The Evolution of Water Management in the Red River Delta of Vietnam and a Case of Chuc Son, Hanoi City

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Abstract. For more than 2000 year, the Red River Delta has been created by (and always tied to) the regime of the Red River. The tradition of building the rive dike system in the Red River Delta has a very long interesting history. Historically, in the feudal period, the dike system was controlled and maintained by the local peasantry which revealed an understanding about the logics of the dynamics of this delta and its landscape. Humans had tamed the Red River's water regime with quite low techniques, simple means, massive human endeavor and ingeniousness. Over time, acquired both indigenous and imported knowledge and new techniques, water management in the Red River Delta has become more refined and more complicated. However, the scope and speed of a swift urbanization nowadays, in combination of the environmental crises, predicted consequences of climate change as well as uncontrollable up-steam river constructions by neighbouring countries, has heralded a new era that demands a radical rethinking of water management. The paper is structured in three main parts. It firstly reviews the Red River Delta's historical water management in order to understand the broader context and eventually draw lessons. Secondly, it discusses contemporary challenges in terms of water management for Vietnam in light of unprecedented modernization and urbanization. The article concludes with the case of Chuc Son, an area in the southern region of the Day River, which is an important tributary of the Red River and significant in terms of the capital city's westward expansion.

Keywords: Red River Delta · Day River · Water management · Urbanization · Climate change · Chuc Son

1 Introduction

Vietnam's Red River Delta has an extremely high population density (averaging 1,004 persons/km^2) [6]) and hosts an ancient wet-rice civilization. The territory has a range of 0.1–1.5 km/km^2 of naturally flowing rivers and 0.67–1.6 km/km^2 of irrigated land [31]. As the geography which hosts most ancient human settlements in Vietnam, the Red River

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Delta has more than 2000 year of land reclamation for paddy farming [4, 23]. Besides receiving the privileges of nature, due to both geography and climate, the Red River Delta endures extremely from natural calamities. The most dangerous disasters are related to water, including annual tropical typhoons, seasonal droughts and floods (Fig. 1). For over 1000 year, mankind has developed water management techniques aiming to reclaim and reconcile with the natural forces. The delta's intricate system of water management has been built both for protection and irrigation since the 8th century. This water management system includes a dense and complex network of semi-permanent and permanent dikes, sluices, and pumping stations [20].

(a)

(b)

Fig. 1. Historically, the Red River Delta has been received natural disasters of seasonal floods and droughts: a) 1930 Extreme flooding in the Red River in Hanoi during rainy season [5]; b) 1927 extreme drought in the Red River in Hanoi during dry season. [Dépôt des archives d'outre-mer, Aix-en-Provence: FR/CAOM/30Fi119/70].

As the same as most large rivers in the world, the Red River's water regime is varied. Its water level fluctuates between 1.41 to 14.3 m throughout the year with an average of flow of 2,640 m^3/s [19, 21]. Over 1902–1990, the average water discharge of the Red River was about 3740 m^3/s at Son Tay [32]. The water volume of the Red River totals approximately 83.5 Mio. m^3/year, and its water velocity can reach 3.45 m/s [19, 21]. This lets the Red River can become one of the world's largest rivers regarding the water flow. Normally, the water level of the Red River rises quite slowly. However, its water level can very quickly rise from 1.0 to 4.0 m within 24 h after the typhoons [9]. Its water carries a great volume of alluvial sediment during floods. The water of the Red River can carry averagely about 1000g of silt/m^3 and about 114–115 Mio. Tons/year [19]. The quantity of water and silt are different throughout a year, where there is 65–80% of water and 90% of silt [19] during the rainy season.

The Day River (15 km to the west of Hanoi) is an important tributary of the Red River, and a strategic branch of the Red River in terms of water discharge during the rainy season and in terms of water supply to the low-lying agricultural fields downstream during the dry season. The Day River used to function as a flood diversion and retention area for the Red River to protect Hanoi's center, as it forms a side-branch controlled by a spillway (Hat Mon), an old sluice (inoperable) (Van Coc), a new sluice (Cam Dinh), a dam (Day Dam) with six old gates and three new gates, and a new Cam Dinh – Hiep Thuan canal. Today, the Day River is considered a 'dead river' from the Day Dam, located 10 km downstream from its confluence with the Red River (Fig. 2). There is no longer enough flow in the river, and navigation is impossible, only leaving it meaningful for irrigation. Therefore, the main challenge for the Day River is to re-articulate its watercourse and return it to a healthy, flowing river. Its large adjacent agro-aquaculture area lies significantly lower than the Day River's flood plain, yet suffers from severe droughts during the dry season. In the rainy season, the area is flood-prone. As well, the area is in the midst of rapid transformation from productive territory with villages towards an urbanized periphery of Hanoi. A great number of urban-industrial development projects and infrastructure are being carried out in the area which are dramatically altering the natural landscape and the existing water management; inevitably large areas will be replaced by hard surfaces that will accompany new development in the coming years.

Fig. 2. The Day River has been become a "dead river" since 1937, when the Day Dam was constructed. It results an extreme water pollution and lack of water during the dry season. [Pham 2011].

According to the Ministry of Construction, it is crucial to create an open landscape and a fresh environment for the Day River, considering the orientation of development of Hanoi towards the west [12]. Therefore, research is required in order to create re-naturalization strategies for the Day River and develop new infrastructure, which works hand-in-hand with urban development and increased aqua-agricultural production to simultaneously address growth, innovation, economy and ecology.

2 Evolution of the Water Management in the Red River Delta

It is essential to understand the Red River Delta's historical water management in order to comprehend the larger context and eventually draw lessons. Vietnamese customs and habits in the Red River Delta remain strongly tied to both water management and agricultural traditions of mono wet-rice [20]. The delicate relationship between human and nature structures both the physical environment and the cultural landscape shown as evident in the national literature as well as legends in Vietnam. Over millennia, water management has been improved as a seasonally complex system, which includes extensive river and sea dike and canal networks, to both regulate water and supply water for irrigation and protect both agricultural fields and settlement (Fig. 3). During the rainy

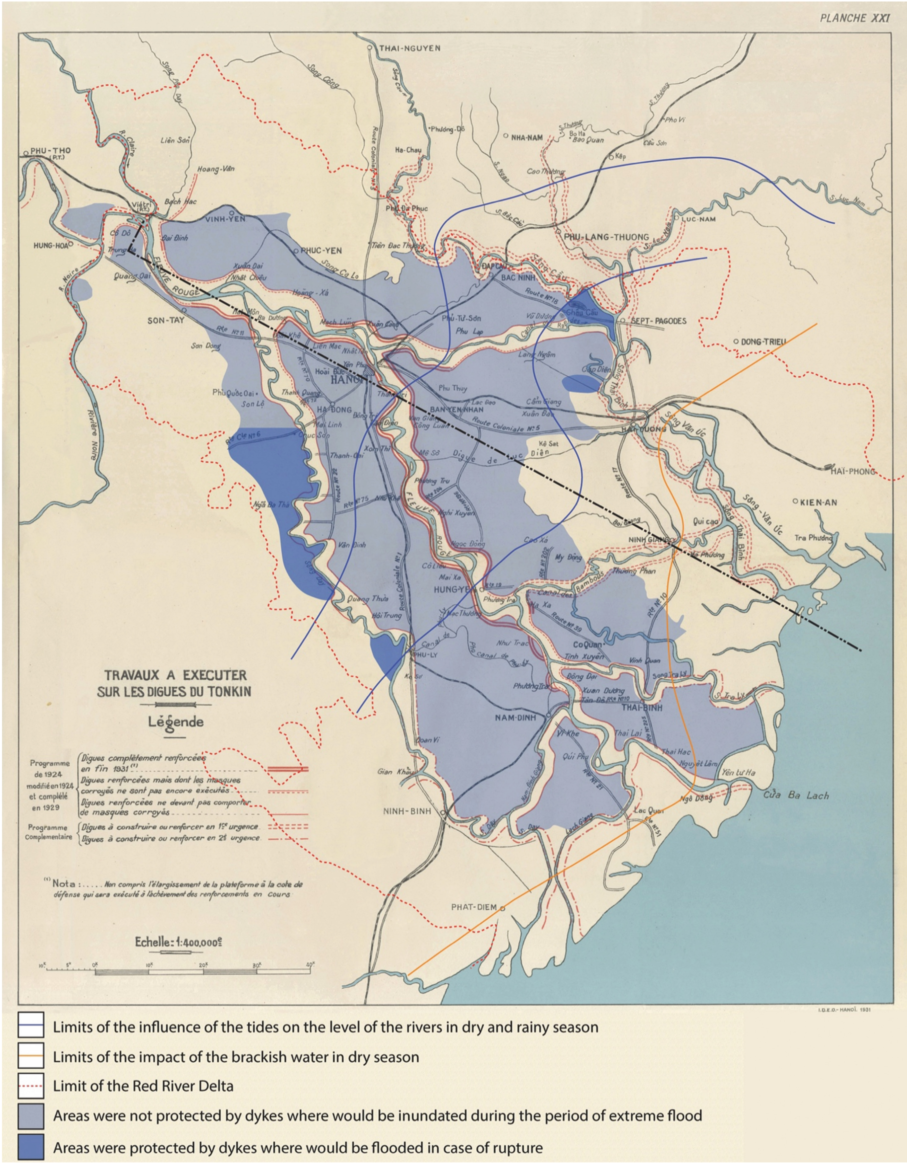

Fig. 3. The entire delta is protected by a dense river and sea dike system. Without this dike system, two-thirds of the Red River Delta would be inundated in the monsoon season. (Pham 2010, adapted from [7, 25]).

season, river intakes of dikes are closed to prevent fields from flooding, while the main canal networks collect surface runoff from fields, which is then discharged into rivers downstream. During summer droughts and dry seasons, irrigation water is provided from the rivers. The main canals network acts as a reservoir system and conveys the water from the intake into the whole irrigated area [4].

During the pre-colonial period (from 939 to 1858), the water management was controlled and maintained by villagers. Rules and regulations of individual water accesses and maintenance of collective reservoirs were stipulated in customary law [4]. Generally, local people initiated small projects in their dwelling areas while larger territorial-scale projects were implemented under the guidance of the State and financed by taxes and inspected by Mandarins [10, 11, 14, 20, 24, 30]. Historically, the initial regional dike system was firstly mentioned in ancient Chinese documents [24]. However, after some centuries of development, the floodwater discharge was difficult due to this regional dike system which become an obstacle. Therefore, humankind concentrated to develop the systems of river dikes, that were particularly well-suited to address seasonal flooding.

According to ancient annals, the first citadel (which worked as a dike) was erected in swampy lands in Hanoi in 767 AD. In 1077, the first river dike that was built and managed by the State was along the Nhu Nguyet River (now the Cau River). Building dike and hydraulic works were amongst the most important State concerns as evidenced in the Royal Proclamation of 1103 [24]. In 1248, a low soil-dike system along the main rivers of the entire delta was built. This dikes' network played significant roles both in protecting the paddy fields from water surges and controlling monsoon water flows into the fields. It was smart control to deposit nutrient alluvial into the delta during the floods. The soil-dike system along the tributaries of the main rivers began construction in 1503 [24]. A gravity-based culverts system was tied to these dikes. They could open to allow water to flow into the fields during dry seasons, which were closed to protect the fields from excess water during the floods [24]. In 1472, the first sea dike was constructed along the coast [15]. Moreover, already in the 11th century, a number of large canals were dug for irrigation networks, such as Dan Nai Canal (1029), Lam Canal (1050), and Lanh Kinh Canal (1089) [17].

The hydraulic works and dike system were repaired yearly by compulsory participation in public works. A lot of people including students and soldiers was mobilized to move massive volumes of earth and to build bamboo embankments in order to reinforce the dikes system [14, 17, 20, 24] (Fig. 4). Nevertheless, after several centuries of water management and flood control, the Vietnamese people understood that there was a limitation of continual heightening of the dike system. It needed to be paralleled with lowering the water level during the floods. Therefore, the digging of new rivers to discharge floodwaters and reduce water levels was begun in 1729 [24] combined with the construction of reservoirs, dams, the widening and dredging of the existing rivers system in 1857, and even the destroying the dike system in the delta [18, 20, 24].

The first Vietnam's complete water management policy was published in 1809. In this document, a hierarchical dike system based on river sizes was regulated clearly (see [24]). The document documented indigenous dike construction, which combined wood, bamboo, and soil. To compact soil of the dike, elephants were utilized, and finally, the dikes system was covered by grass [24]. However, the proclamation was quite generic. It did not specify any different rivers' characters as well as their water levels. The highest water levels in various rivers were only mentioned when the 1838 annex was issued [24].

Fig. 4. Pre-colonial dike repair and public works: The mandarins directed the population to repair the dike system and hydraulic works. In the instance above, the work is carried out on a dike in Thai Binh, Red River Delta. [Source: Dépôt des archives d'outre-mer, Aix-en-Provence: BB/SOM//D3685].

With French colonization, there as a significant shift in flood control and water management in the entire Red River Delta. The dike system had become a substantial concern from both French and Vietnamese regarding to water management and flood control in the whole delta (Fig. 5). There were so many solutions debated in various degrees, such as upstream afforestation, construction new reservoirs, diversion of water from the Red River into the other its tributaries, complete canalization of the Red River and even destruction of the river dike system. These solutions had also been discussed often in the pre-colonial period [24] (Fig. 6). Ultimately, the French intensified and rationalized the whole infrastructural system including the dike system in the Red River Delta. There were 30 primary hydraulic units in the entire dike network system with respect to independence of water management and flood control [4].

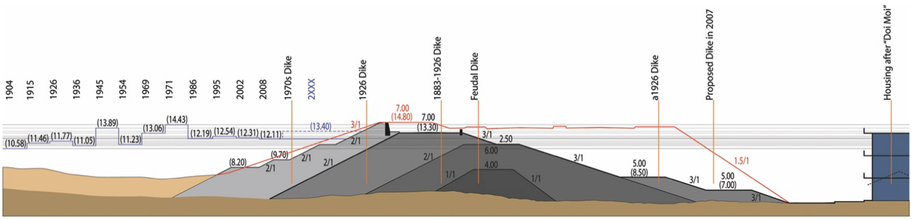

Fig. 5. Evolution of dike's typology: Ever since French colonization, the dikes in the Red River Delta have been almost continuously heightened and strengthened. (Pham 2010, updated from [5, 27]).

Fig. 6. To canalize the Red River was proposed by Nguyen Canh in 1920s, aiming to improve the ability of water discharge to the East Sea in the rainy season. (Pham 2010, redrawn from [13]).

The quantity and quality of the dike system were increased significantly by using mechanical techniques which was the first-time implementation in Vietnam (Fig. 7). At the same time, techniques in dike construction were regularly improved and in 1926, a new profile (the step dike) was introduced. For the first time in Vietnam, new materials such as concrete was used to constructed modern waterworks, for example: Lien Mac Sluice (1937), Day River's Dam (1932), and Vinh Yen Dam (1896), to control water that flowed into the Red River's tributaries as well as into the delta strategically [22].

Fig. 7. In the 1930s, for the first time, heavy construction machinery was introduced in Vietnam which had increased the quantity and quality of the dike system in the Red River Delta [5].

There was massive destruction of the dike system in the Red River Delta during the Vietnamese struggle for independence from the French. Therefore, from the end of 1945 until early 1946, the State mobilized an exceptional social labour to repair the dike system, see [17, 24]. More than 80% of the State direct investments were dedicated to water management improvements. Irrigation schemes and large drainage were constructed to complete a complex canal network classified in four levels [4]. However, the achievement of hydraulic works improvement and development was interrupted seriously during the First Indochina War.

Once again, the method of water management and flood control in the Red River Delta changed siginificantly under the political framework of agriculture collectivization and cooperative settlement under the independent North Vietnamese State in 1954. After establishing a Ministry of Hydraulics in 1958, water management became a high priority, especially with respect to flood control in the Red River. Due to receiving the specific assistance of Chinese and Russian experts during this period, the development of hydroelectric plants was carried out in many studies which has purposes for both flood control and industrial development. At the same time, the system of river and sea dikes was substantially upgraded [24]. Nonetheless, during the Second Indochina War, the hydraulic works in the Red River Delta were again destroyed and interrupted seriously. Destruction the dike system become a strategic activity of the American military. This ambitious military action was impacted significantly the fledgling Vietnamese State. It also emphasised the vital importance of the dike system in the Red River Delta for both politics and economics in Vietnam.

After receiving a devastating flood in 1971, it was concluded that flood control as well as water management for the Red River Delta had to be rethought fundamentally. Parallel with strengthening and heightening the dike system, a number of flood retention basins were created to divert floods from the Red River. At the same time, large-scale engineering solutions were concerned significantly including to plant new hydroelectric plants [24]. With the help of Russian experts, a largest hydroelectric project in Vietnam, the Hoa Binh Hydroelectric Plant, had been constructed from 1979 to 1994. It was also the first important one on the Red River Delta and contributed substantially to the Red River's flood management.

3 Contemporary Water Management Challenges for the Red River Delta

In 1986, due to recognizing the failure of the "great socialist agriculture" policy, the Vietnamese government decided to change the policy through economic liberalization (called "*doi moi*") and reorient it towards a "socialist-oriented market economy". Both cities and the countryside were radically transformed due to the territorial ordering was inseparable from the logics of settlement structure and production. At the same time, water management was changing in order to respond to a series of new challenges.

Since "*doi moi*", there has been massive rural to urban migration and the country witnessed a 3.17% average annual urban population growth from 2000 to 2019 [6]. As its unprecedented modernization and urbanization continue, both urban and rural territories are transforming at a scale and scope previously unseen. This fragmented and dispersed development reveals a challenge that is increasingly difficult to control. New settlement colonizes both agricultural low-land and floodplains everywhere in the Red

River Delta. Land-filling on the low-lying land is changing significantly the permeability of the territory and affirming many pressures on existing water management. There has also been an explosion of unauthorized settlement outside the dike system where is unsafe and floodable areas. These areas and their populations have become the most vulnerable to the impending effects of predicted climate change. These settlements, mostly built by the poorest sector in society, are now part of the speculative market games of the rising entrepreneurial class. The dense occupation has led to the conversion of the permeable and natural flood plains into hard surfaces, seriously compromising natural discharge and increasing flood levels. Furthermore, the region's aging water treatment system has been overloaded with a swift urbanization that brings polluted water in the whole delta, particularly in the large cities.

Vietnam is one of the most vulnerable countries in the world due to predicted climate change (and more specifically to sea-level rise) [2, 21]. The effects are expected to be the most severe in the whole deltas in Vietnam including the Red River Delta. Already, the monsoon regime has become increasingly complicated: there is less water and unprecedented heavy rains in the dry season but more water in the rainy season. Additionally, the dike system retains floodwater that carries massive amounts of sediment during the time of floods. Therefore, the sediment in the floodwater cannot enter the delta; it drifts to the mouth of the main rivers and settles in their estuaries, blocking water from flowing to the East Sea. Otherwise, water locked inside the dike system causes further rising of rivers' water levels, increasing the risk of dike failures. The risks of the predicted rising sea levels (inevitably reducing rivers' capacity for water discharge), coupled with higher river floods (due to stronger storms and heavier rainfall) are inevitable. Moreover, in case of heavy rains, the water accumulating in the territory's expansive lowlands cannot naturally drain due to a higher elevation of the riverbed. Finally, the frequency and severity of floods have been increasing. There was witness happened in November 2008, when Hanoi become a victim of the most extreme inner-city floods to date. There was a devastating death toll of 94 lives and damages were estimated at VND 7.3 trillion (USD 430 Mio.). As well crops and livestock were destroyed, including 210,000 ha of vegetables, 30,000 ha of rice, 10,000 ha of orchards, 40,000 ha of fishponds and nearly 200,000 livestock [3]. Additionally, before 1970, the frequency of heavy rains and floods in Hanoi occurred every 15–25 year. However, due to climate change, over the past 60 year, floods have become more frequent with a frequency of 5–7 year [16].

The Red River Delta is also confronted with many problems by the upstream reservoir and dam construction, both in Vietnam and outside of Vietnam (by China). These reservoirs and dams are needed for both electric power and water management. As throughout the world, the effects of the large engineering works are hugely controversial on local populations, whereas the flows of water are highly manipulated, and often there is a reduction of water for agro-aqua-culture. A number of reservoirs constructed in China reveal many troubles related to watershed management, which work irrespective of national boundaries and politics (Fig. 8). The Red River Delta is the mouth for water discharge of the whole hydraulic system of the Red River Basin into the East Sea. There is no transparency between the Vietnamese and Chinese governments with regards to water management due to contentious politics; the result is that the safety in the delta is endangered since water flows remain veiled. To date, the Red River Delta suffers the consequences, such as flood and drought, water pollution… of being the outlet of the Red River. Otherwise, the river fluctuations are no longer decided by both the vagaries of natural regime and the politics/economics of its neighbours (similarly by China's and Laos' contemporary dam building in the Mekong Delta).

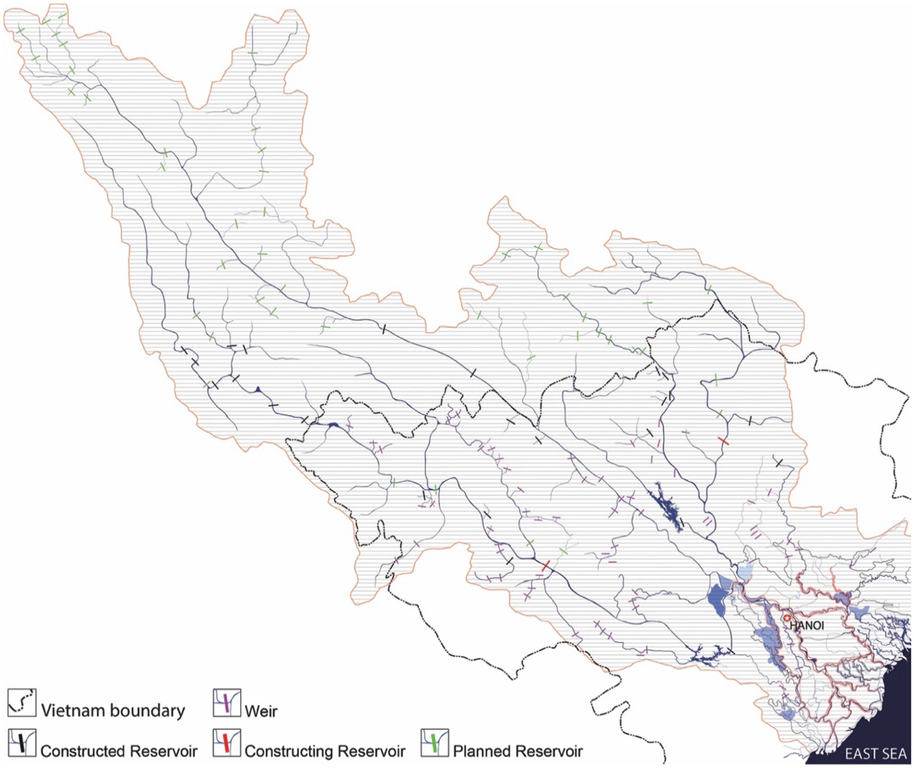

Fig. 8. According to Ha 2010, on the upstream Red River system, China has a plan to construct 52 hydroelectric plants (23,24,5 and 2 dams that are on upstream Thao River, Da River, Lo-Gam River, and Bang Giang-Ky Cung Rivers in respectively), of which 8 dams were complete with the capacity of water restoration being about 2.0 billion m^3 of water. [Pham 2011, addapted form google map, 1, 8].

Finally, once Vietnam entered its "doi moi" period, flood control and water management has become a part of the interests and investments of the larger international (donor and for-profit) community. A large number of Vietnamese experts have been given the opportunities to study abroad; at the same time, many international experts have become advisors in Vietnam, as in the French and Soviet-influenced eras. A number of studies, particularly in the Hanoi area, have continued with the old paradigm of hard engineering. It is clear that the shift to combine hard- and soft-engineering and to "make space for the water" and to "give room to the river" has not yet genuinely reached Vietnam. However, such notions are increasingly spoken about in academia and selected governmental departments.

Between 2004 and 2006, "Pilot Project C: The Improvement Plan and Strategy for the Outside-of-Dike Area", as a part of HAIDEP project (Hanoi Integrated Development and Environmental Program – The Comprehensive Urban Development Programme in Hanoi Capital City), studied 40 km long of flood plain area along the Red River's banks in Hanoi, where has been illegally appropriated by housing development during the past decades [9]. The project investigated and proposed a new strategy for development of this area through a number of alternative scenarios. The research recognized that the area outside the Red River's dike system is a precious asset for the entire city because of its historical and landscape value, as well as prevention capacity with respect to the natural calamities. They also value it for the potential of urban development, which could be argued to go against the environmental principles and the notion of giving more space to the water dealing with floods and the predicted consequences due to climate change (particularly increasing water in the rainy season). In this project, a second dike closer to the river was proposed to enhance the potential development of the areas outside the existing dike system and to secure citizen's quality of life. To face up to the waves of swift urbanization, the study suggested that, in the future, the location of existing cultural areas and urban communes outside of the dike system would be allowed to have "controlled development" behind the second dike system. All the rest of land outside of the dikes system would be preserved as open space for recreation and agricultural production. Security was a high priority in the research and residential areas along the river terraces, around bridges, nearby the dike roads system would be relocated for safety concerns during the flooding times [9] (Fig. 9).

From 2006–2007, a cooperation research between the capital cities of Hanoi and Seoul studied for new urban development along the Red River in Hanoi (RRPT). The project investigated how to integrate the flood control with new urbanization which can compromise the riparian recreation, economic impetus, and its identity. A suggested mega infrastructural system including the dike system with large arterial roads became the backbone of the study. There was a new incredible high-rise was grafted on the infrastructural system in a combination of new waterfront landscape system along the entire length of the Red River flowing through Hanoi [28]. A second dike system was also proposed as the same as the Japanese HAIDEP project's strategy. However, this dike system was much more intrusive and the flood plain of the Red River was radically reduced in width (Fig. 9). As compensation, the banks of the river were excavated in some places, but the overall space for water was lost and replaced by new urban development. Inevitably, the risks of flooding would be exacerbated by land-filling [27].

Finally, in 2010, the Vietnamese themselves, through the Institute of Water Resources Planning (IoWRP), also made a proposal for the flood control project for Hanoi's entire river system. Their project ambitioned to upgrade the whole dike system according to a new classification for river dikes (see [19]). A series of concrete embankments were suggested to construct and improve where there exists the most vulnerability resulting from the Red River's flooding. Additionally, new landmarks of floodwater discharge points as well as new positioning dikes around dense settlements of the Red River and Duong River for flood control were proposed. All three projects relied heavily on hard engineering and mere protection from rising waters, rather than strategies of accommodating floods (Fig. 9).

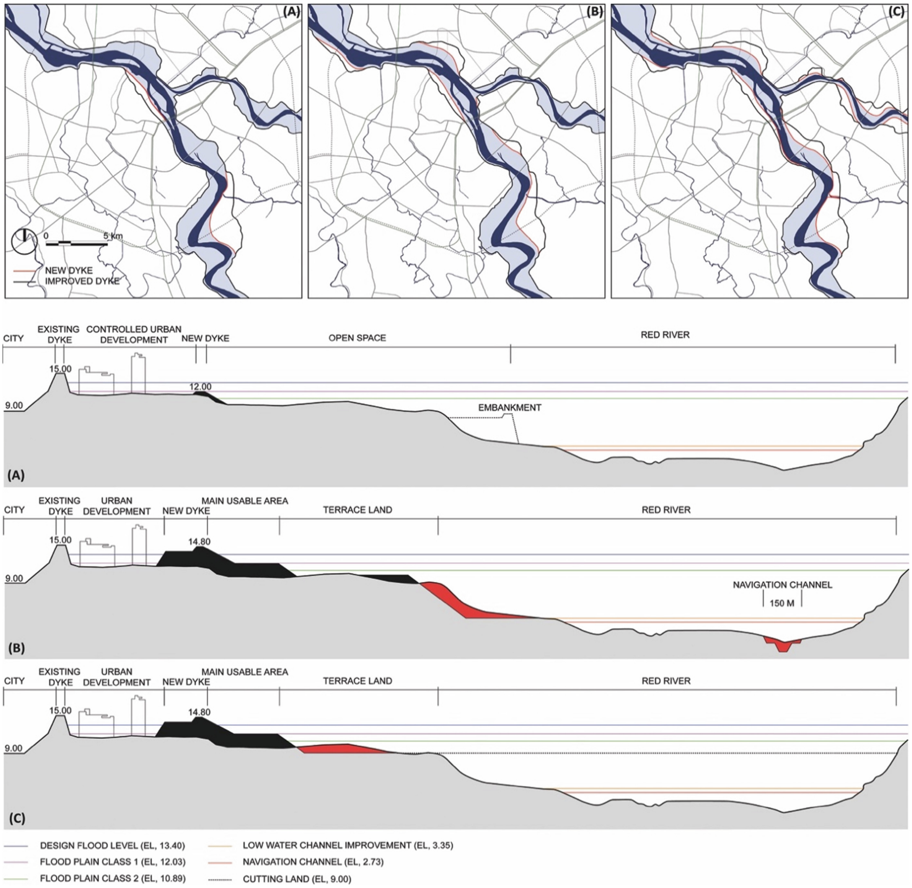

Fig. 9. The Japanese (A) South Korean (B) and Vietnamese (C) proposals for reconfiguring the dikes along the Red River all compromise severely the natural ecologies and dynamics of the water flows for the urban and economic development (Pham 2010, adapted from [9, 19, 27]).

4 Expansion to the West: The Case of Chuc Son

4.1 Contemporary Water Management Challenges for the Day River

Based on the evidence receiving during fieldwork, since the Day River has been cut off from the Red River, the difference of water levels between the rainy season and dry season is only 3–4 m (while it is approximately 13 m on the Red River itself). The reduction of water flow has caused it to become an ecologically dead river. The naturally reduced water flow is compounded by floating agricultural production and natural floating plants, particularly fast-growing water hyacinth. Moreover, little control by authorities means that there is more freedom regarding the cut-and-fill activity of land on the flood plain. The new land is elevated for settlement as well as the planting of trees along riverbanks. All these activities further obstruct water flows and the entire water regime of the flood plain.

Nonetheless, the Day River still retains its beauty and diversity as both a natural and artificial landscape. Over time, different uses of water and farmland transformed the riverbanks into a tranquil rural landscape [22]. Most of the area for rice cultivation is outside the dike system, while most of the area for vegetable cultivation is inside the dike system (on the regional flood retention areas). However, rice productivity is low due to poor soil quality and flood risk. The region's paddy fields are idle from the beginning of October to the middle of January. However, many farmers use their paddy fields for other purposes such as fish ponds. Over the past decades, the landscape of Chuc Son has evolved into a rich landscape mosaic of aqua- agriculture due to the ingenuity and economic ambitions of local inhabitants who have developed different methods for irrigation and utilized rainwater harvesting, wells and ponds to work with the seasons.

Historically, there was a clear hierarchical irrigation system in the territory, which included the Nhue, Day, and Tich Rivers. Today, water moves throughout the Red River Delta with extensive mechanical means; a series of pumping stations along the Day River dike supply water for irrigation and discharge waste and flood water. From the Day and Nhue Rivers, water is pumped into the main canals or smaller natural rivers, which then naturally flows downstream (by smaller irrigation systems) into the hinterlands. Because of the scarce and polluted water in the Day River, occasionally clean water is pumped from the hinterlands into the flood plain of Day River for irrigation during the dry season. Otherwise, famers only use black water (mostly from Nhue River and traditional agricultural production) for paddy fields. For vegetables and grain, they use either rain- or well-water (from either individual or collective wells). However, these activities lead to the risk of underground water becoming polluted since this area is often flooded. During floods, water that carries toxins or harmful substances mix with underground water through the wells. The quality of underground water is thus dramatically reduced.

In August 2008, the Prime Minister approved the area expansion of Greater Hanoi; there was almost a twofold increase in population (from 3.8 M to 6.2 M) and more than threefold increase in the territory (from 920.97 to 3,344 km^2) [29] with an average density of 1,863 persons/km^2. Evidently, the environmental balance of the large territory is slated for major upheavals. There are five satellite cities and three "ecological towns" planned. As a result, the existing and very large low-lying natural-agricultural land will be replaced by new urban development. This, in turn, raises many new challenges concerning sustainable development, with new infrastructure demands, increased housing density, lost open space (green and water space) and degradation as well as homogenization of the rich environmental diversity of the region. Hence, there is not enough space for water and significantly reduced permeability of the land. Chuc Son, the southern area of the Day River, is a representative case in the transformation of the territory in the western expansion of Hanoi.

It is obvious that the dike system of the Day River continues to have an important role in the relationship of settlement, productivity and infrastructural development. Typology of the Day River dike is quite simple. Since the severe flood in 1971, the dike system along the Day River has been carefully studied. While the existing left-bank dikes of the Day River were widened, strengthened and heightened, a series of new dikes on the rivers right bank was constructed on suitable for flood retention areas of the Chuc

Son (as realized under a 2011 Prime Minister's Decree) [26]. The new dikes were constructed further to the west and incorporated the existing mountains as a natural defence system. Moreover, a number of new spillways were created by lowering existing dikes downstream (Fig. 10). The dikes along its banks are smaller than those of the Red River dike but have innumerable more (in)formal functions and activities. Due to the combination of a number of contradictory elements (natural/artificial topographies, commercial areas/settlement and aqua- and agricultural/industrial production areas), a diversity of landscapes and spaces along the dike system exist. In addition, with the new demands of the free market and diversified economy, there is an increase in local demands for space, which is as close to the dike and infrastructure system as possible. A process of elevating land up to the height of the dike system is presently occurring in the area, which causes fundamental changes in both the function of the landscape and the dike system. New challenges in terms of water management require annual strengthening and frequent stability checking of the dike system will continually need to be dealt with.

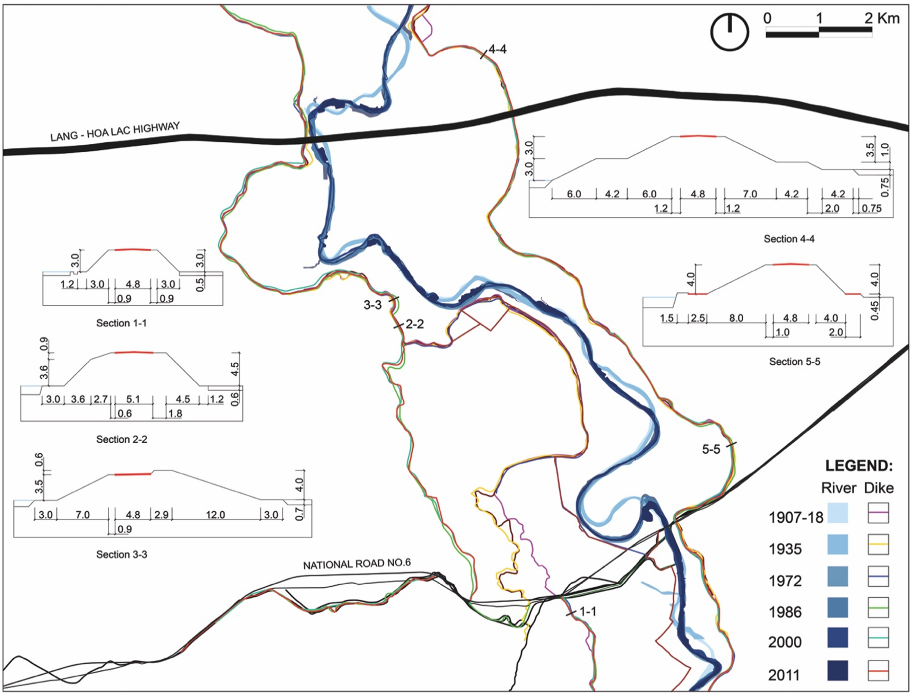

Fig. 10. Typology and movement of dike in Chuc Son: The profile of the Day River dikes is similar to others in the Red River Delta and historically were adopted to the dynamic flows of the river's flow [22, 23].

Between 1907 and 2005, there was little change in the urban footprint of Chuc Son. Afterward, however, there was a swift change of both rural and urban morphologies. A great number of projects for urban and industrial development as well as water management were carried out on the left side of the Day River dike and territory will inevitably continue to change dramatically in the coming years. The agro-natural landscape will continue to be replaced by the hard surfaces of new development. A larger looming threat than the legal construction (including administrative buildings, schools, markets,…) made by local government is the illegal constructions inside the dike system that fills the floodplain and further alters the already severely damaged hydrology of the region (Fig. 11).

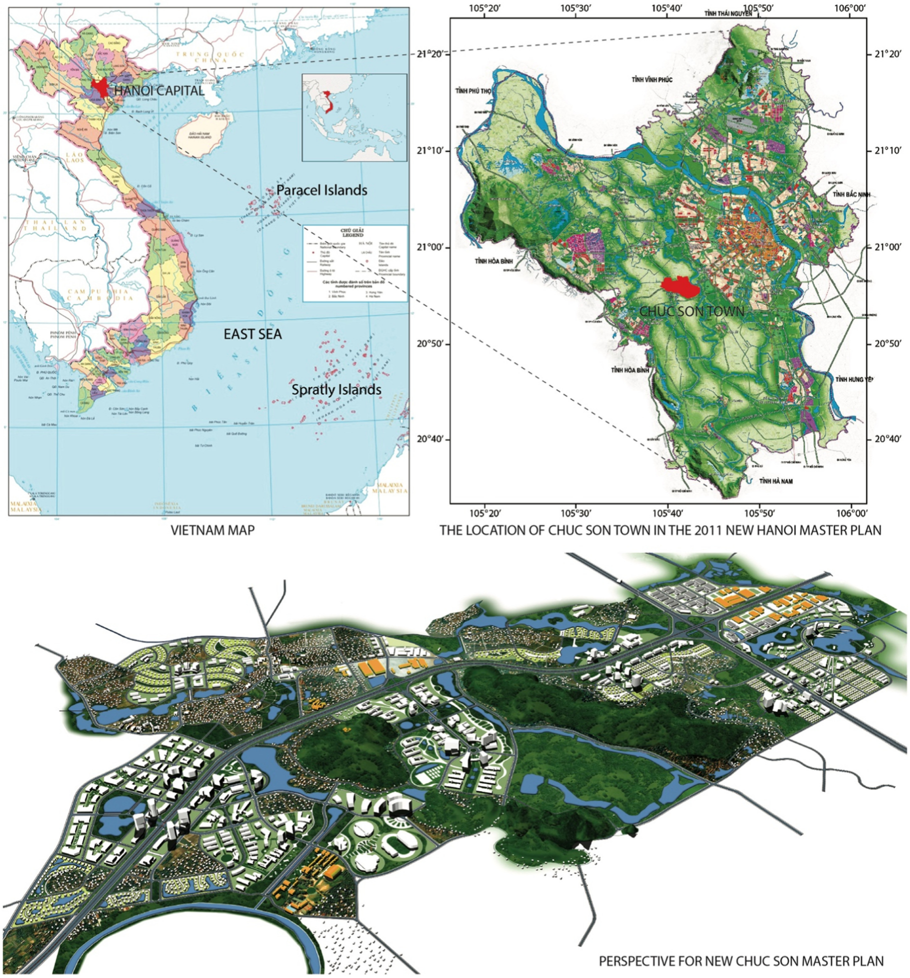

Fig. 11. Chuc Son as envisioned in expansion plans: As Hanoi expands, so to does its agricultural hinterlands—at least in the dreams of the planners for the new master plan for the capital city. Chuc Son is slated to become an "ecological urban area" between the Day River's flood plain and its hinterland. (Pham 2020, adapted from [12]).

4.2 The Case of Chuc Son

The case study area of Chuc Son has relatively flat topography. Most of the land is a flood plain of the Day River, which is a bit higher than its hinterland due to sedimentation (Fig. 12). This character is one of the reasons why water flows quite easily from the flood plain into hinterland but, at the same time, has difficultly discharging back into the river in the rainy season. The little water in the Day River can hardly flow into paddy fields in the dry season. Since a natural water flow no longer exists, a huge artificial system for water control in this area is required. The relatively flat topography has slight differentiation in levels, which, in turn, determines distinct (and often conflicting) land designations such as agricultural production/settlement, flood-prone/safe land, natural/artificial water management, etc. A diversity of agricultural land-use reflects inherent landscape logics: low-lying land is cultivated as paddy, naturally higher lands are used for more flood-vulnerable crops such as vegetables, flowers, fruit trees or ornamental trees, and the highest natural (and artificial) lands are occupied by humans (residences, industries, social spaces,…). On a relatively smaller scale, the topography is often artificially modified following a 'cut-and-fill' logic. The earth that is cut to make ponds or components of the irrigation system is used to create raised and safer lands.

The design research proposes alternatives to business-as-usual and seeks to capitalize on interplays and synergies between urbanization, infrastructure, and landscape. The vision for Chuc Son provides a crucial frame for development through enhancing the existing water-based infrastructure of the territory. The ultimate aim of the design research is to protect the flood plain of the Day River as the main water discharge area for the expanding urban area of Hanoi. Since the city is expanding westwards, and in case of failure reservoirs upstream and unpredictable extreme floods, existing villages outside the Day River's dike system should be consolidated and expansion should be limited while existing villages inside dike system should not be allowed to develop and expand. The nature of the Day River, and more specifically address the unique character of Hanoi's urban and rural periphery, is structured by strategic, yet flexible, a development that relies on the water system as an ecological backbone. 'Soft engineering' is proposed to work with the dynamics of water and reduce and mitigate the predicted impacts of natural disasters due to climate change (Fig. 13).

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In order to counter pressure from urbanization on the eastern side of the Day River, an elastic linear park is proposed along the left dike to protect the Day River and its flood plain. The elastic nature of the green zone has to do with its capacity to respond to season variations in water levels and to act as a flood mechanism. As well, the flexible/seasonal water network is planned to addresses both water quantity (including flooding, storm/rainy water retention, drainage and irrigation) and water quality (including sewage and purification) issues and the recreational use of water. Amongst the elements

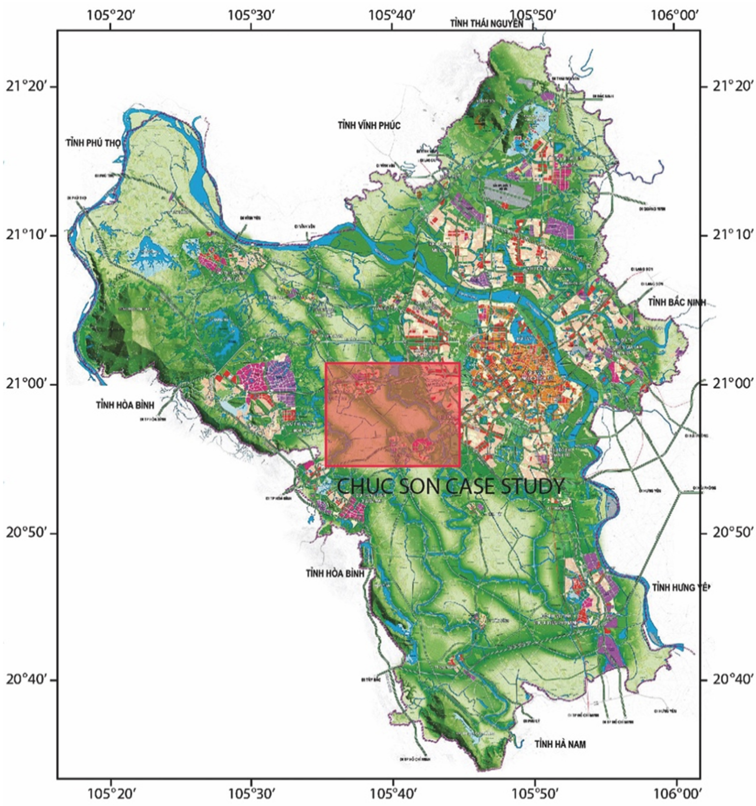

Fig. 12. Location of the Chuc Son case study in the Hanoi Construction Master Plan to 2030 and vision to 2050 (Pham 2020).

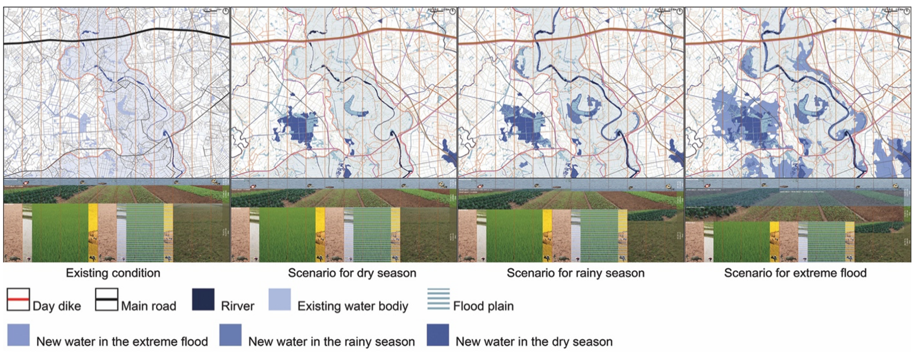

Fig. 13. Three water retention strategies: More water space gives more potential for agro-aquaculture production and reduces the unused land of paddy fields in the case study [22, 23].

in the water system are storm water management, a decentralized waste water purification network which combines constructed wetlands and chemical treatment plants, and a system of water retentions such as: lakes, ponds and alluvial traps for agriculture. The same area would be physical structure to direct and limit urban development and protect nature along the Day River. New towns should be developed at the intersections of the main roads. This can help to reduce construction and expansion in the surrounding villages (Fig. 14). This new urbanization should be built on safer land (by inter-cut-and-fill process) on both sides, strongly related to the existing topographical conditions. Hence, a balance for development on both sides of the Day River would create an ecological (and recreational) corridor as well as part of an expanded and protected flood plain.

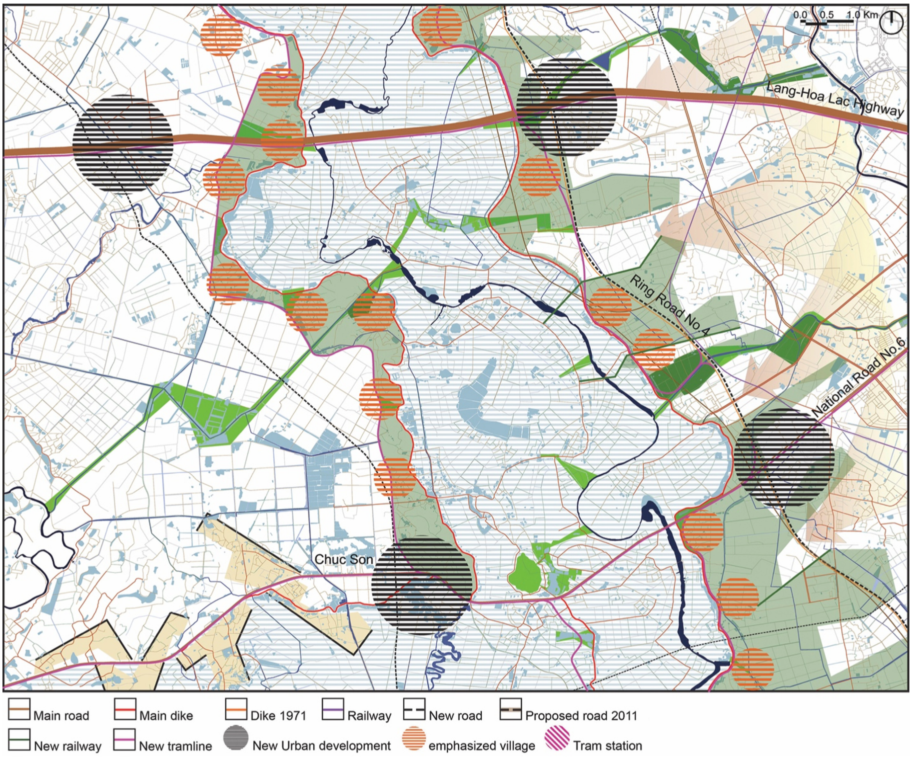

Fig. 14. Frame structure for urbanization: An alternative linearity along and outside the Day River dikes (with the possibility of new interplays of landscape, infrastructure, and urbanization) creates a series of different centralities [22, 23].

To emphasize the elastic green zone between new urban development and the recovered nature of the Day River and to simultaneously improve the living standard in present villages along Day River dikes, a new tramlines network (which could help to reduce the pressure of transport on the present-day dike system) could be configured for the area. Apart from melding with existing dikes to become a more functional hybrid dike in places, new tramlines will pass villages and paddy fields with the aim to link existing villages together as much as possible and connect to region's crucial infrastructure. Hence, the Day River dikes will also serve more functions than mere technical roles of water management.

In addition to the primary linear park along the Day River, a system of secondary linear parks along small rivers and main canals for irrigation which connect the Nhue, the Tich, and the Day Rivers could also be created. Such a system could improve not only environmental condition but also contribute to create a hierarchical system of green and open spaces for the whole Hanoi region. As well, the system both could preserve and provide new open spaces for compensation of nature for new urban development and work as links to maintain an ecological balance and create gradual alteration between urban and rural areas.

Waste water management is also a very important issue in the case study; particularly since urbanization is juxtaposed with the Day River. At the confluence with smaller rivers and with the meetings of villages (traditional agricultural production), such as the So village (one of the main sources of waste water discharging directly into the Day River), aerated/green lagoons could be located (combined with the secondary linear parks in one). Such lagoons could be integrated into the flood management for the plain and work as both flood mitigation devices and retention basins.

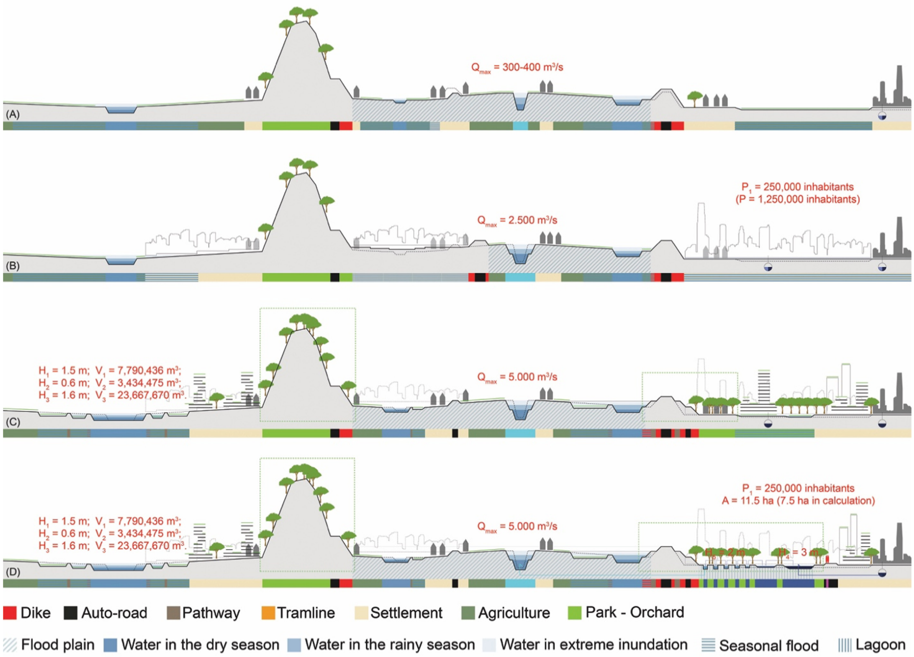

Fig. 15. Diagram sections guiding urbanization: Existing condition (A); expected urbanization in Hanoi Construction Master Plan to 2030 and vision to 2050 (B); new strategies across new urban district (C) and lagoon (D) [23].

A combination of re-naturalizing the Day River, preserving its flood plain, and creating a water retention system is one of main solutions to protect Hanoi in water management. The ecosystem of the Day River and its flood plain will become an important 'green lung' for Hanoi's sustainable development. In terms of urbanization, on the eastern side of the Day River, a dispersive development of new urban districts on the low-lying agricultural lands lead to increasing risks of inundation due to the proliferation of hard surfaces. Therefore, it should be developed more compactly to save land for blue-green spaces, which are used for urban agriculture, recreation, decentralized bio-filters, or seasonal/flexible water areas (Fig. 15). New ecological towns proposed in the Hanoi Construction Master Plan to 2030 anh vision to 2050 on the other side should develop outside the Day River's flood plain.

Parallel with the water retention system on the hinterland could be another system along the Day River banks to increase the capacity of retaining water in the area during the monsoon season. It would be an opportunity to improve waterscape and also work as a system to trap fluvial during floods to improve the quality of the soil. However, construction of new forms for water retention would cause complicated water flows and therefore the forms of the traps need to be studied carefully in order to protect riverbanks in terms of hydraulics.

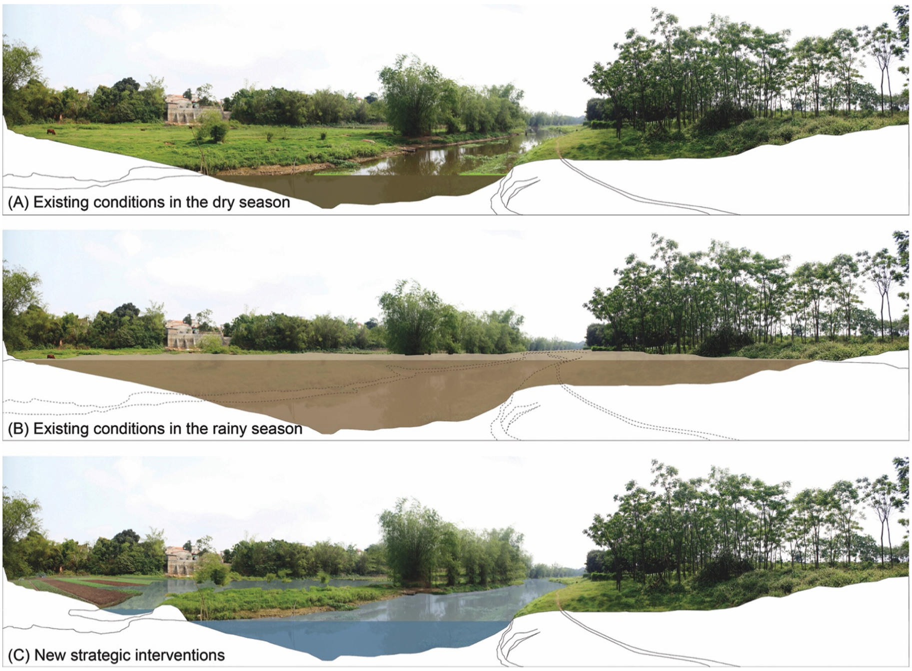

Fig. 16. Space for the Water: Interpretative mapping is not merely descriptive but mirrors realities. By the form of collage, it reduces to the essence and unfolds the hidden potentials and discloses conditions to emerge new realities that are suitable with new strategic interventions. Water retention along the Day River is an opportunity to improve the landscape, water management, and agricultural production [22, 23].

At a larger territorial scale, the Day River flood plain is extremely important for flood diversion and retention in case of extreme failures of upstream Vietnamese reservoirs and for unexpected water coming from China. As part of the proposal, a series of new water retentions basins would also be created. The locations and configurations of the basins would be based on the existing elevations of land and water demands for irrigation on areas in the dry season; they would also serve as rainwater harvesting basins and thereby improve the aqua- agriculture economy of the region. Indirectly, the quality of soil due would also be improved due to the fluvial in the flood water, increasing areas for vegetable and aquaculture by reducing unused land of paddy (Fig. 16).

5 Conclusion

The water management and dike building traditions for flood control in the Red River Delta have a long and distinguished history. Historically, people had controlled and maintained the dike system by the local peasantry, which revealed an intimate understanding of the logics of the delta's landscape and its dynamics. Mankind had reclaimed the Red River's water regime with quite low techniques, simple means, massive human endeavour and ingeniousness. Over time, acquired both indigenous and imported knowledge and new techniques, water management in the Red River Delta has become more refined and more complicated. Nonetheless, nowadays, a combination of existing position of urbanization, environmental crises, predicted consequences of climate change as well as the uncontrollable up-steam river constructions by neighbouring countries, has brought these traditions of water management into a new era that requires a fundamental rethinking.

The Day River is one of the most important natural rivers in the Red River Delta regarding both water management and environmental protection. It is a specific and fragile spatial edge of Hanoi's development and in the midst of rapid transformation from an aqua- agricultural territory with traditional villages towards a fully urbanized periphery. It is receiving massive pressure to urbanize and infrastructure construction has already begun. However, since it has ceased to exist as a functioning ecological entity it demands urgent attention. Its ecological integrity needs to be recovered and it should be reconfigured to work as Hanoi's 'green lung'.

Through the lens of the water urbanism, the research results of the Chuc Son case study suggested several solutions that can become lessons for others areas in Hanoi as well as other cities in Vietnam. There is a need of multi discipline co-operation, such as urban planning, water management, and landscape architecture… to enhance the environmental and landscape quality, values of agro-aqualcutural production, and quality of citizens' life. They can be adaptive solutions to deal with the Hanoi's future growth and predicted climate change.

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