The Impacts of Environmentally Mitigated River Channelization on Agriculture in Hong Kong

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Abstract

Cities struggle with diminishing stormwater risks and improving urban climate resilience while supporting urban functions and enhancing the well-being of the residents. These circumstances have allowed studies on river renaturation to progress rapidly since the early 21st century. Nevertheless, the existing research has primarily focused on European or North American contexts, leaving the river renaturation for high-density Southeast Asian areas largely unexplored. This study seeks to advance the understanding of how environmental mitigation works impact the physical transformation of the landscape amid post-channelization in high-density Southeast Asian peri-urban areas, using the case study of the Sheung Yue River, Hong Kong. Longitudinal data on the morphological change of the Sheung Yue River and the landscape pattern modifications of a selected 1-km2 area from 1995 to 2005 were harvested from aerial photographs and analyzed. The outcomes suggested that the negative impacts of channelization on the landscape transitions could be limited by environmental mitigation work in the high-density Southeast Asian peri-urban context. Through these results, this study aims to contribute to policymaking on urban water management and river renaturation in the high-density Southeast Asian context.

Keywords

Channelization, Environmental Mitigation, Urban Water Management

1. Introduction

The territory of Hong Kong extends over 1,106 km² and comprises about 200 watercourses, many of which are seasonal unnamed streams. In Hong Kong, roughly three types of watercourses exist: (1) small streams in the pristine Country Park environment, which are essential to the city water collection; (2) channelized (locally known as nullah) or culverted watercourses, which are typically polluted and found in highly urbanized areas; and (3) relatively large watercourses in the alluvial terrains of the North Territories, which were historically crucial to local agriculture. While the first category is well-preserved, and the second focuses on highly publicized ongoing amelioration projects, the third has long fell outside the main interests of the local society and scientific community. Nevertheless, as the sleep of reason produces monsters, in peripheral territories flood protection river training works have often triggered vicious cycles of degradation that, when combined with rampant urbanization, have transformed once pristine watercourses into ugly nullahs that will, before or after, require massive resources to be reclaimed as spaces with environmental and sociocultural value. In other words, the process of channelization has resulted in a considerable loss of economic, environmental, and sociocultural capital. In recent years, the New Territories of Hong Kong and their rivers have increasingly been the centre of attention due to their pivotal position between two of the world's more advanced cities, Hong Kong and Shenzhen. Although the primary aims (i.e., flood protection) remain unchanged, river training works have been conducted using a much more interdisciplinary and integrated approach (i.e., environmental mitigation). The effects of this new approach to assessing agricultural activities are the object of the empirical study presented in this paper. More specifically, this research aims to answer the following question: How is environmentally mitigated river channelization impacting agriculture?

The significance of this research extends far beyond the case study and the territory of Hong Kong, and the results will be of interest to policymakers in the Guangdong–Hong Kong–Macao Greater Bay Area specifically and East Asia more broadly. This region is undergoing a progressive degradation of agricultural land on the fringes and between megacities. In these peri-urban areas, the channelization of rivers accompanies the expansion of unregulated, urban-oriented activities that threaten the health of local populations and ecosystems (Talamini et al., 2022). The outcome of such a leviathan transformation is the loss of an immense environmental and sociocultural capital. Yet these regions are central in the global urbanization process, and their populations are expected to grow by one hundred million people over the next decade. Their fate ultimately depends on the effort to manage the water infrastructure sustainably. Thus, due to its early development, Hong Kong can provide a crucial lesson on the impact of environmentally mitigated river channelization on the persistence of agriculture.

2. Urbanization and stormwater management

While urbanization has significantly boosted economic growth, the phenomenon has also resulted in rising demand for ecosystem services and natural capital (Grimm et al., 2008; United Nations et al., 2019). Urban agglomerations face an increased risk of suffering from flooding, scour, erosion, urban heat island effect and a shortage of water resources because the construction of urban infrastructure and buildings significantly affects the land surface, from permeable to impermeable cover, and intensifies the adverse effects of environmental and climate change (Grimm et al., 2008; Liu and Jensen, 2018). Concurrently, since the XIX century, hegemonic engineering approaches have governed the exploitation of stormwater capital through channelization, reservoirs, dams and concrete sewage systems, which are primarily intended to prevent urban flooding and spatially bound floodplains, and provide areas for economic development and growth (Cosgrove and Petts, 1990; Fox et al., 2016; Grabowski et al., 2017; Habel et al., 2020; Juan et al., 2020; Westerman, 2012). The engineering-driven modification of the hydrologic systems relieved the pressure of flooding from urban settlements for decades but eventually revealed the shortcomings of the modification, which manifest via negative impacts on the ecology and environment.

The urbanization process usually entails the spatial interweaving of urban and rural characteristics in peri-urban areas, often altering rural landscapes and ecological systems (McGee, 2008, 1991, 1989). In peri-urban areas of densely urbanized regions, the spatial capital of cultivation and irrigation systems built over centuries often gets dilapidated by poor stormwater management approaches, along with cultural and social-cognitive influences on the riparian areas. Previous research has supported the idea that urban infrastructures, particularly for water management, have significant impacts on the rural-urban landscape due to the massive modification associated with the environment and the ecology (Alberti, 2005; Cosgrove and Petts, 1990; Meulder and Shannon, 2013). Landscape transformation resulting from water management also lacks a comprehensive, large-scale approach (Cosgrove and Petts, 1990).

The idea of sustainability as a human society living and thriving within limits was developed during the European Enlightenment, subsequently driven by the environmental and ecological consequences of industrialization (Caradonna, 2014). The environmental movement after World War II contributed to further increasing public awareness of the need to protect the ecosystem. The growing consensus was catalyzed by theoretical propositions (e.g., Ian McHarg's design with nature) and policies (e.g., Clean Water Act; Fletcher et al., 2015; McHarg, 1969). With the gradual recognition of such consensus, sustainable urban stormwater management emerged as a relatively new field in the 1980s and 1990s, in contrast to the engineering-driven stormwater management approaches with a long history in urban development (Fletcher et al., 2015). Managing stormwater sustainably entails combining structural and non-structural approaches while preserving natural resources and meeting long-term development needs (Barbosa et al., 2012). As Petts posited, the human-nature relationship is transforming from man versus environment to people within environment with the progress of urban development and water management (Cosgrove and Petts, 1990).

2.1. From channelization to river renaturation

Rivers are complex social-ecological systems because people perceive, value and interact with rivers in various ways (Verbrugge and van den Born, 2018). The landscape ecological principles, first gradually adopted from the 1980s to the 1990s, later evolved to riverscape ecology in the early 2000s (Dunham et al., 2018). At the same time, the negative impacts of channelization on the ecology and environment have been revealed. First, due to the performance requirements of construction materials, modifications typically result in more impermeable land cover, which reduces stormwater resilience in waterside areas and necessitates further construction to expand the stormwater capacity of the infrastructure. Additionally, urban growth and densification have exceeded the capacity of conventional solutions, such as combined and separate sewer systems (Liu and Jensen, 2017, 2018). Second, the physical alternations in the river bank and riparian land can exacerbate structural changes in ecological regimes (Juan et al., 2020). Third, artificial modification of the hydrologic systems significantly lowers the capacity of natural water bodies' resilience to anthropogenic or natural contamination thresholds (Duh et al., 2008). Low water quality is also frequently a result of the altered water bodies due to urbanization as an environmental stressor. Such changes may have social repercussions in areas with a high population density (Falkenmark, 1979; Talamini et al., 2016). As a result, to convey stormwater away from urban habitats and increase stormwater capacity, the engineering-driven modifications to hydrologic systems frequently disrupt the dynamic equilibrium of the hydrologic system at the expense of adverse environmental, ecological and social effects.

Under these circumstances, river renaturation has been widely implemented to improve the riverside ecological condition, promote a high-quality urban environment, build climate resilience and stimulate economic benefits (Brunetta et al., 2019; Palmer et al., 2005; Talamini and Tritto, 2020). The main goal of river renaturation is to improve the natural environment (Gordon, 1996). Previous studies have shown that river renaturation not only provides environmental values but also significantly impacts the residents' quality of life (Agyeman et al., 2009; Davenport and Anderson, 2005; Jacobs and Buijs, 2011; Verbrugge and van den Born, 2018).

Ample research analyzes the impact of regenerated rivers, but the studies largely focus on developed regions. Comparatively, the review of previous research and practices revealed that little research has investigated how environmental mitigation strategies in channelization can impact the physical transformation in peri-urban areas in the high-density Southeast Asian context. Nevertheless, the attempts at river renaturation in the high-density Southeast Asian areas attract growing attention. Hong Kong presents a good example: while the drainage channel was designed to prevent floods in the last century, the public gradually realized the significance of natural ecology and attempted to restore the natural environment and promote public space. The Drainage Services Department of Hong Kong SAR promotes environmental mitigation work with plants and eco-conservation methods, including providing the conditions for vegetation growth and mimicking natural stream environments to increase river biodiversity by preserving natural ecosystems and promoting wildlife growth rather than enlarging a drainage channel (Drainage Services Department, 2021). Recent river renaturation practices in Hong Kong consist of the Ho Chung River, Ma Wat River, the Lam Tsuen River, Shenzhen River, Kai Tak River (Wong Tai Sin Section), Tai Wai Nullah (from Heung Fan Liu to Man Lai Court), Fo Tan Nullah (from Kwai Tei New Village to Hong Kong Sports Institute), mid-stream of Tuen Mun River Channel (from Siu Hong Station to Tuen Mun Station), Jordan Valley Nullah (from Shum Wan Shan Pumping Station to Jordan Valley Swimming Pool), and Tung Chung River (Drainage Services Department, 2021).

2.2. Towards a water-friendly Hong Kong

Between the 1990s and 2000s, the Drainage Service Department of Hong Kong carried out a series of drainage improvement works for urban flooding control, including straightening, enlarging and deepening river channels to boost stormwater capacity (Drainage Services Department, 2021). The increased stormwater capacity from channelization has significantly reduced flooding threats for surrounding villages and agriculture during the extended wet season (Drainage Services Department, 2021; Hong Kong Observatory, 2021a). At the same time, however, the advancements in environmental and landscape ecological research have identified concrete riverbeds and riverbanks as threatening the ecosystem of the river regime (Barbosa et al., 2012; Petts and Calow, 1997). Further, channelization generated steeper riverbanks than a natural stream, limiting access to the river for local users and diminishing the river's social value. In response, early attempts at river improvement work—including compensative wetlands, gabions and grasscrete, among other environmental mitigation approaches—were introduced to some peri-urban rivers during this period.

In the 2010s, the local government proposed the revitalization of water bodies through drainage improvement projects using blue and green infrastructure, and a water-friendly culture was promoted in the 2015 Policy Address (Drainage Services Department, 2015, 2017). Since then, many historically channelized streams and urban channels have been under river renaturation. Currently, two types of river renaturation projects exist in Hong Kong: semi-natural renaturation for the previously channelized natural streams primarily located in peri-urban areas, which this research will focus on, and artificial-characteristic-dominated renaturation for nullahs (Drainage Services Department, 2021). Growing attention has also focused on the connectedness between the public and the rivers (University of Hong Kong, 2022).

3. Methods

3.1. Research design

In this study, we used a spatial-temporal analysis of the landscape transformation to explore how environmental mitigation during channelization impacts the landscape transformation, using the selected 1-km2 area in the middle course of the Sheung Yue River as a longitudinal case study (Bicudo da Silva et al., 2020; Biró et al., 2022; Dadashpoor et al., 2019; Liang et al., 2019). Aerial imagery data of the Sheung Yue River from 1995 to 2005 was purchased from the Land Department of Hong Kong SAR and manually interpreted in AutoCAD to classify and capture various land cover types and their transformations, with attention to agricultural land and water bodies. The aerial imagery data are true colour aerial photographs produced from the original aerial film taken by the Lands Department through scanning at a resolution of 1,800 dpi or better with a high-precision photogrammetric scanner. The landscape classification includes (1) green space, (2) natural river, (3) artificial nullah, (4) village small house, (5) arable land, (6) parking, (7) storage, (8) vacant land, and (9) container yard.

3.2. Study area

Hong Kong was proposed for this research based on its revelatory merits—urban development occurred here earlier and may reveal patterns currently emerging in adjacent regions. Like many other cities that experienced or are undergoing rapid urbanization, the peri-urban areas in the New Territories of Hong Kong faced landscape transformation with socio-spatial impacts. The climate in Hong Kong is defined by wet and dry seasons, with an average annual precipitation of 2,398 mm. Approximately 80% of the annual precipitation falls between May and September, including via extreme stormwater events such as tropical cyclones (Faridatul et al., 2019; Hong Kong Observatory, 2021b).

Moreover, according to the observation, from 1884 to 2020, the annual precipitation over various sections of Hong Kong has been increasing by 2.3 mm per year due to climate change (Francesch-Huidobro, 2015; Hong Kong Observatory, 2021c). On the other hand, the rapid urban development within limited land has increased the impermeable surface. This land cover transformation enlarged Hong Kong's vulnerability to various climatic crises, among which urban flooding has been a significant concern in local urban water management (Drainage Services Department, 2021).

This research proposed a longitudinal study with attentiveness to the peri-urban areas in the New Territories and the landscape transformation accompanied by the alternation in the revelatory case of the Sheung Yue River. Such alternations came in the forms of channelization (1998–2001) and environmental mitigawhich this research will focus on, and artificial-characteristic-dominated renaturation for nullahs (Drainage Services Department, 2021). Growing attention has also focused on the connectedness between the public and the rivers (University of Hong Kong, 2022).

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4. Results & Discussions

4.1. Morphological transformation of the river course

Figure 1 demonstrates the morphological transformation of the river course from 1995 to 2005. In the period from 1995 to 1998, the natural river maintained its original shape. After the channelization with environmental mitigation works from 1998 to 2002, the width of the flat nullah varied from 4.5 m to 16 m. The drainage channel covered in concrete, as shown in Figure 2, occupied 2.79 hectares in 1999, then decreased to 0.80 hectares in 2005. The subsequent environmental mitigation work that has since laid grass on the riverbed to encourage vegetation growth. As a result, the natural plants can grow through the gabions of river banks, replicating the natural setting for a drainage channel and reducing the adverse effects of the attempt to prevent flooding.

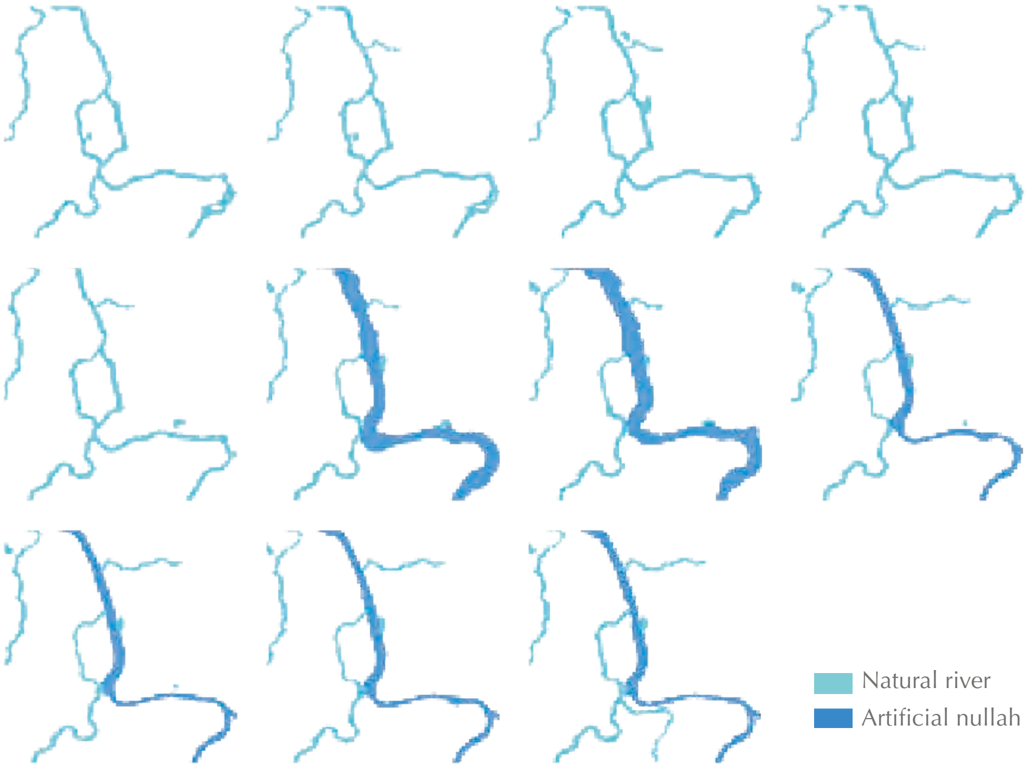

Figure 1. Morphological transformation of waterbodies in the study area, 1995 (top left) - 2005 (bottom right).

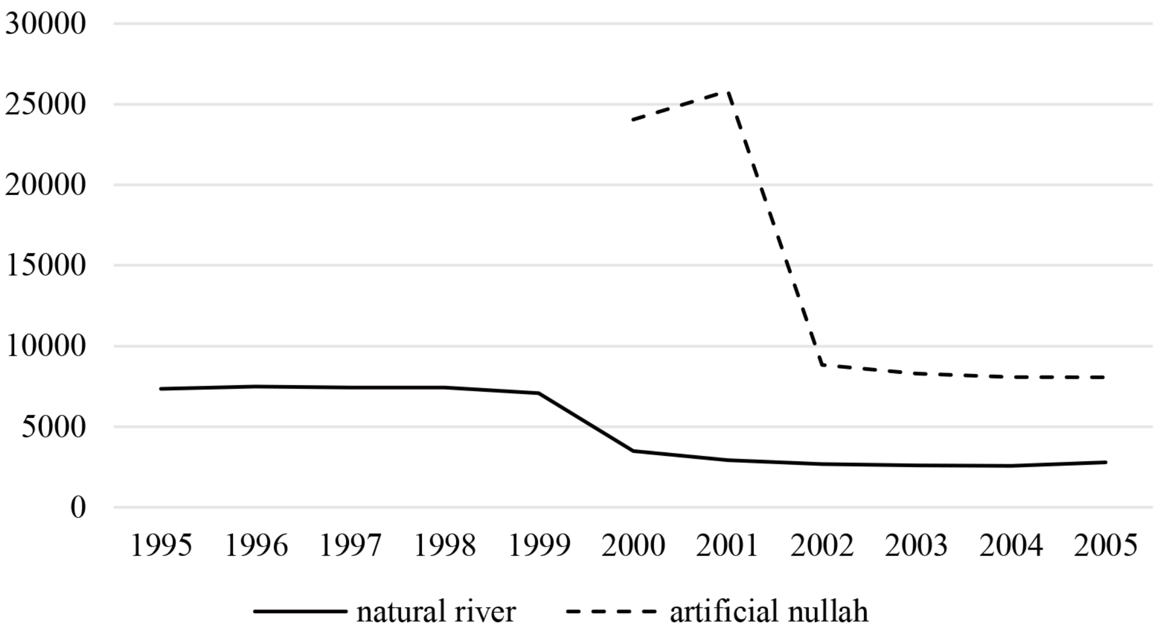

Figure 2. Quantitative transformation of the waterbodies (m2) in the study area (1995–2005).

4.2. Landscape transformations

Figure 3 displays the occupation of various types of landscapes and their transformations from 1995 to 2005 after we reinterpreted and measured the 1-km2 area based on the aerial photographs in AutoCAD. The storage, parking space and container yard were grouped into the category of non-conforming land use. The area of arable land occupied the largest ratio of the Lin Tong Mei research area, although it significantly changed due to the channelization between 1999 and 2000. Green space increased between 1995 and 1998, followed by a sharp decrease in 1999 and a decreasing tendency between 2000 and 2005. This decrease can be explained by part of green space changing into arable land after 2000. The arable land tended to increase through 1995–1998 and then sharply decreased in 1999. Notably, a recovery tendency in arable land occurred after 2001, especially between 2002 and 2005. The other significant change is the vacant land, which sharply increased in 1999 and experienced a stable decrease between 2002 and 2005. The non-conforming land use and the village remained stable between 1995 and 2005, while the area of non-conforming land use had a slight decrease tendency after 2001; the area of the village increased after 2001.

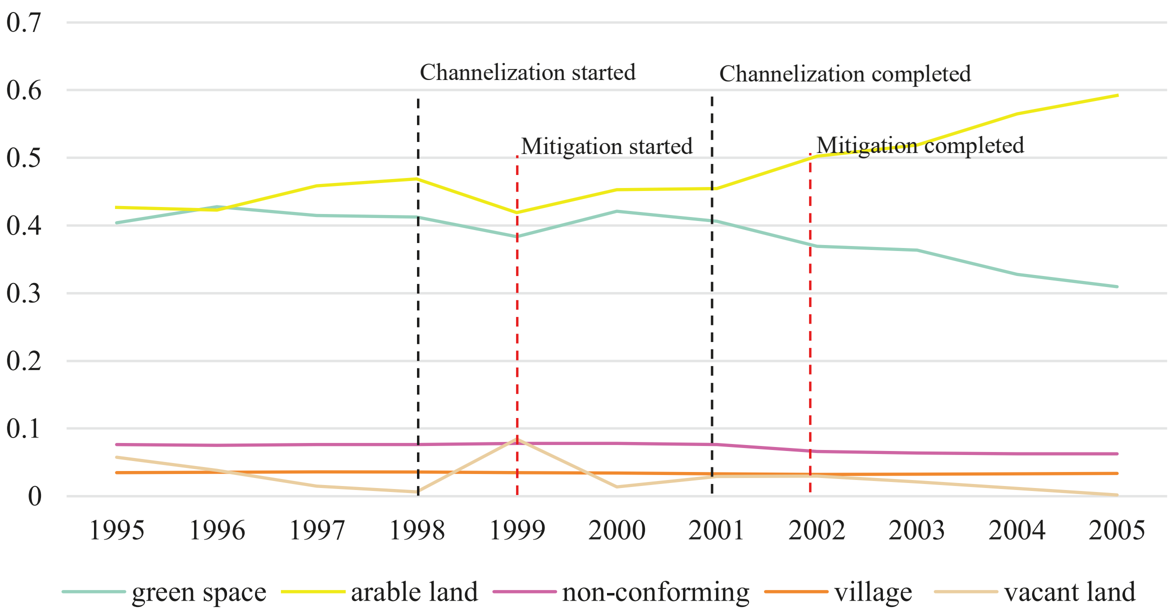

Figure 3. Land use variations from 1995 to 2005 expressed in percentage (x*100%).

The results can be credited to the environmental mitigation work that helped reduce the adverse effects of channelization on arable and green space land. However, such credit should not imply that maintaining agricultural activity is solely dependent on environmental mitigation efforts. The recovery of arable land should instead be stimulated by various economic, environmental, cultural and social variables.

5. Conclusions

When the necessity for rapid development collides with the desire to maintain the natural environment, river renaturation emerges as a promising option. The content of river renaturation has been expanded and improved by research and practical applications over the past 20 years. Notably, studies on river renaturation have been conducted from various perspectives and at various phases of the hydrologic cycle. With increased awareness and focus on peri-urban development, growing social expectations from residents and the need to promote ecological and environmental resilience are integrated into river management strategies in high-density Southeast Asian areas.

Through a longitudinal case study of the Sheung Yue River in Hong Kong, this research seeks to enhance the understanding of how environ-

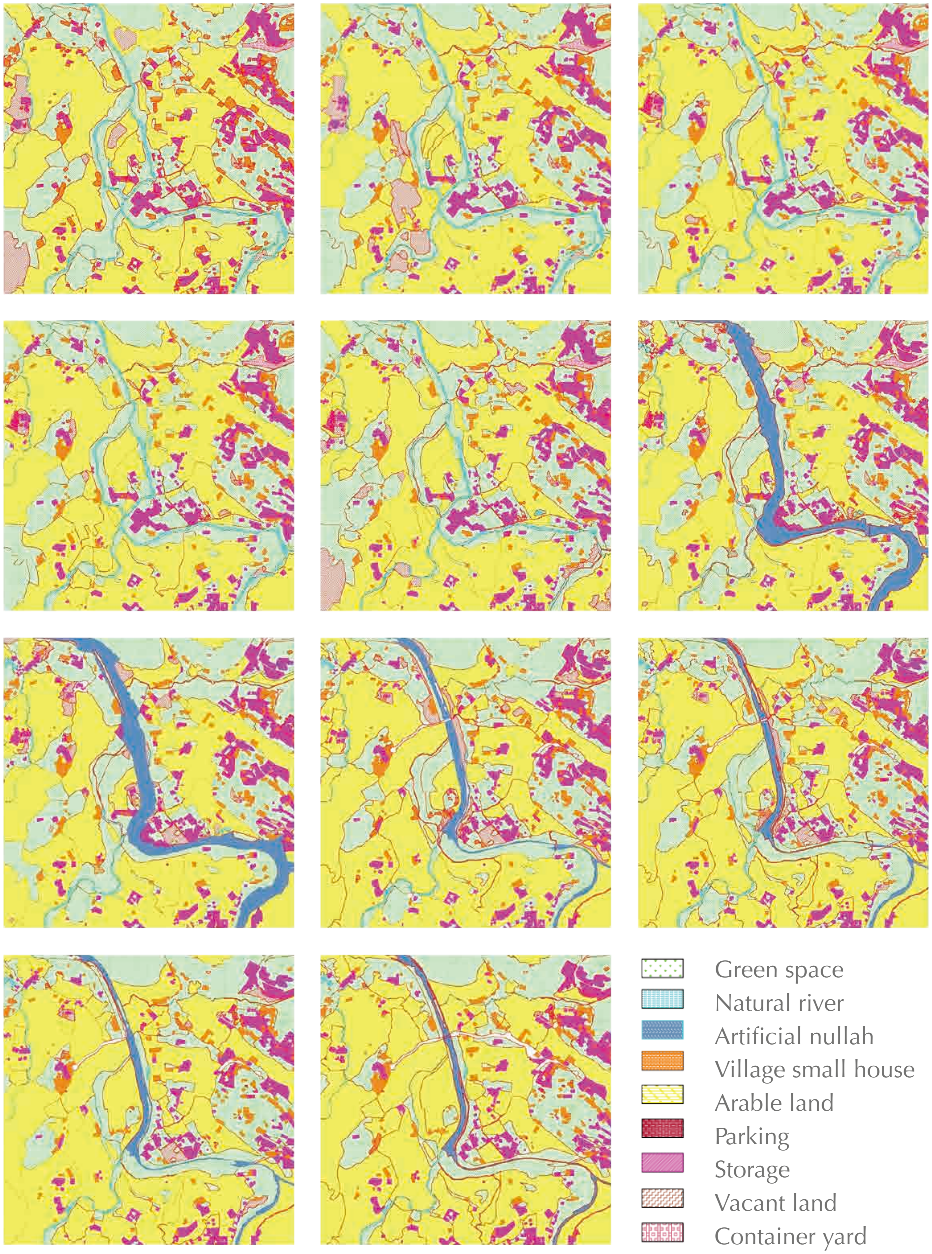

Figure 4. Land use pattern, 1995 (top left) - 2005 (bottom right).

mental mitigation strategies affect the physical transformation of the post-channelized landscape in peri-urban areas. The selected area of study is limited to 1 km2, but the results indicate the drainage channel with environmental mitigation work can reduce the adverse effects on the arable and green space land. Through such findings, the research highlights the significance of environmental strategies in territorial development for Southeast Asian policymaking that seeks to mitigate the adverse effects of urbanization.

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