the global south' the intention is to reverse the stereotype of less valuable and present the innovations and knowledge present in these overlooked areas. In the wealthier nations of the global north, homogeneous, high-tech infrastructures are being deployed in response to climate events. Designed primarily by and for affluent communities, these single-purpose solutions, considered 'best practice,' are so often counterintuitively incompatible with local conditions and the living water systems that have been evolved by local communities (Nunn, 2017). This current practice fails to acknowledge that an immediately available and more equitable typology of solutions already exists. In the global south, there are thousands of sustainable Lo—TEK living water solutions that have evolved by continual adaptation over millennia in response to climate extremes. Instead, the south is sold a belief that the high-tech solutions of developed nations are superior to their own local innovations, even though the latter embody the intelligence of the environments and cultures that have evolved them.

This article challenges this 'north knows best' narrative on the topic of climate solutions that disregards traditional knowledge and frames the need for high-tech and costly infrastructures. Many of the cities and coastal communities in the global south that will be greatly affected by a rise in sea level are already living with these climate extremes, and have developed ecologically intelligent resilient living water systems. This research argues for the imminent need to recognize these overlooked climate solutions, which are inspired by indigenous innovation and embedded with the traditional ecological knowledge (TEK) of communities working with ecological systems thinking.

The research presented here documents the traditional, indigenous responses to coastal resilience found across the global south that amplify local cultural, ecological, economic, and agricultural resilience. These indigenous innovations acknowledge the human relationship to water, through both built infrastructure and cultural practices. The following chapter examines three systems written in collaboration with local indigenous experts. These technologies have evolved from traditional ecological knowledge and work with local conditions and culture. The examples explored are the *Kuttanad Kayalnilam* Farming System in India, the *Sangjiyutang* Mulberry Dyke and Fish Ponds in China, and the *Ramli* lagoon farms in Tunisia. While indigenous peoples and their responses to coastal resilience remain largely excluded in global discussion on design solutions, these studies, reframed through an architectural lens, intend to inform the future of design for climate resilience.

Lo–TEK

Lo–TEK, a term coined by designer and author Julia Watson, is defined as resilient infrastructures developed by indigenous people through traditional ecological knowledge (TEK) (Watson, 2019). The movement to bring these innovations to the forefront of the design field counters the idea that Lo–TEK indigenous innovation is *low-tech*, a term often incorrectly applied to indigenous innovation that means unsophisticated, uncomplicated, and primitive. Instead, Lo–TEK aligns to today's sustainable values of low-energy, low-impact, and low-cost, while producing complex nature-based innovations that are inherently sustainable. Forming the foundation of indigenous technologies, TEK is a field of study in anthropology defined as a cumulative body of knowledge, practice, and belief, handed down through generations by traditional songs, origin stories, and everyday life. By using TEK, humans have been able to harness the energy of ecosystems and adapt to environmental obstacles using soft and symbiotic living systems. Developed through direct contact with nature, TEK is engineered to sustain, rather than exploit resources. It fosters symbiosis between species, while making biodiversity the building block used to construct sustainable technologies.

Lo–TEK innovations come from a deep understanding of working with nature and are evolved from the philosophy of radical indigenism. Coined by a citizen of the Cherokee Nation, Professor Eva Marie Garoutte, radical indigenism argues for a rebuilding of knowledge and understanding of indigenous philosophies from their roots (Garroutte, 2006). For design, this rebuilding can expand our understanding of nature-based technologies and generate new, sustainable, and resilient infrastructures informed by TEK. Lo–TEK is how humans have been dealing with the extremes of the climate for millennia, by harnessing the energy and intelligence of complex ecosystems. It is eminently possible to weave ancient knowledge on how to live symbiotically with nature into the ways in which we shape the cities of the future. We can rewild our urban landscapes and apply Lo–TEK ecological thinking to climate solutions for sanitation, storm surge, sea level rise, drought, deluge, wildfire, food supply, and water, that have worked for indigenous peoples for thousands of years. Lo–TEK expands the definition of contemporary technology by rebuilding our understanding of climate resilient design using indigenous knowledge and practices that are sustainable, adaptable, and borne out of necessity.

Role of Lo–TEK in IPCC Adaptation Pathways

In 2019, the Intergovernmental Panel on Climate Change, a UN body that evaluates climate science and analyses adaptation and resilience options, released a special report on the ocean and cryosphere in a changing climate. The fourth chapter of the report focused on sea level rise and the implications for low-lying islands, coasts, and communities by outlining five typologies of response: protection, accommodation, advance, retreat, and ecosystem-based adaptation. In the following article, the two climate adaptive scenarios in the advancing and accommodating classifications are reframed using the underwater and intertidal technologies of indigenous peoples.

Presently, the IPCC acknowledges the political and social challenges that arise with the current toolkit of responses, but continue to undervalue indigenous innovation. Categorizing the following indigenous innovations - the *Kuttanad Kayalnilam* Farming System by the Malayalis in India, the *Sangjiyutang* Mulberry Dike and Fish Ponds in Huzhou and Shenzhen, China, and the *Ramli* Lagoon Farms of the Andalusians in Ghar El Melh, Tunisia - in accordance with the IPCC's definitions of response towards sea level rise opens the door for our contemporary, resilient design strategies to embrace the more equitable TEK approaches. The IPCC strategies outlined favour western responses of hard protection such as sea walls or relocation, for responding only when it is already too late. While the IPCC acknowledges the political and social challenges that arise in the discussion of which response to take, existing indigenous knowledge remains an unrecognized or undervalued factor, that can be a part of resilience today.

Kuttanad Kayalnilam Farming System by the Malayalis in India

Kuttanad, a low-lying wetland at the mouth of the Vembanad Backwaters in India, is the only place in the country where paddy farming has been practiced below sea level for more than two centuries. Due to this area's unique geographical phenomenon, life here revolves around water with the daily activities like commuting, bathing, washing, and their livelihoods and seasonal celebrations like the snake boat race festivals. During the Pre-Holocene period this was a shallow embayment in the Arabian Sea that later silted up, giving rise to a deltaic formation at the confluence of four major river systems and the backwaters (Padmalal et al., 2014). In the 1800s, when the region encountered an acute food shortage, these virgin landscapes, considered a gift from the backwaters, were reclaimed in a process colloquially known as *Kayalkuthu* which literally translates to thrusting into the backwaters (Chandran & Purkayastha, 2021) .

This comes under the Advance strategy as classified by IPCC which is adopted in many coastal cities, and through which land is expanded into water by reclamation or by the use of dikes. In this system, the artificially created landforms are called *Kayalnilams*, where *kayal* means backwaters and *nilam* means ground, implying that they were lifted out of water (Chandran & Purkayastha, 2021). The *Kayalnilam* system intelligently accommodates seasonal flooding and salinity intrusion, allowing the Malayalis to grow rice, coconut, and other fruit trees through the local technology and water management practices associated with the *Kayalnilams* (Figure 1)

FIGURE 1 An aerial view of two Kayalnilams separated by a water canal, which is similar to the dike and polder system in the Netherlands. (CGH Earth Resort, 2021)

Existing as a striated topographical undulation rising and falling above the backwaters, the system is composed of bio-bunds and canals (Figure 2). The constructed module forms a two-tier system, making it adaptable to seasonal precipitation. The bio-bunds, known as *kuttiyum chirayum*, are made of local materials including coconut poles, bamboo mats, sand, twigs, and sedges like cattail (*Typha latifolia)* and common three square (*Schoenoplectus pungens),* interspersed with high quality clay dug from a lake depth of 20-25m (Nagarajan et al., 2014). The bunds separate the canals which hold water used for irrigation. The water enters the paddy fields through a flexible opening in the bund called a *thoomba*. However, to avoid excess water entering the paddy fields, dewatering[1] technologies called *pettiyum parayum* (Figure 3) that periodically remove water, are placed at strategic junctures between the bunds and the canals. To block the seasonal entry of salt, temporary barriers called *orumuttu,* made of sand bags and twigs are built above the salt level allowing only fresh water to enter the paddy fields. The entire system is lined with an exterior bund two metres above the intertidal level, which acts as a sea defence barrier against fluctuating tidal levels.

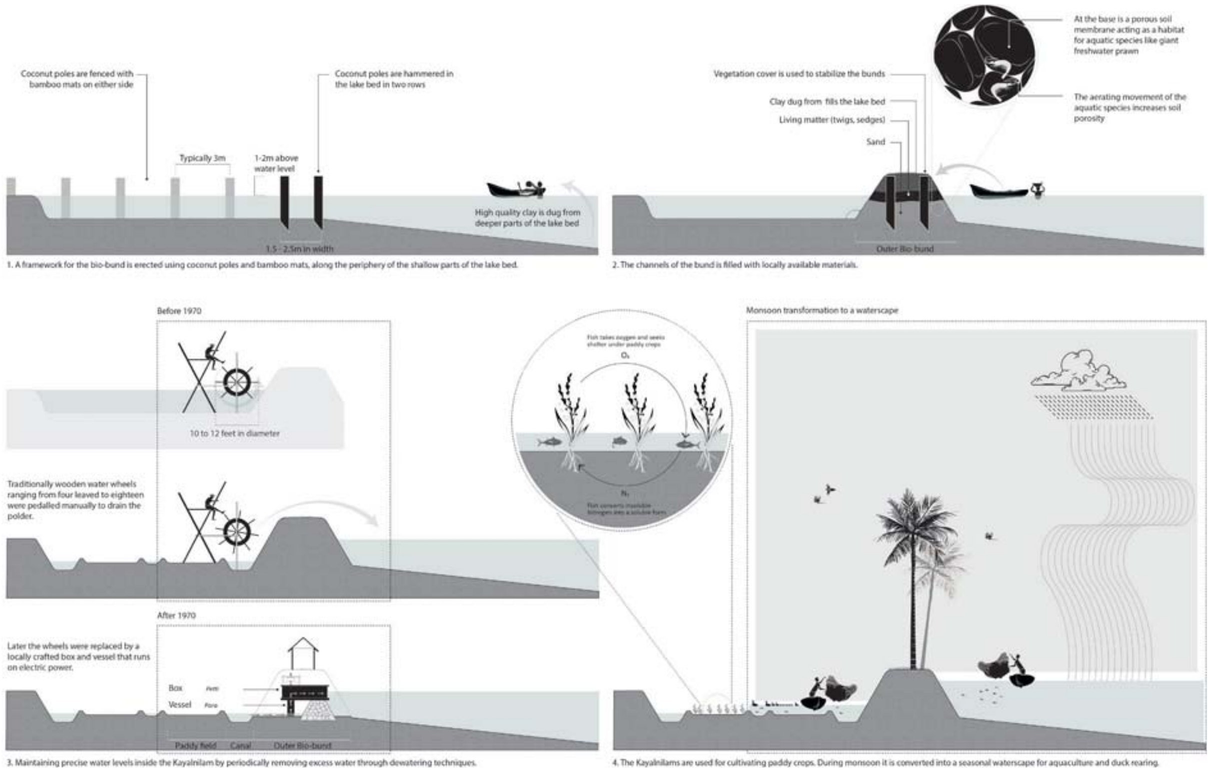

FIGURE 2 The stages of construction of the Kayalnilams and their performance through multiple seasons. The drawing is based partly on research developed within the Circular Water Stories graduation lab at TU Delft. (Ali, 2021)

Beyond climate resilience and agricultural optimization, these bunds and canals also improve water quality and structure a complex habitat. As a permeable structure, the bunds act as a favourable ground for freshwater prawns and other aquatic species while the canals serve both as a fish nursery and hunting ground. Fish venturing upstream during high tide are trapped in the system by a detachable net fitted inside the dewatering technology. The introduction of fish into the system creates opportunities for aquaculture with some fish that seek refuge under the roots of the paddy crops. Stirring movements of the fish aerates the planting bed improving the surface soil conditions both in terms of porosity and fertility. This accelerates the growth of paddy crops which in turn provide oxygen and food for fish, as their roots favour the growth of microorganisms which are natural fish food. This symbiosis between rice and fish is further enhanced by the recurring movement of salt and water in the system.

1 Dewatering is the process of pumping water out from the low-lying paddy fields to the major canals or backwaters. Traditionally, wheels of ten to twelve feet in diameter with a blade width of one to fifteen feet were used. They were pedalled manually by men to remove water. The water wheel ranged from 4-leaved to 18 leaved. Owing to the extensive labour, these wheels were later replaced by a technology crafted by local blacksmiths which runs on electric power.

FIGURE 3 The pettiyum parayum is an indigenous dewatering technology, which runs on electric power, to periodically remove excess water from the paddy fields. (George, 2021)

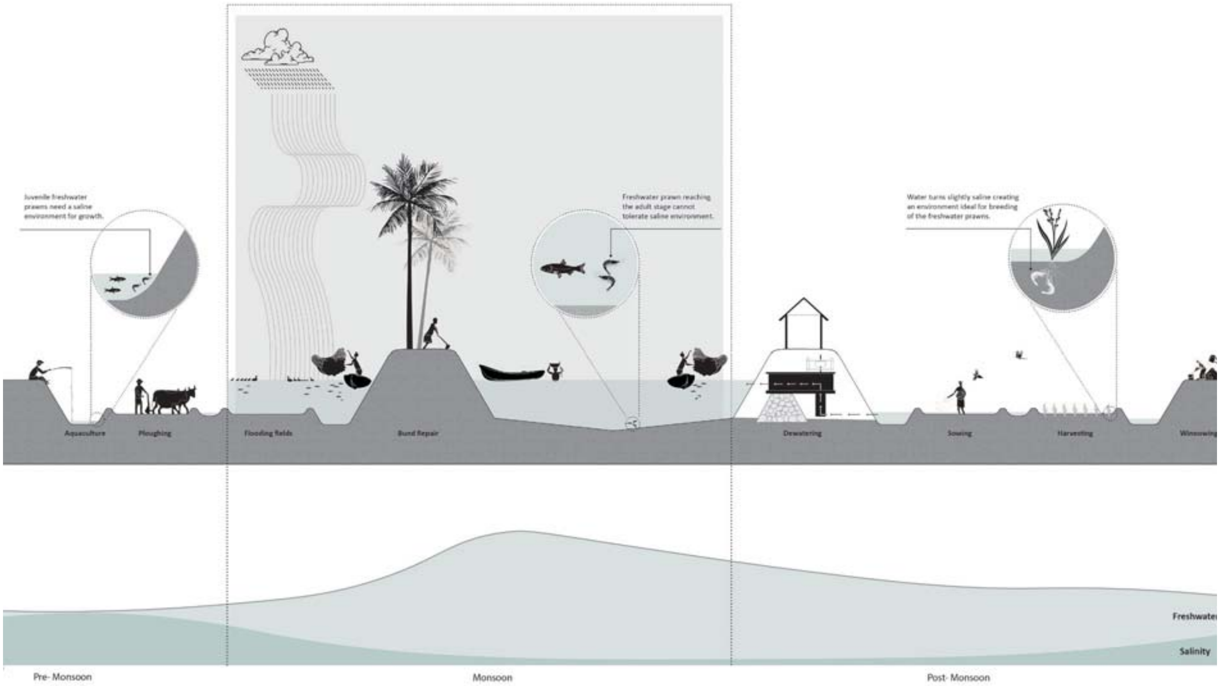

FIGURE 4 The cycle of shrimp, salt and water which influences the seasonal operations of the Kayalnilams. The drawing is based partly on research developed within the Circular Water Stories graduation lab at TU Delft. (Ali, 2021)

Rotating between agriculture and aquaculture, the people of Kuttanad live in harmony with the seasonal mixing of fresh and saline water (Figure 4). While water flows from rivers into the sea for most of the year, during the pre-monsoon when river flow drops below sea level, water flow reverses to travel inland from the sea, bringing salt which is universally considered a curse for farmers. The increased salinity is unsuitable for paddy cultivation, so *kayalnilam*s are deliberately flooded to create a watery landscape for the seasonal transition to aquaculture and duck rearing (Figure 5). With the onset of the monsoon, river flows again reverse and flow back into the sea, restoring the freshwater needed for paddy cultivation. Paddy fields accommodate excess water during heavy rains while the soil is enriched with silt and duck droppings. During this period, the farmers prepare the submerged ground with simple tools and animals. Post-monsoon, water levels recede, and the paddy fields are dewatered to begin growing crops, which are harvested before the next saltwater intrusion from the sea.

FIGURE 5 The Kayalnilams flooded during monsoon. (Chandran, 2021)

Due to the resemblance with the Traditional Dutch landscape, Kuttanad is often referred to as the *"Holland of the East"* by the western world. But unlike the polder dike system constructed for flood prevention in the Netherlands, the *kayalnilams* engineered in local building materials allow a higher degree of flexibility for seasonal exchange of salt and water, while exerting less control over the natural processes. As a local technology, the *kayalnilams* are living, intertidal landscapes that adapt to the vulnerability of flooding and salt intrusion by supporting food production, securing livelihoods, and minimally disturbing the natural balance of the ecosystem. At the watershed scale, these landscapes act as a seasonal retention basin, harmonizing the construction, maintenance, and operation of agricultural infrastructure with the water cycle.

The circle of life in the *kayalnilams,* characterized by a multi-species ecosystem, is linked to this cycle of water and salt, intermingling with the cycle of agriculture and aquaculture. This relationship with water is further accentuated by the daily lifestyle of the people and their unique cultural practices. In the wake of global food insecurity and salt intrusion upon vital coastal agricultural lands, further aggravated by climate change, this traditional land-water technology can be a model for the future direction of intertidal agricultural landscapes.

Sangjiyutang Mulberry Dike and Fish Ponds in Huzhou and Shenzhen, China

For over five thousand years, parts of the Yangtze and Pearl River Deltas have flourished through the development of an ingenious adaptation technology of dikes and fish ponds located in low-lying areas, which aligns to the ‘advance’ strategy of sea level rise adaptation. Advancing by way of polderization has a long history in China as well as in Germany and the Netherlands (IPCC, 2019). This system uses polders to redirect water, forming a new ecosystem and a sustainable water management system that fully integrates the water cycle. This honeycomb-like network of polders and dikes appear as a sprawling mosaic of ponds, interconnected by ribbon-like green strips that are dotted by dense settlements (Figure 6).

FIGURE 6 The honeycomb morphology of the mulberry dike and fish pond system in Huzhou, China. (Dai, 2017)

This system, which is still in use today, first developed in Huzhou in the Yangtze river delta, and began with the planting of mulberry trees and the subsequent rearing of silkworms, known as sericulture. However, the lower reaches of the district of Huzhou faced serious seasonal waterlogging during the monsoon from the flow of the Dongtiao River. In response, the farmers converted the seasonally flooded areas into fish ponds lined by dikes, and the entire system integrated the mulberry tree sericulture practice with the rearing of fish and livestock. Two thousand, five hundred years later, a similar dike-pond system emerged in the lower reaches of the Pearl River Delta, with fruit trees, like banana, planted atop the dikes surrounding the fish ponds (Gongfu, 1982) (Figure 7). In the early seventeenth century, the system evolved into a combination of mulberry sericulture and aquaculture, farming four major fish species and creating a local silk and fisheries economy integrated with industries and settlements (Figure 8). For both systems located in a low-lying marshy ecosystem, the dike-pond technology is the smallest module of a multi-scalar water management system for these deltas (GIAHS, 2017).

FIGURE 7 A more recently constructed mulberry dike and fish pond system located in Shenzhen, China. (Sun, 2019)

FIGURE 8 Sited within a dense urban settlement and surrounded by industries, the mulberry dike and fish pond system serves multiple functions. (Sun, 2019)

FIGURE 9 Sericulture on the banks of the fish pond amidst the leaves of the mulberry trees. (Okic, 2021)

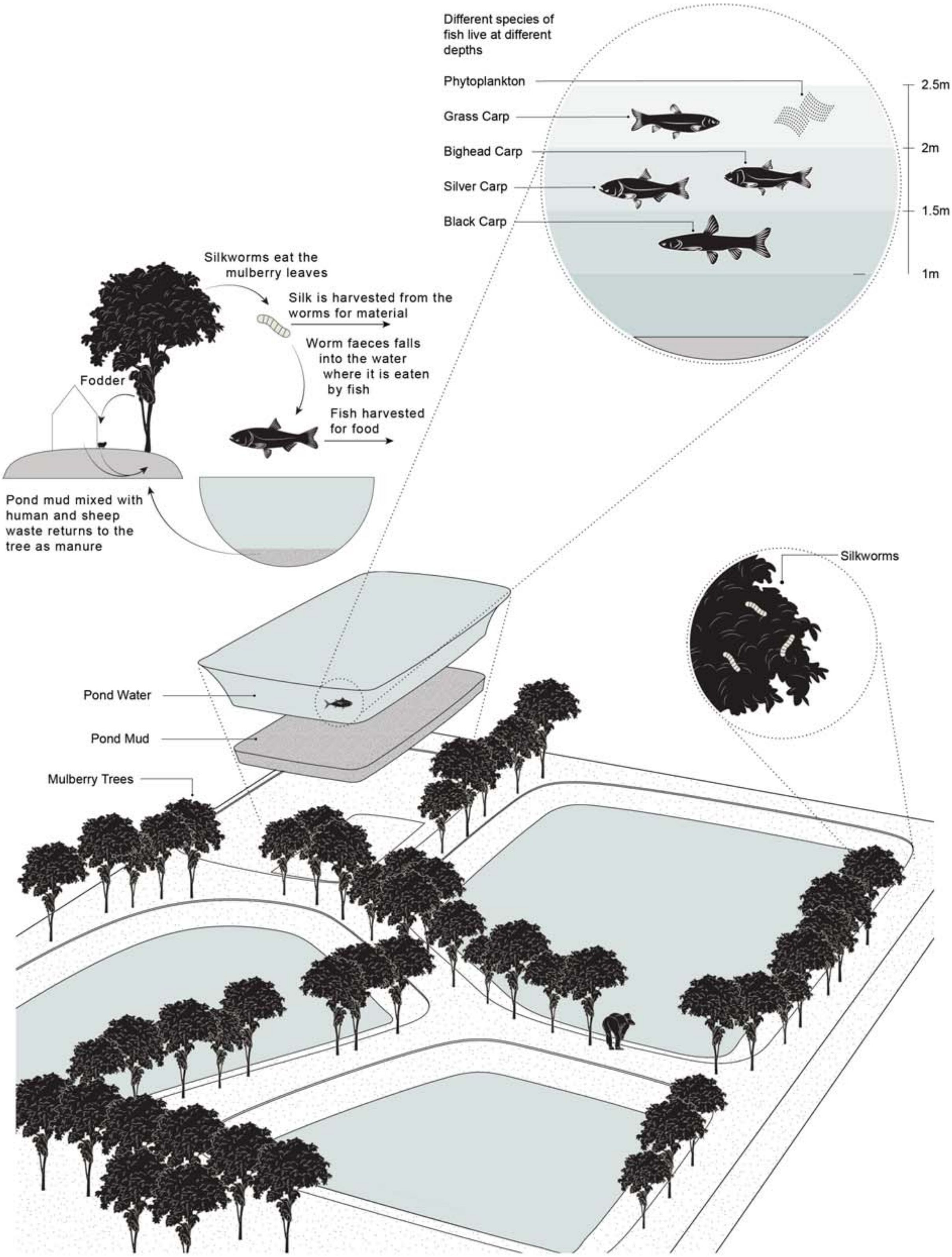

FIGURE 10 The closed-loop energy and material cycle of the mulberry dike and pond system. (Robertson and Ali, 2021)

The systems are characterized by their ability to maximize productivity within closed-loop energy and material cycles. Grown on the banks of the fish ponds, mulberry trees (Figure 9) provide leaves for silkworms to eat, while silkworm faeces and sloughs falling into adjacent ponds provide food for fish. The fish faeces along with the unconsumed silkworm and mulberry waste, are then decomposed by aquatic microorganisms, which produce nitrogen, phosphorus, and potassium, that return to the mulberry trees as nutrient-rich manure, thus restarting the cycle (Gongfu, 1982). Species selection is foundational in maintaining a biological balance in this circular ecosystem. The four fish species introduced were chosen according to the level of water in which they reside. The slopes between the mulberry fields and the fish ponds creates a trapezoidal pond edge, which reduces soil erosion in the mulberry fields. In addition, fertilizer leaching from the mulberry fields in the rainy season flows down the slope and into the pond, contributing to an organic cleansing technique (Qing, 2013). The system also introduced other seasonal activities that integrated symbiotically with the sericulture cycle, including raising a special breed of sheep adapted to the cycle of sericulture. Mulberry leaves provided the main fodder for the sheep. In return, sheep manure was then combined with human waste to fertilize the mulberry trees, introducing a secondary cycle of symbiotic activity (Figure 10).

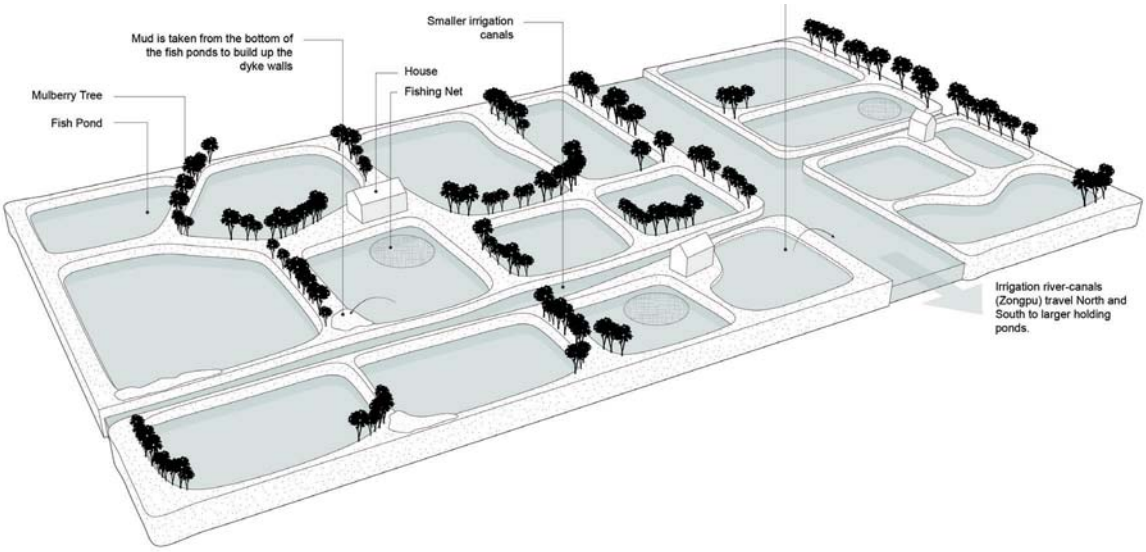

FIGURE 11 The aggregation of ponds and canals in the mulberry dike and fish pond system. (Robertson, 2021)

Besides complimenting the sericulture cycle, the fish ponds are the smallest unit of a larger irrigation, drainage, and flood prevention system (Figure 11). The lowland of Huzhou has always been vulnerable to flooding because of poor drainage during the monsoon, resulting in long-term, large-scale waterlogging. In these lowlands, the fish ponds were integrated into a larger water management system, called *Hengtang-Zonglou* reaching Lake Tai, the largest freshwater lake around the Yangtze River Delta (Zhuang, 2018). The fishponds maintain the water level in the surrounding settlements by accommodating excessive rainwater, while the overflow drains to Lake Tai in monsoon season, through *Zonglou*, a water channel system perpendicular to the lake. In the dry season, the water is led into the fishponds to soften the channels and dikes. On the other hand, *Hengtang* are rainwater channels that direct water from the east and west mountain areas into the lake. Together, both these networks of channels create a checkerboard-like water-management pattern. The same process occurs in the fishponds of the Pearl River delta near Shenzhen, where the fluvial swamplands are converted into a fishpond landscape connected to a multi-scalar water management system.

FIGURE 12 Satellite image of the Huzhou area showing the dike and fish pond system connected to the macro water management network. (Google Earth Pro, 2021)

The mulberry dike fish pond systems have an ecological multiplier effect upon the ecosystems they inhabit, beyond creating a closed-loop water management system. Local resources are maximized to produce commodities like fish and silk, which in turn provide income and secure livelihoods. The nutrient-rich mud creates an organic fertilizer and a terraforming building material. This recycling of waste and energy replaces the need for chemical fertilizers, pesticides, herbicides, and concrete flood barriers, while cutting costs. Further, due to the aquatic diversity of the ponds, they also act as excellent carbon sequestration technologies. When coupled with the Mulberry tree - an air purifier, and carbon sequestering vegetation more effective than other agricultural plants - a carbon negative, zero-emission, textile-producing, aquaculture, agriculture, waste-water system emerges (GIAHS, 2017). This integrated system of water and land forms a resilient, hybrid solution that can inform both water and land management practices, in areas that experience frequent flooding. The system can serve as an inspiration for managing highly urbanized intertidal zones or frequently flooded urban areas to constitute a new typology of the green city. The Shenzhen area is a living example of how these Lo–TEK solutions weave the threads of the city's past with legitimate technological ambitions of the present-day while bringing biodiversity back into the city and humans closer to nature - ultimately crafting a resilient future with added economic and ecological benefits.

Ramli Lagoon Farms of the Andalusians in Ghar El Melh, Tunisia

A strategy for sea level rise outlined by the IPCC is 'surrender' or 'accommodate,' which takes the approach to sea level rise of letting water in. This strategy can take place at various scales, methods, and levels of temporality. It can be applied in urban environments through flood zoning restrictions, insurance plans, warning systems, emergency planning, setbacks, and flood barriers. The IPCC's definition of accommodation refers to the redesign of physical and political infrastructure to accommodate sea level rise and reduce vulnerability. In addition to urban flood accommodation measures, strategies include updating building codes, raising buildings on stilts, floating houses and gardens, aquaculture and adapting to salinity intrusion, though changing crop varieties and land use. In this section the *Ramli* Lagoon farms in Ghar El Melh, Tunisia, are explored, due to their unique agriculture on man-made islands that utilizes fresh water accumulation on salt water surface.

On the shores of Ghar El Melh lagoon, adjacent to the Mediterranean Sea, is a drastic gradation across the landscape from a thin belt of elevated dense urban fabric opening to a vast lagoon with scattered irregular sized vegetated islands (Figure 12). In the 17th century, following a Roman invasion, the Andalusian people (of modern day Southern Spain) were forced to relocate to places along the coast of Tunisia. These farmers established crops by terracing the foothills of the Ennadhour mountain and feeding the agriculture with manure transported on the backs of men and donkeys. Today, some of the terrace agriculture that was managed by families remains, while much of it has moved to the shores where it was better protected from invaders by the Ennadhour mountain (FAO, 2020) (Figure 13).

The Tunisian coastline today is home to nearly two-thirds of its population of twelve million people. However, these dry, coastal areas make agriculture a challenge. The early inhabitants who occupied the banks of the Ghar El Melh lagoon located in the Gulf of Tunis faced a shortage of arable land with the city wedged between the shores of the lagoon and the rocky mountains of Jbel Ennadhou (IUCN, 2020). At the time, the only arable land was in the mountains and fed by natural springs. In response to the lack of cultivable coastal land, the poor-quality soil, and the scarcity of irrigation water, came ingenious agricultural techniques like the two hundred and ninety ramli farms cultivated by the farmers, or fallahs. Since the year 1000A.D., the lagoon has silted up, which has led to the formation of sand barriers parallel to the coastline. In the 17th century, a coastal barrier called a *Boughaz*, separating the lagoon from the Mediterranean Sea, was introduced, allowing seawater to flow into the lagoon (FAO, 2020) (Figure 14). Today, the lagoon is further shaped by the construction of the ramlis using sand excavated from the shoreline. The word *ramli*, which means sand in Arabic, points to this transportation of sand from the shores to reclaim land along the shoreline of the lagoon (Aissaoui, 2020) (Figure 15).

FIGURE 13 An aerial view of the ramli lagoon system showing the artifical islands located south and downstream of Mount Ennadhou. (Google Earth Pro, 2021)

FIGURE 14 In the background lies Mount Ennadhou, which supplies irrigation water to the ramli farms by natural springs and run-off from seasonal rains. (Aissaoui, 2020)

FIGURE 15 Ramli plots are divided by sugar cane fencing to protect crops from sea spray and wind. (Aissaoui, 2020)

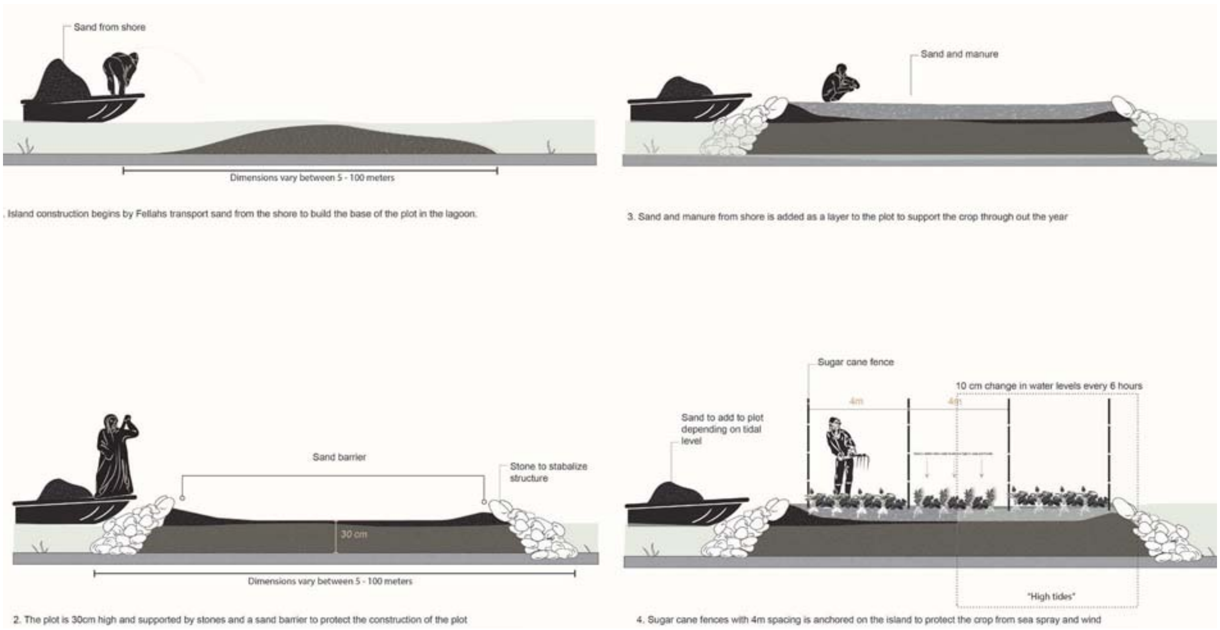

FIGURE 16 The four stages of construction of a ramli artificial island. (Abukhodair, 2021)

The varying sizes of the ramli sand beds form the base modules of construction for growing an intensive polyculture of seasonal, shallow-rooted crops like potatoes, onions, watermelons, tomatoes, pepper, and fennel (FAO, 2020). The whole system is lined by reed trays, planting hedges, and fruit trees located peripherally with sugarcane branch fencing added every four meters between crop rows to protect them from the sea spray, slow the evaporation process, and stabilize the sand beds. (Figure 16). A major challenge these cultivated plots encountered was saline intrusion from the lagoon. In response, the *fallahs*, or farmers, developed an innovative year-round passive irrigation system that makes use of freshwater tidal fluctuations in the lagoon (EuropeanSeed, 2020). Relying on tidal movements in the lagoon, and seawater being denser than freshwater due to its salt content, freshwater reaches the plant roots through capillary action (FAO, 2020). This layer of fresh water moves up and down about ten centimetres, twice a day, every six hours, at high and low tides. As the freshwater saturates the sand twice daily, it nourishes the roots of the crop from the ground up. Any imbalance to the system, such as low roots that come into contact with saltwater or high roots that dry, will cause the crop to fail (Aissaoui 2020) (Figure 17). The *fallahs* who manage the system are charged with balancing both the sea and soil levels which must remain equal, by adding sand and manure (GIAHS, 2020)(Figure 18).

FIGURE 17 The Coastal Barrier Boughaz in view with the Ramli plots landscape. (United Nations Development Programme - Tunisia, 2021)

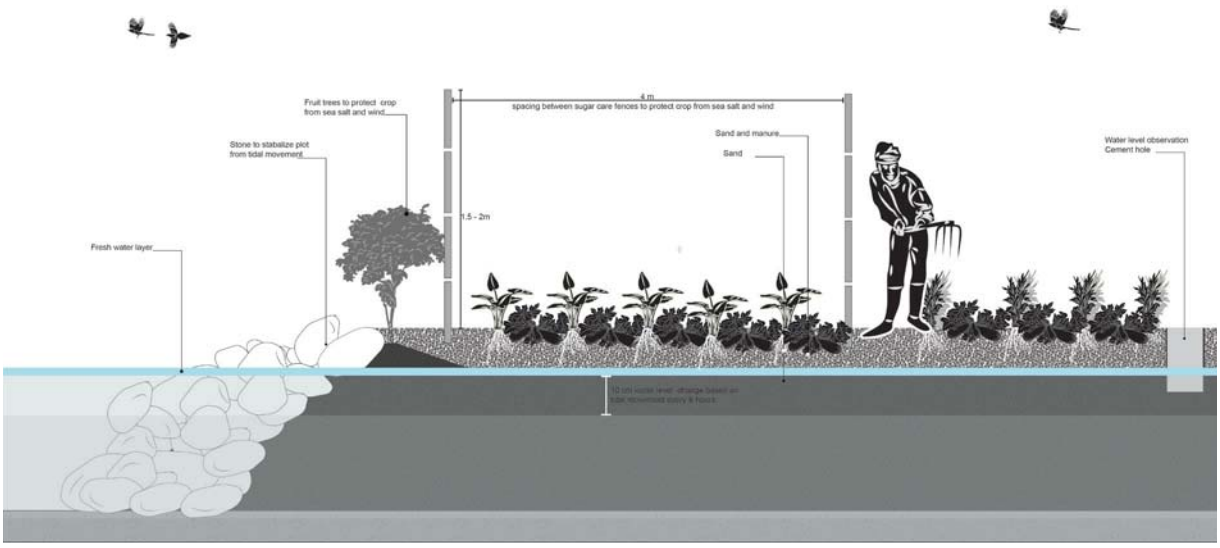

FIGURE 18 The technology of the ramli artificial islands works with tidal levels and a thin sliver of freshwater which is more buoyant than the salt water. (Abukhodair, 2021)

Although the island farms were constructed to support agriculture in a lacustrine environment, they have also played a critical role in shaping the morphology of the lagoon (IUCN, 2020). Without the farms, the lagoon banks and subsequently the city would have washed away. The *RAMLIS* offer a living example of humans and nature exchanging roles, alternating between being makers and takers of the landscape. With half of the village populations along the coastlines dependent on ramlis for their daily livelihood, the balancing act of the system plays an incredibly vital sociological and ecological role. By planning intelligent crop rotations, the *RAMLIS* can be cultivated throughout the whole year. Due to these ingenious, natural irrigation methods that work symbiotically with the water cycles and the water regimes of the plants, these techniques are vital to areas facing water scarcity due to the lack of availability of freshwater and where saltwater poses a constant threat.

Lo—TEK for Climate Resilience

Climate change and sea level rise are unprecedented adversaries that are adaptive, responsive, and capable of complex interactions along coastlines. Variations in local conditions, communities, and ecosystems coupled with global weather patterns warrant unique responses that amplify strengths and counter weaknesses. In the end, avoiding catastrophe will largely depend on individual responses by communities and governments, rather than universal approaches. While the global north biases the universal climate solutions of high-tech, hard infrastructures and carbon-credited conservation areas, another approach found predominantly in the global south remains unacknowledged. The existing and undervalued Lo—TEK nature-based technologies that have evolved from thousands of years of place-based knowledge are continually erased following the 'north knows best' narrative (Watson, 2019). These local technologies offer a more socially and environmentally equitable alternative for nations fortunate enough to have these highly sophisticated technologies that work in complex symbiosis with their natural systems still in existence.

Scientists have acknowledged that the world is in the midst of the earth's sixth mass extinction, but species extinction alone will not be the twenty-first century's greatest loss. Those same forces that drive species extinction endanger the local, nature-based technologies - not yet recognized as technologies - that may hold a key to the survival of the world's population in the global south. These are technologies that have evolved and passed through generations in response to flood, fire, drought, sea level rise, and severe weather – the same crises we face today. These are incredibly well adapted to their environments and play an important role in conserving global biodiversity.

Indigenous people have learned to live symbiotically with their environments, especially water. In this article, three case studies have been presented. The examples are inherently resilient to the stresses of the climate and are multi-functional, symbiotic structures themselves. While not directly intended for protection from the new challenge of sea level rise, they can inform how we can build accommodating and advancing protection systems that work with the environment, rather than disrupting it, and provide services in the forms of agriculture and aquaculture. These Lo—TEK infrastructures are not a replacement for sea walls and urban hard infrastructure, but are an important part of designing for overall sustainability in the face of climate change as they work with rather than against nature. We cannot go backwards, fixing all of the hard infrastructures, creating more extractive activities, and displacing more communities in the name of conservation. These activities have caused and exacerbated climate change and a great loss of biodiversity. Further, the thinking that glorifies high-tech infrastructures has undervalued the Lo—TEK solutions and has eventually put them in a position of risk. Instead, we can go forward by funding, rethinking, rebuilding, and scaling Lo—TEK climate solutions that support the resilience of both communities and cities, while addressing the inequalities and distance from nature that our current systems and climate solutions support.

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