Interiority, 2022, Vol. 5, No. 2, 179–196
DOI: 10.7454/in.v5i2.210
ISSN 2615-3386 (online)
ISSN 2614-6584 (print)

Water-Based Settlement and the Loss of Community Water Resilience

Patiphol Yodsurang,[1] Yasufumi Uekita,[2] Ikuro Shimizu[3]

[1]*Kasetsart University Thailand*

[2]*University of Tsukuba Japan*

[3]*Shibaura Institute of Technology Japan*

Abstract

After the first dam was built in the Chao Phraya River during the 1950s, several water-controlled structures and megaprojects were built throughout the basin. For the first 30 years, water levels were stable, and the dams largely provided flood prevention. However, in recent years, global warming and climate change have been driving the frequency and intensity of extreme events. Local people have gradually lost their resilience against living with water during the years of a stable flood and flow system. This caused the interiority of the amphibious culture to drown into an oblivion state in the water-based settlement. The investigation was conducted in two villages with identical environmental conditions and similar cultural livelihoods in the floodplain of Ayutthaya Province against seasonal water intrusion. The physical characteristics of housing and cultural landscape of the waterfront villages were analysed via floor plans and cross-sectional study to explain the physical changes through time. The primary investigation revealed that the loss of the underneath space is an important indicator of housing changes resulting from the water conditions becoming more stable. Individuals have started to forget how to live with water. At the same time, the characteristics of the stilt house with an underneath space indicated that the communities continue to practice resilience to co-exist with the flood phenomenon.

Keywords: cultural landscape, waterfront, settlement history, resilient community, climate change effect

Correspondence Address: Patiphol Yodsurang, Faculty of Architecture Kasetsart University, 50 Ngamwongwan Road, Jatujak, Bangkok 10900, Thailand. Email: patiphol.y@ku.th

Introduction

Riverside communities and livelihoods are characterised by the cultural landscape and driven by the river flow pattern (Yodsurang et al., 2016). These communities are the backbone of the important riverfront culture; they feature the ecological environment, water behaviour, local vegetation, and production systems suitable for their location and sustainable use of available local resources (Kwansuwan, 2015). Thus, they have illustrated the human interaction with environmental resources on land and water for hundreds of years and reflected in the interior spaces, which could be perceived as an embodiment of the socio-cultural roles, values, and relationships (Atmodiwirjo & Yatmo, 2022). As part of riverside geography and cultural context, interiority is manifested through the local inhabitants of the amphibious culture. These communities reflect the diversity of landscapes, cultures, and agricultural activities. People in such communities have gradually developed water resilience and functionality. Water resilience refers to the ecological aspects of water quality or flood mitigation, engineered infrastructure, social inclusivity, and equitable governance related to a safe and reliable water supply and flood mitigation (Rodina & Chan, 2019). It is related to social systems, particularly in the context of water resource management and governance (Rodina, 2018). However, such resilience extends beyond the actual settlement site and includes a broader landscape and waterscape, a whole place with geological, biological, and human interactions. All places have a relationship with people, perceived and defined by those interacting with them.

However, following the construction of the first dam in the Chao Phraya River during the 1950s, several water-controlled structures and megaprojects were built throughout the basin to provide water for consumption, irrigation, and industrial processes. Water levels were stable in the first 30 years, and the dams largely provided flood prevention. However, the record of climate change and its drastic impact on urban development after the 1980s reveals a consequential impact on community resilience. Housing styles and the cultural landscape are testaments to these phenomena. The existence of riverfront communities in modern society reveals how such concerns might be addressed in the context of global change. This study investigates two significant agricultural areas in the Greater Chao Phraya and its basin to identify the distinctive water behaviour associated with geology, biology, topography, and traditional livelihoods, creating a paradigm shift from the actual location of cultural landscape properties to pursuing a broader context.

In villages located near the river, people have been living in various styles of houses, such as stilt, raised floor, and floating, with their livelihoods depending on the ecological environment of the watershed. Today, despite countries advancing their efforts to preserve rich cultural diversity on waterfronts, the cultural landscape has been lost due to changes in the ecological environment and living style. In many waterfront villages, traditional cultural landscapes are currently in crisis due to changes in the ecological environment and socio-economic aspects. The traditional house design of an elevated floor on high stilts to overcome flood and facilitate ventilation has primarily changed regarding efficient utilisation of the underneath space and modern lifestyle. Meanwhile, local materials like wood and bamboo have been replaced by reinforced concrete, slate, and iron sheets due to the labour load and durability required in preparation and construction. As a result, the form of the house and the way of living were homogenised long ago and have gradually changed. Consequently, the traditional knowledge, labour exchange, and mutual help essential for preserving the cultural landscape, are being lost. Furthermore, the relationship between man and water will be changed forever.

This study aims to present a shift in the water resilience of two villages in the floodplain area by emphasising their indigenous cultural heritage and traditional knowledge of how people live with water and reduce damage from water overflow. The results highlight the importance and urgency concerning the changes in river floods and the flow system and its effect on local community resilience. The study aims to understand the community's resilience through the physical characteristics of housing and cultural landscape in a waterfront village, focusing on the changes in river flow as part of the cultural landscape. In addition, the social bonds, relationships, and professional expertise related to the cultural landscape and management of the ecological environment are investigated. The cultural landscape has a strong affinity with water, and an efficient methodological model must be established to maintain its cultural diversity. Thus, it is vital to consider the community's resilience against changes in river flow and loss of the water-based cultural landscape. It is part of the community's living heritage to maintain the authenticity and integrity of these properties. Ultimately, the actual water system must be involved in the crucial consideration of any development program across the heritage setting.

Methodology

This qualitative investigation was conducted to study how humans adapt to environmental and water-based changes, leading to a

grounded theory emphasising these phenomena with data derived from actual living conditions. This paper aims to explain the physical changes occurring in the traditional houses of two agricultural villages in the central flood plain of Ayutthaya by presenting information on the architecture, community, and cultural landscape. This investigation is primarily based on a physical survey and a review of related studies, including climate change and water management records. However, the data derived from the survey on physical conditions is designed to understand the nature of the changes occurring and settlement continuity in a comparative, multi-case study. The results of the data analysis reveal the changes and the threats affecting the whole riverfront community. The case study selection procedure employed the snowball sampling technique, consisting of 20 cases in two villages located in the central flood plain of Ayutthaya.

The derived data were organised in chronological order and subjected to cross-case analysis. Data from observations and interviews were categorised according to the sequence of events and the occurrence of significant changes in the Greater Chao Phraya River Basin overall and the case study area. The analysis compared aerial photographs, architectural characteristics, and interview data with any changes within the case community over time by analysing the physical characteristics of the architectural data via floor plans and cross-sectional study.

Context of Study

A critical examination was conducted on the resilience of two villages in the floodplain of Ayutthaya Province against seasonal water intrusion. These villages demonstarte a unique characteristic in response to flood events which has been extremely important to the development of community settlements and social structures which have clear relationships with the water ecosystem. Most (flooded) rice cropping techniques and ecological situations are subject to land-use intensity, variety, and cropping calendar (Kasetsart University & ORSTOM, 1996). Thus, a comparative study was conducted throughout a flood-prone area inside and outside the Sena Trough, which faced high flood levels of more than 1 m for seven months of the year (Kaida, 1974). This study investigated two communities in Phra Nakhon Si Ayutthaya Province, both characterised by the seasonal flood. Ecological services produced by flood pulse dynamics were essentially the basis for rural economic development, especially deep-water rice and fish (Nilaponkun & Thaitakoo, 2019). The first case study involved a community located along the natural canal in the southwest of the island of Phra Nakhon Si Ayutthaya, a World

Heritage Site. The second case study involved a village located on low plains along the canal in the Sena Trough, on lower land than the rest of the basin and subject to high flood levels and a long flood period (Tanaka et al., 2015).

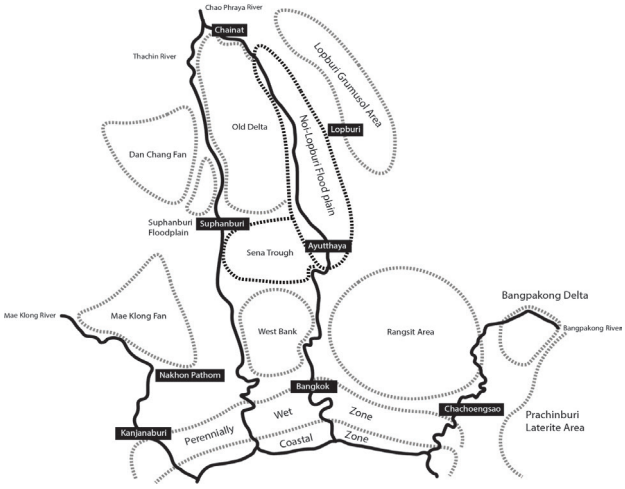

Figure 1
Map showing the location of the Sena Trough and Noi-Lopburi Floodplain (Image by authors; adapted from Takaya, 1987)

The traditional housing groups and case studies were selected according to the house characteristics, settlement patterns, and their association with the kinship system. The purposive selection was utilised for the case studies based on housing appearance to provide traditional elements and an association with the surrounding cultural landscape. A total of 20 participants were selected from two communities to be interviewed and provide architectural drawings. Interviews were conducted with the primary users of traditional houses (i.e., owners and/or dwellers).

Result & Discussion

Post-1960s irrigation development

Due to the modern irrigation system, rural villages and farming in the Ayutthaya Basin drastically changed during the 1960s–1980s. The Greater Chao Phraya Project impacted water control, shaping the new geography of the canal system in several ways. The whole Chao Phraya region has been subject to a magnificent water control scheme since the completion of the Chainat diversion dam and subsequent upgrading of irrigation networks during the 1960s (Puckridge et al., 2000). *The Ditches and Dikes Project*'s objective was to improve water distribution by adding to the existing distribution network of canals and laterals with a partial network of small ditches. Thus, the water was conveyed closer to the individual farms from 1963–1968, although some work continued into the 1980s (Small,

1973). Even though this project aimed to reduce the incidence of severe crop failure due to drought by 51%, it would also help to draw floodwaters away from the river (Vongvisessomjai, 2006). According to Small (1973), this objective was a way of 'stabilising' production.

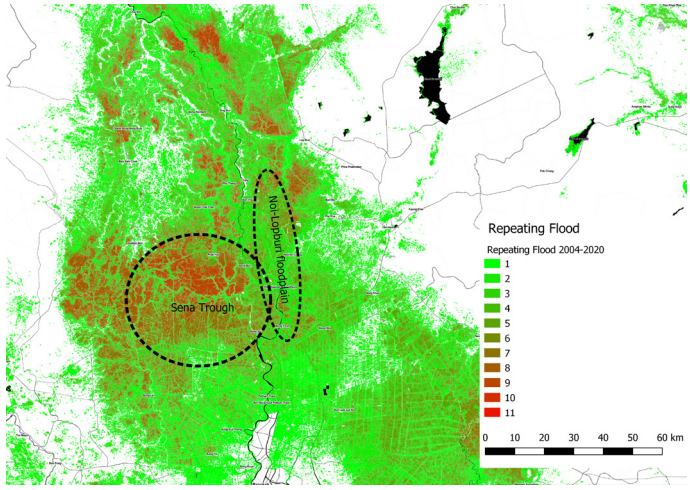

Figure 2
Map showing flood risk area during the eleven years gap from 2004–2020 on stamen map (Image by Thai Flood Monitoring System)

Following the completion of the Greater Chao Phraya Project in the 1970s, there has been a drastic impact on the water level in the study area due to greater stability in the water supply and reduced flood inundation (Figure 2). A comparison of the annual highest water level (HWL) between the Sena Trough (at C.37 station) and the Chaophraya River (at C.35 station) of the Noi-Lopburi Floodplain revealed that both areas had been affected by a 0.65 m reduction in the average HWL before and after the construction of Bhumibol and Sirikit Dams. The riverbank of the Ayutthaya flood plain was higher than the Sena Trough at almost 0.78 m. Even though the water flow exhibited greater stability, the annual floods (the HWL was higher than the riverbank) still hit several villages in the Sena Trough as in the past, with its geographic area facing an enormous water mass from all directions. Since 2000, this area has faced annual flood events almost every year, leading to individual flood planning in preparation for flooding the following year. In comparison, the situation in the Noi-Lopburi Floodplain appears different from other typical villages, according to the latest survey of the Central Region Irrigation Hydrology Center (2020). The survey revealed that water overflows hit the area only seven times in the past 30 years, equating to an average flood recurrence interval of 4–5 years.

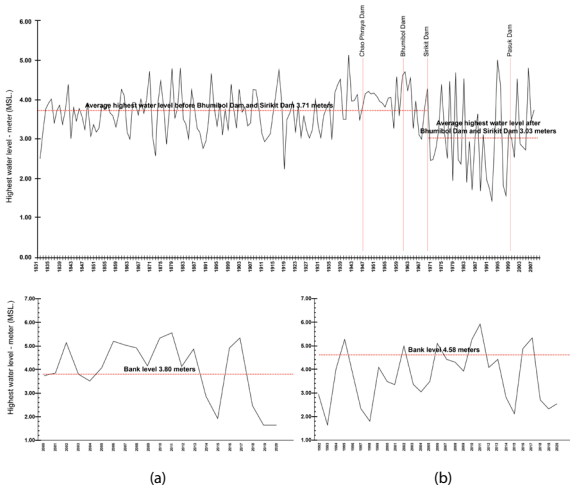

Figure 3
Bank-level and HWL at C.37 station in the Sena Trough (a) and Chao Phraya River at C.35 station represented by Noi-Lopburi Floodplain (b) since 1831–2020 (Image adapted from the Bureau of Water Management and Hydrology, 2011; Central Region Irrigation Hydrology Center, 2020)

Housing and associated cultural landscape in the Sena Trough

The relatively low altitude in the Sena Trough and surrounding area makes it more sensitive to flood. Most of the area is located on the west bank of the Chao Phraya River. According to the flood statistics, before 2006, several districts in this trough were declared flood disaster zones every year. During the reign of King Rama V (1868 onwards), there was a large expansion of farming settlements in the central region, unlike the old delta area between Chainat Province and the northern part of Ayutthaya, where settlements have existed for a much longer time (Ingram, 1971). The linear community settled along the canal, along the former course of the Chao Phraya River, clustered according to kinship groups and connecting to the canal. Water from the Chao Phraya River entered the canal and overflowed into the village along the former canal, penetrating the underneath space toward the paddy fields, which flooded first.

This area's cultural landscape and hydrology represent the natural conditions in the Sena Trough which has the lowest amount of vested land in the lower basin. This area serves as a natural monkey cheek that is usually flooded. The annual flood in the Sena Trough occurs between September and December, reaching an average water level of 30–40 cm for up to 10–15 days in 111 villages. This water level means that the entire Bang Ban District naturally floods during that period. After the major flood in 2006, affecting 605,401 households in 32 provinces and costing Thailand at least US$447.37 million in damages (OCHA Services, 2006), government agencies began to study the potential of the Sena Trough (formally named Thung Bang Ban Project). The area has up to 89.63 million m^3 of water storage capacity. The project is capable of diverting floodwater of

3 m in depth, generating US$1.13 million per year (Sapphaisal, 2008). Since 2012, the Sena Trough reservoir has been part of the Bang Ban Monkey Cheek Project.

The study area is home to an indigenous community living in traditional Thai houses. The houses have raised platforms on high stilts and open basements in the underneath space, although some have been changed into contemporary and modern styles. The traditional house has also undergone some physical changes, but for the most part, it retains the characteristics of the traditional housing ideology. Since the study area is subject to severe floods every year, flooding countermeasures have been implemented, including temporary modification of the underneath living space in the house and adjusting the level of the basement structure to make it higher than the annual flood level, vertically adjusting and expanding the area according to the period of residence, and providing a temporary wooden platform and bridge to elevate the floor inside the house in case a major flood reaches the second-floor level. Although these houses can co-exist with water during flood, the high-floor houses are also connected to the rivers and canals in the dry season.

The Noi-Lopburi Floodplain

The Chao Phraya River Basin in the lower central region has been formed by the sedimentation of the riverbed over the past thousand years, helping the floodplain of Ayutthaya to produce fertile, nutrient-rich sediment. Besides, several rivers and canals flow through and crisscross the area, making this floodplain highly fertile and suitable for rice cultivation (Intorpetch et al., 2014; Team Consulting Engineering and Management, 2012; Udomsri et al., 2004). The flood season from September to November helps traditional rice-growing at water depths of 80–120 cm (Ruensuk et al., 2021). Thus, the area has become predominantly reliant on rice cultivation and provides an outstanding example of rice culture practices (Yodsurang & Yasufumi, 2016). The settlement aligns linearly with the canal, surrounded by a vast rice field. In the past, the canal provided a shortcut to the Chao Phraya River and the only transportation route connecting to other communities. Although nowadays the canal is less important, it remains a useful source of natural drainage.

The settlement in the Noi-Lopburi Floodplain was a typical, traditional rice cultivation community, with the houses established along the canal, surrounded by a rice field at the rear. By the 1840s, typical settlements in the Noi-Lopburi Floodplain were small, all situated in the lowlands where rice cultivation required minimal effort and provided the greatest reliability (Falvey, 2001).

Even though the history of this community has not been formally recorded, a physical survey reported that some houses were over a hundred years old. Due to agricultural expansion and the development of an irrigation system, a new canal with a dike road system was constructed as part of the major Chao Phraya Basin irrigation system in the 1960s, changing the face of the area at the micro-scale community level. Water gates were built on the upper and lower areas of the canal mouth to control the water during the dry season. The new waterway provided freshwater for agricultural activities, while tap water was used for household purposes. The canal and natural water bodies could not flow naturally because of the new water management mechanism and subsequently became abandoned and polluted.

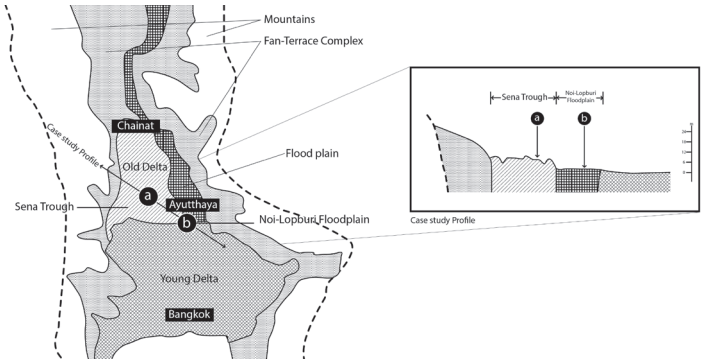

Figure 4
Cross-section of the Ayutthaya flood plain showing the Sena Trough (a) and the Noi-Lopburi Floodplain (b) (Image by authors; adapted from Takaya, 1987)

There is clear evidence to suggest that many traditional Thai houses survived in this community, retaining several important elements of the original Thai house design (Pinijvarasin, 2003). Yet, some might not appear in all houses. However, a Thai-style steep-curved roof, terrace, and patio space modification, the most important parts of the original Thai house, can still be seen. Most of the unoccupied or abandoned houses remain in their original traditional state, while most of the active houses have added another permanent extension to the underneath space over the past 10–20 years. This physical change in housing characteristics was prompted by cultural development, with high stilt living no longer necessary due to a more stable water level. Besides, socio-economic changes were inevitable due to the various impacts of global events and domestic issues. The traditional farming culture, which relied on a cool breeze from the underneath space during hot days, has shifted, with most routine workers being out for most of the day and the elderly unable to climb up to the upper floor. Thus, the space in a house with a single upper storey may not be sufficient for contemporary living. The construction of on-ground modern houses in groups with no

fence also meant that the communal intimacy of kinship gradually disappeared. In the past, there was often an empty space between the houses which acted as a walkway to connect the underneath space. The transformation of interconnected kinship spaces underneath the houses affected the communal designation of common and private spaces (Khwansuwan, 2017). Consequently, the meaning of the underneath space in modern society has been transformed.

Comparative Analysis

A comparative analysis was performed on the architectural elements and arrangement of the space in each house, divided according to the area. The general characteristics of changes in flood patterns were identified to ascertain their effect on the adaptability of local communities.

Traditional dwelling units and their associated cultural landscape

There have been settlements in both study areas for several decades. They were important agricultural frontiers with rice as the major crop, responding to the physical characteristics and cultural landscape affected by river overflow. The central region is subject to seasonal floods almost every year due to the lowland geomorphology, which supports a volume of water flow, especially during October, when the tropical cyclone arrives. The water overflows on both sides of the Chao Phraya River. The heavy rain flows into the lowland area behind the embankment, a long narrow line parallel to the Chao Phraya River on both sides after water stabilisation due to the Chao Phraya Water Management Project. In addition, the right bank (Ayutthaya Basin) of the Chao Phraya River has a bank-level 80 cm higher than the Sena Basin. Moreover, the Ayutthaya Basin benefits from urbanisation and the construction of industrial estates east of the Chao Phraya River, which began in the 1980s, when the management plan altered the river flow in the two areas due to external factors. As a result, the average water overflow statistics in both areas differed. The basin area is still flooded yearly (with large floods every five to seven years), while the Ayutthaya Basin has not been flooded for more than 30 years.

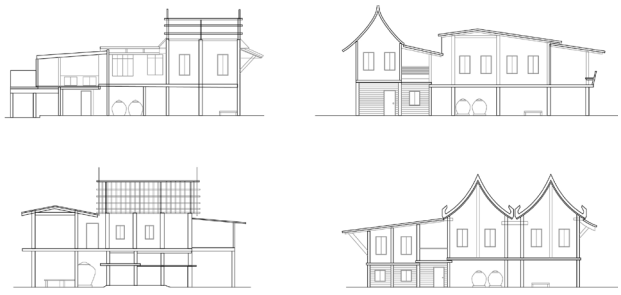

Figure 5
Series of typical sections of traditional dwelling units and their associated cultural landscape in the Sena Trough (a) and the Noi-Lopburi Floodplain (b)

Originally, both settlements under study had almost identical environmental conditions and similar cultural livelihoods, although their water management has differed over the last 60 years. The effect of water management megastructures can be seen in the typical sections of traditional dwelling units and their associated cultural landscape (Figure 5). In the Sena Trough (Figure 5a), the irrigation dike and polder road have facilitated the development of an entire village, potentially turning it into a river-edge reservoir in the flood season. As the water overflows from the natural canal, this structure helps prevent flood and reduces flow to the paddy field across the road. While in the Noi-Lopburi Floodplain (Figure 5b), the natural canal remains unused, and the water sluice gates at both ends have made the canal smaller and shallower. In the rainy season, water overflows from a paddy field and the new irrigation canal. The irrigation dike and polder road in this area block rainwater interpenetration to the village.

Indigenous cultural heritage and traditional knowledge system

The gradual changes taking place over a long time are reflected in the physical characteristics of the housing and community complex (Figure 6). Traditional houses in the Sena Trough (Figure 6a) expand horizontally rather than vertically, as can be typically observed in the area under investigation. The construction of a temporary, adjustable wooden platform In the space underneath the houses enables the basement to accommodate different flood levels. This temporary basement adaptation demonstrates the villagers' resilience in coping with different flood events. During a flood event, the residents' preparations include repairing ships and moving items, including livestock, from the underneath space up to the platform. This preparation is done with the cooperation of neighbours and relatives. This traditional knowledge and management system has been retained over time.

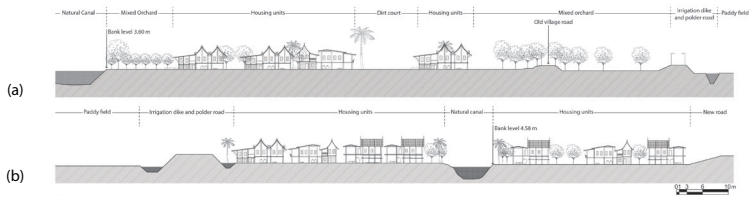

Figure 6
Sample of typical sections of traditional dwelling units in the Sena Trough (a) and the Noi-Lopburi Floodplain (b)

However, in the Noi-Lopburi Floodplain area (Figure 6b), houses tend to expand to cover the ground level. The underneath space was added for convenience, and the physical characteristics of the houses have changed to accommodate the modern lifestyle, especially since the area has been safe from flood for an extended period. The additional

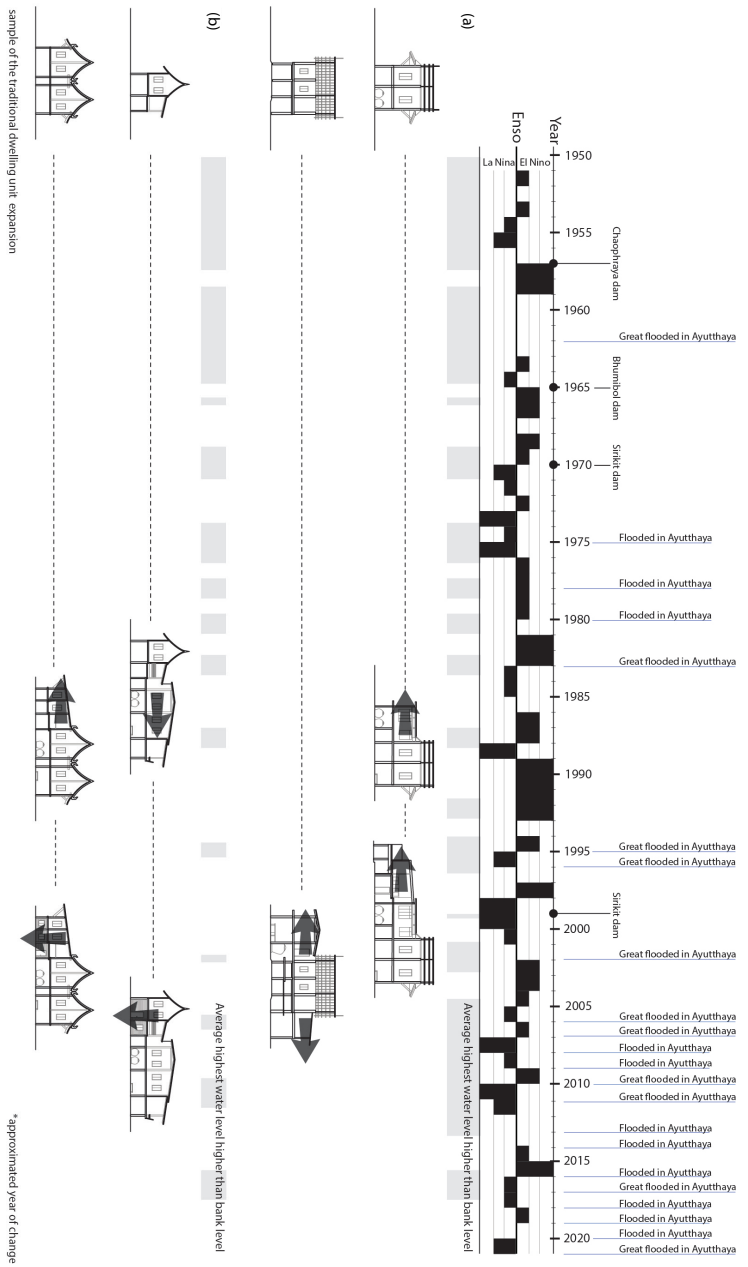

Figure 7
Comparative time series analysis of the traditional dwelling unit and its associated ENSO years in the Sena Trough (a) and the Noi-Lopburi Floodplain (b) (Image by authors; adapted from Null, 2022)

parts could be built using an alternative construction method and appropriate materials to provide new, permanent structures better suited to the contemporary way of life and offer more convenience in both dry and flood seasons. Thus, the loss of the underneath space is an important indicator of housing changes in the area, with villagers becoming more confident in the water management and infrastructure created by the authorities. The loss of this underneath space and the construction of permanent basements and solid walls resulted from the water conditions becoming more stable.

The relationship between the average highest water level and changes to the underneath space in both areas is revealed in Figure 7. Local dwellers in the Sena trough (Figure 7a) are affected by water overflow from the river almost every year. The flood frequency in the area ranges from one to four years. Housing and dwelling units must maintain the flood response characteristics previously mentioned. The significant loss of flood-responsive structures can be observed in the 13 consecutive El Niño years from 1989 to 2002. The housing has expanded vertically to cover the ground level in the Noi-Lopburi Floodplain (Figure 7b) due to drier weather. People have begun to change and adapt their built environment to a new, more familiar, drier environment. However, the shift in rainfall patterns over the past 20 years is worrying. For example, the 2011 Thailand flood crisis has been associated with two successive El Niño-Southern Oscillation (ENSO) events, resulting in heavy rainfall in Southeast Asia and Northern Australia. The ENSO phenomenon seems to have occurred with enhanced frequency and duration in recent years (Ueangsawat et al., 2015). This phenomenon has caused severe flood problems in almost every region of Thailand. It is predicted that climate variability will increase in frequency and cause more severe events in the future. The non-flood-risk areas, which have not been affected by past flood events, will be subject to severe floods and landslides. Individuals have forgotten how to live with water since they turned their backs on the river, losing resilience over time.

Discussion and Conclusion

According to the primary investigation, the local people have gradually lost their flood resilience against living with water over the past 50 years due to the flood and flow system becoming more stable. Interior spaces have been changed over time due to the significant shift in hydrogeology characteristics and socio-economic development. Houses have been extended to cover the ground level, with agricultural landscapes shifting to deal with new irrigation systems, leaving the natural canal unused, never to return. Local communities became more global and started to lose

their resilience and, consequently, sense of place. According to the data, the indigenous population has gradually lost its resilience since the 1970s. However, since the area has retained the physical characteristics of the stilt house with an underneath space, the communities must continue to practice resilience to co-exist with the flood phenomenon.

Furthermore, these external factors have also affected traditional livelihoods, physical characteristics of housing and interiority, and the cultural landscape. Inhabitants of the amphibious culture have been affected by the consequential impacts of global historical events and various domestic issues. The agricultural depression in the 1980s caused workers to migrate to the industrial and service sectors (Pholphirul & Rukumnuaykit, 2010). Thus, traditional agricultural practices had insufficient labour and budget to continue caring for the agricultural landscape. Time passed with several changes gradually damaging the agricultural landscape and indigenous physical characteristics, with material durability reaching its limit. At the same time, local dwellers lost their resilience to adapt to modern requirements. New agricultural practices increasingly rely on monoculture and innovative irrigation systems. Intensive monoculture farming practices have impacted biodiversity, causing various environmental problems (Killebrew et al., 2010). Besides, pesticide and fertiliser use have polluted water bodies. The new, effective water-stabilisation dam and watergate have become barriers to fish migration, making it harder for fishermen to survive. Natural irrigation systems have deteriorated and been left unused, subsequently leading to abandonment. The resurrection of the relationship between man and water is complicated, and the loss of resilience seems irreversible.

However, severe flood damage occurs almost every year. Major economic and commercial settlements are often located along the waterside, such as Nakhonsawan, Ayutthaya, Suphanburi, Chachoengsao, Pathumthani, and Nonthaburi. Meanwhile, Thailand's capital city, Bangkok, has faced several severe storms, often resulting in loss of life and property far beyond the expectation of the authorities. Global warming and climate change are driving the frequency and intensity of extreme events. Individuals can no longer keep up with the accelerating rate of such environmental changes, and several urban developments have gone wrong (Onrubia, 2015). Therefore, the root causes of these impacts need to be addressed to help people regain their flood resilience and better adapt to changing conditions. Some traditional knowledge systems for managing flexible space should be appropriately re-used and re-innovated. The indigenous

cultural heritage and traditional knowledge system adopted through living with water have given the community resilience and need to be maintained. It is important to remind the younger generation how their elders live or used to live with water. They must be convinced that some ideas inherited from the past could be adapted for contemporary use. Sharing information on architectural tectonics in dealing with water is recommended to ensure public and individual flood preparedness.

Acknowledgement

This work is supported by JSPS KAKENHI Grant Number 18H03451.

References

Atmodiwirjo, P., & Yatmo, Y. A. (2022). Interiority from the body, mind, and culture. *Interiority*, *5*(1), 1–4. https://doi.org/10.7454/in.v5i1.209

Bureau of Water Management and Hydrology. (2011). *The annual highest water level (HWL) at Phra Nakhon Si Ayutthaya Province between 1831 to present comparing the average before and after the Bhumibol Dam and Sirikit Dam were constructed* [Data set]. http://water.rid.go.th/hydrology/downloads2554/

Central Region Irrigation Hydrology Center. (2020). *Annual highest water level (HWL) in the central region* [Data Set]. http://hydro-5.rid.go.th/Data/4/4-05.html

Falvey, J. L. (2001). Thai agriculture from Ayutthaya to the early 20th century. *Asian Agri-History*, *5*(4), 283–296.

Ingram, J. C. (1971). *Economic change in Thailand, 1850-1970*. Oxford University Press.

Intorpetch, B., Wisawapipat, W., Arunlertaree, C., & Teartisup, P. (2014). Soil physicochemical status and nutrient management for paddy soils in the lower central plain of Thailand after the flood disaster in 2011. *Environment and Natural Resources Journal*, *12*(1), 57–67. https://ph02.tci-thaijo.org/index.php/ennrj/article/view/71178

Kaida, Y. (1974). Pioneer settlements and water control development on the west bank of the lower Chao Phraya Delta: Water conditions in the deltaic lowland rice fields (II). *Japanese Journal of Southeast Asian Studies*, *11*(4), 512–524. https://doi.org/10.20495/tak.11.4_512

Kasetsart University, & ORSTOM. (1996). *Agricultural and irrigation patterns in the Central Plain of Thailand: Preliminary analysis*

and prospects for agricultural development. DORAS Project. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers16-06/010008037.pdf

Khwansuwan, P. (2017). *The continued existence of amphibious settlements in the Chao Phraya Flood Plain* (Publication No. 600793) [Doctoral dissertation, Kasetsart University]. Kasetsart Library Catalog.

Killebrew, K., Wolff, H., Anderson, C. L., & Gugerty, M. K. (2010, March 17). *Environmental impacts of agricultural technologies*. Evans School Policy Analysis & Research Group (EPAR). https://epar.evans.uw.edu/research/environmental-impact-agricultural-technologies

Kwansuwan, P. (2015). Traditional communities: Definition, value, regeneration mechanism to everyday life practice. *Journal of the Faculty of Architecture King Mongkut's Institute of Technology Ladkrabang*, *20*(1), 1–17. https://so04.tci-thaijo.org/index.php/archkmitl/article/view/38521

Nilaponkun, K., & Thaitakoo, D. (2019). Flood pulse dynamics and ecosystem services of Chaophraya Delta: A case study of Ladchado community Amphoe Pukhai Ayutthaya Province. *Sarasatr*, *2*(2), 256–270. https://so05.tci-thaijo.org/index.php/sarasatr/article/view/189691

Null, J. (2022). El Niño *and* La Niña *years and intensities: Based on Oceanic* Niño *Index (ONI)* [Data set]. Golden Gate Weather Services. https://ggweather.com/enso/oni.htm

OCHA Services. (2006, October 29). *Flood situation in Thailand*. reliefweb. https://reliefweb.int/report/thailand/flood-situation-thailand-29-october-2006

Onrubia, A. F.-L. (2015). *Indigenous knowledge of a changing environment: An ethnoecological perspective from Bolivian Amazonia* (Publication No. 9788449058523) [Doctoral dissertation, Universitat Autònoma de Barcelona]. Tesis Doctorals en Xarxa (TDX).

Pholphirul, P., & Rukumnuaykit, P. (2010). Economic contribution of migrant workers to Thailand. *International Migration*, *48*(5), 174–202. https://doi.org/10.1111/j.1468-2435.2009.00553.x

Pinijvarasin, W. (2003). E*xperiences of well-being in Thai vernacular houses* [Doctoral dissertation, The University of Melbourne]. Minerva Access.

Puckridge, D. W., Kupkanchanu, T., Palaklang, W., & Kupkanchanakul, K. (2000, December 12–15). *Production of rice and associated crops in deeply flooded areas of the Chao Phraya Delta* [Conference session]. International Conference on the Chao Phraya Delta: Historical Development 1 Dynamics and Challenges of Thailand's Rice Bowl, Kasetsart University, Bangkok.

Rodina, L. (2018). Defining "water resilience": Debates, concepts, approaches, and gaps. *WIREs Water*, *6(*2), 1–18. https://doi.org/10.1002/wat2.1334

Rodina, L., & Chan, K. M. A. (2019). Expert views on strategies to increase water resilience: Evidence from a global survey. *Ecology and Society*, *24*(4), 28. https://doi.org/10.5751/ES-11302-240428

Ruensuk, N., Rossopa, B., Channu, C., Paothong, K., Prayoonsuk, N., Rakchum, P. & Malumpong, C. (2021). Improving water use efficiency and productivity in rice crops by applying alternate wetting and drying with pregerminated broadcasting in farmers' fields. *Agriculture and Natural Resources*, *55(*1), 119–130. https://doi.org/10.34044/j.anres.2021.55.1.16

Sapphaisal, C. (2008). *The management and development of large-scale agricultural area in mitigation of medium to large floods in the Chao Phraya River basin according to the Royal Initiative Pilot project: Monkey Cheek in Bangban area (1).* Retrieved from http://elibrary.trf.or.th/project_content.asp?PJID=RDG5130008

Small, L. E. (1973). Historical development of the Greater Chao Phya water control project: An economic perspective. *Journal of the Siam Society*, *61*(1), 1–24. https://thesiamsociety.org/wp-content/uploads/1973/03/JSS_061_1b_Small_ricalDevelopmentOfGreaterChaoPhyaWaterControlProject.pdf

Takaya, Y. (1987). *Agricultural development of a tropical delta: A study of the Chao Phraya Delta* (P. Hawkes. Trans.). University of Hawaii Press. (Original work published 1985)

Tanaka, W., Wattanasiriserekul, R., Tomiyama, Y., Yamasita, T., Phinrub, W., Chamnivikaipong, T., Suvarnaraksha, A., Shimatani, Y. (2015). Influence of floodplain area on fish species richness in waterbodies of the Chao Phraya River basin, Thailand. *Open Journal of Ecology*, *5*(9), 434–451. https://dx.doi.org/10.4236/oje.2015.59036

Team Consulting Engineering and Management. (2012). *Final environmental impact assessment: Tha: Ayudhaya natural gas power project*. https://www.adb.org/sites/default/files/project-document/73982/46907-014-tha-eia.pdf

Thai Flood Monitoring System. (2021). *Flood information* [Data set]. https://flood.gistda.or.th/

Udomsri, S., Huntrakool, K., & Watana, S. (2004). Characterization of established soil series in the central plain region of Thailand. *Office of Surveying and Mapping Technology, Department of Land Development, Kasetsart University, Kamphaeng Saen Campus Nakhon Pathom, Thailand*. http://oss101.ldd.go.th/web_standard/_doc_std/series_desc/D_520_Established%20soil%20series%20in%20the%20Central%20Plain.pdf

Ueangsawat, K., Nilsamranchit, S., & Jintrawet, A. (2015). Fate of ENSO phase on upper northern Thailand, a case study in Chiang Mai. *Agriculture and Agricultural Science Procedia*, *5*, 2–8. https://doi.org/10.1016/j.aaspro.2015.08.001

Vongvisessomjai, S. (2006). Chao Phraya Delta: Paddy field irrigation area in tidal deposit. 19th International Congress and 56th International Executive Council of ICID, THAICID-Multifunctional roles of irrigation water in Thailand. Retrieved May 14, 2022, from https://www.rid.go.th/thaicid/_5_article/2549/10_1ChaoPhraYaDelta.pdf

Yodsurang, P., Hiromi, M., & Yasufumi, U. (2016). A traditional community in the Chao Phraya River basin: Classification and characteristics of a waterfront community complex. *Asian Culture and History*, *8*(1), 57–68. https://doi.org/10.5539/ach.v8n1p57

Yodsurang, P., & Yasufumi, U. (2016). A traditional community in the Chao Phraya River basin II: Influence of water circulation on the traditional living culture according to the settlement pattern. *Asian Culture and History*, *8*(1), 112–125. https://doi.org/10.5539/ach.v8n1p112