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REVIEW ARTICLE

A review of the drivers of 200 years of wetland degradation in the Mekong Delta of Vietnam

Hoang Huu Nguyen[1] · **Paul Dargusch**[1] · **Patrick Moss**[1] · **Da Binh Tran**[2]

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Abstract This paper examines the anthropogenic factors that have contributed to wetland loss and degradation in the Mekong Delta, Vietnam from 1816 AD to present. Our analysis is framed over five historical periods and highlights the role that seven drivers of wetland degradation have played in the Mekong Delta, including: resettlement and economic development policies; population growth and urbanization; demand for food and reclaiming wetland for agriculture; construction of canals construction of dykes flood protection systems; expansion of travel systems (waterway and roads); and exploitation of wetland natural resources. Of these, government policies for resettlement and economic development seem to have had the greatest impact on wetland loss and degradation in the Mekong Delta throughout the course of history. As a result of these factors, only 0.068 million hectares of the original 4.0 million hectares of the Mekong Delta currently remains as primary swamp forest ecosystem. History suggests that future management of the Mekong Delta should take a holistic approach that includes a better understanding of the implications of past decisions on wetland loss.

Keywords Wetland · Mekong Delta · Drivers of degradation

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✉ Hoang Huu Nguyen
h.nguyen26@uq.edu.au; huuhoangnguyen2012@yahoo.com

Paul Dargusch
p.dargusch@uq.edu.au

Patrick Moss
patrick.moss@uq.edu.au

Da Binh Tran
tranbinhda@gmail.com

[1] School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane, QLD 4702, Australia

[2] The Vietnam Forestry University, Hanoi, Vietnam

Introduction

Stretching about 200 km from the border of Cambodia and the South China Sea, the Mekong Delta (MD) is one of the largest delta systems in the world. It is located downstream of Kompong Cham, Cambodia, and covers a total area of 4.95 million hectares, of which 4.0 million hectares (74 %) is located in Vietnam and the remaining 26 % in Cambodia (White 2002; Hoa 2008). The MD (from here, referring only to the part of the delta in Vietnam) comprises generally fertile, alluvial soils, of which 2.4 million ha is now used for agriculture and aquaculture, 0.4 million ha for forestry, and the remaining area for settlement and construction (Clough et al. 2000; Leinenkugel et al. 2011). Meanwhile, the total protected wetland area in MD constitutes only 1.7 % of the whole delta (Buckton et al. 1999; Vietnam-EPA 2005). The MD (Fig. 1) plays a very important role in the agricultural and aquaculture production of Vietnam [i.e., producing 50 % of the nation's rice yield that contributing more than 30 % of the nation's Gross Domestic Product (Evers and Benedikter 2009)].

The human exploitation of the MD has led to changes in natural hydrological, ecological, and morphological processes. Drainage and canal construction for agriculture and transport first occurred over 1000 years ago (Biggs 2004).

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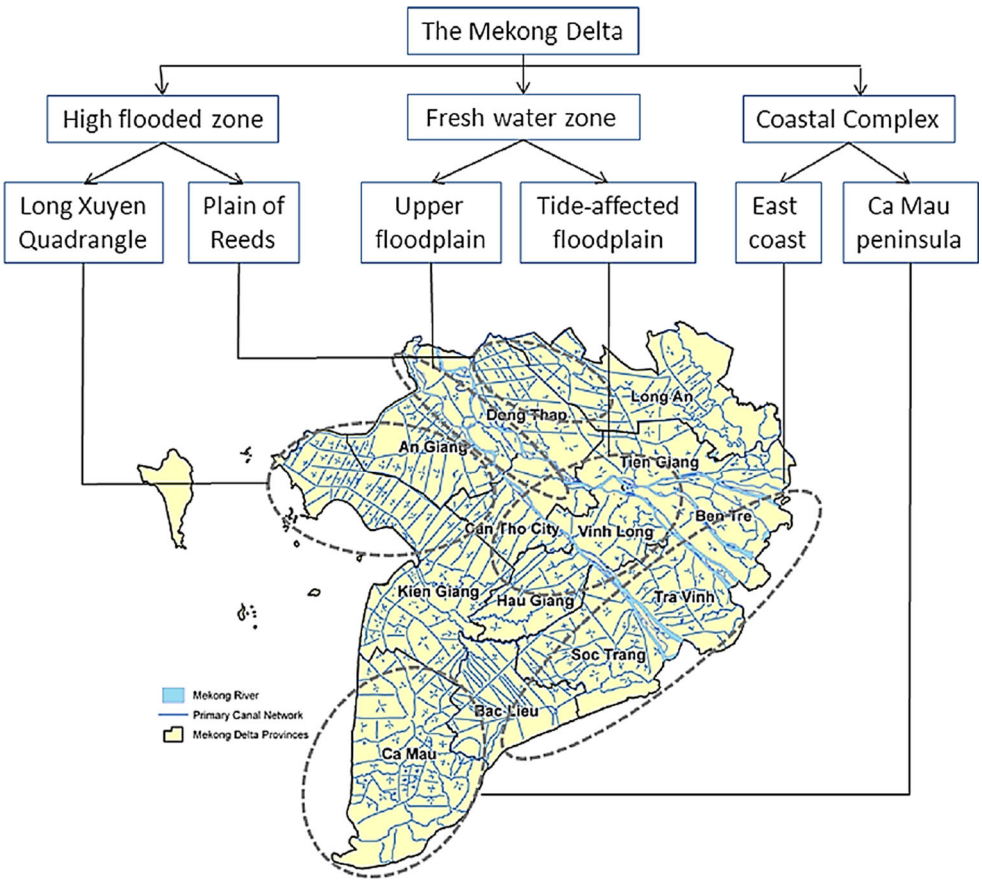

Fig. 1 Map of Mekong Delta with the different wetland ecological zones [*Source*: Vormoor (2010)]

Canals were constructed primarily for transport (Paris 1931). Large-scale canal construction for irrigation and drainage commenced in late nineteenth century by the French and continued until the end of Indochina War in 1975 (Sluiter 1993). A more recent phase of canal construction commenced after 1975, under central government schemes for irrigation and land reclamation for rice production, resulting in more than 10,000 km of major canals (Hashimoto 2001; Miller 2006; Hoa et al. 2007). These canals have dramatically changed the nature of the delta and profoundly altered the basin's hydrology, as excessive drainage of surface water from the wetlands has reduced the period of flooding from 12 to 4–6 months (Ni et al. 2003). Today, the MD is one of the most heavily populated regions of Vietnam, and many areas of former swampy terrain and dense wetland forests (Biggs 2004; Mather 2009) have been transformed into housing and farms (Torell and Salamanca 2003; Smardon 2009). The MD, which was once one of the world's great wetlands, has now become a rice bowl (Käkönen 2008), with only about 1–1.5 % of the wetlands remaining in a natural or seminatural states (Hashimoto 2001; Mather 2010).

Without a detailed understanding of the implications of past decisions, it is difficult to abate the rate of ecological alteration and degradation and find more sustainable solutions. Therefore, understanding the dynamics and drivers of regime change is essential for effective wetland management. According to Finlayson (2014), the Emerging Baselines (EB) concept can be used to describe the ecological character of a wetland as part of a management plan in order to determine the causal processes, drivers of human-modified system or component of the system. The statistical analysis of the different effects of these historical drivers on the baseline will facilitate understanding of the relationships between the natural and human drivers of change and biodiversity.

A history of wetland loss and degradation

Before 1600s–1836: Great March South of Vietnam

The history of wetland loss and degradation in the Mekong Delta can be divided into five historical periods (Fig. 2). The first period was before 1836 when Nguyen Dynasty expanded the frontier to the south. This era can be named "Early delta settlement and southward expansion." Before Nguyen Dynasty, the Vietnamese began to migrate

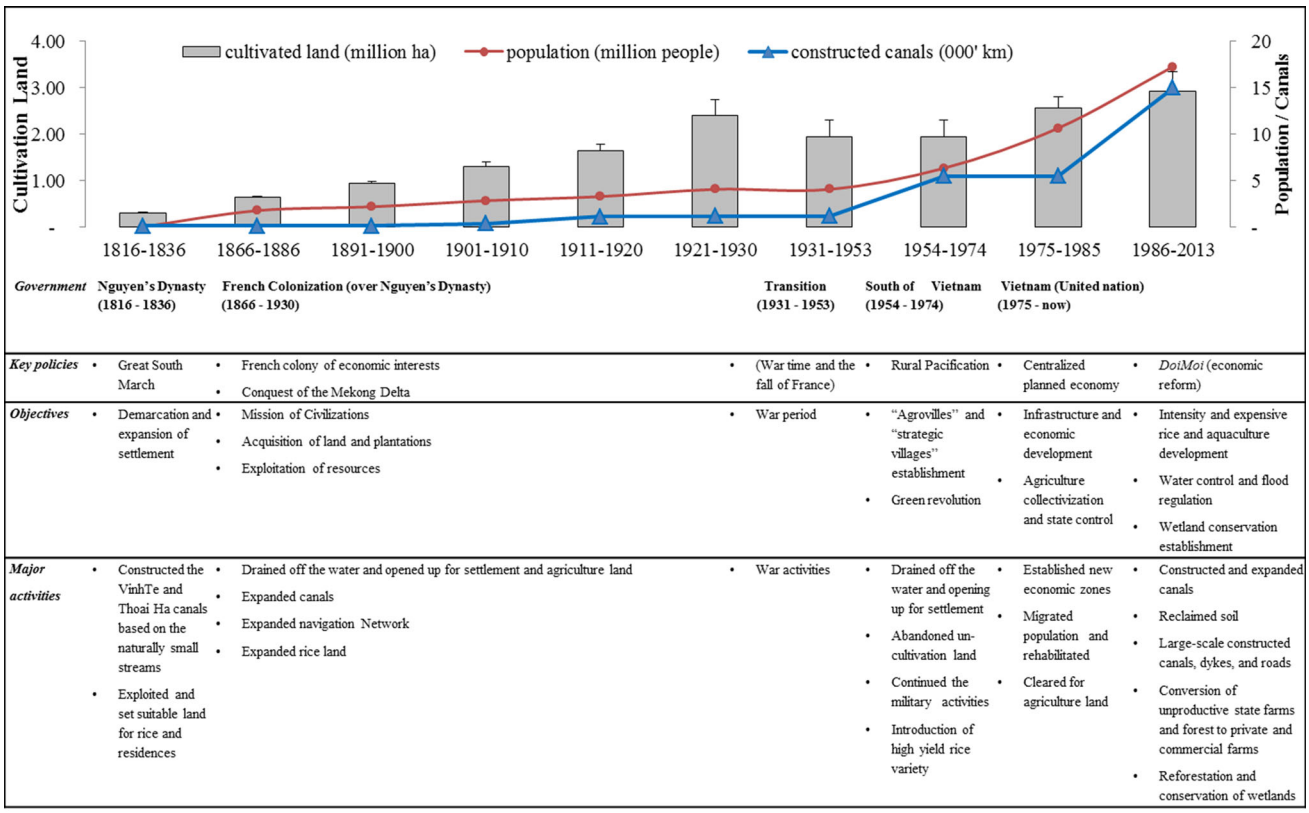

Fig. 2 History line of loss and degradation of the natural primary wetlands in Mekong Delta of Vietnam and the impacts of anthropogenic activities and land use policies [*Sources*: Data collated from Pasquier (1930), Xuan and Matsui (1998), Owada-Shibuya (2003), Vietnam-Netherlands Corporation (2011) and GSO (2014)]

southward out of the Red River Delta (from the North), forcibly occupying territories formerly controlled by the Cham and Khmer kingdoms. Villages were established by these migrants as the military frontier moved southwards down the central coastal plain and into the upper MD (Rambo 1977). In another study, Biggs (2004) suggested that in the 1600s the Vietnamese and Chinese settlers from Bien Hoa migrated to the MD where land was still densely covered by swamps and forests. However, since 1816 the Nguyen Dynasty launched a stronger program with the major policy to demarcate and expand the settlement. This program was strongly amplified within 1816–1836 with two main activities [i.e., firstly, constructed the Vinh Te and Thoai Ha canals based on the naturally small streams that became the border between Vietnam and Cambodia, and secondly exploited and set suitable land for rice and residences (Fig. 2 and Supplementary)]. Consequently, about 130 km of canals and 310,000 ha of rice land were recorded in this early phase (Biggs 2003, 2004). The population of the MD in this stage was not recorded clearly; however, there have been approximately 50,000 people involved in these dredging activities in the early stage of Nguyen Dynasty (Biggs 2004).

1866–1936: French colonization—the era of "la mission civilstrarice"

The second period started from 1866 when the French colonized Vietnam, marking a new epoch of "la mission civilistrarice" or "civilizing mission." Started in the 1860s, a century after the Vietnamese migrants settled in the delta, the French established a colony in southern Vietnam (Biggs 2004; Miller 2006). The French colonists soon declared its "la mission civilstrarice" (Maspero 1929) to control the land (Cleary 2005) to exploit and generate revenue for the colonial power (Barker and Molle 2002). The mission focused on four major activities [i.e., water draining and opening land for settlement and agriculture; expanded canals; expanded navigation networks; and expanded rice production (Fig. 2 and Supplementary)]. Similar to Nguyen Dynasty, the French colonists firstly continued with the construction of a canal network that was used primarily for strategic purposes (Reis 2012) and so began an era of the intensive and extensive drainage (Biggs 2004) aimed at developing agriculture production. The canals rose dramatically after 60 years under the French mission era with the effort of mechanization dredging work to replace

manpower [i.e., the canals length increased from 130 km from the previous stage to about 1790 km at the end of this period (Pasquier 1930) in 1936 (Fig. 2)]. In addition, over 80 % of forests in the west of the delta were cut down and 1.4 million hectares of land were drained (Callison 1983; Brocheux 1995). The combination of the efforts of settlers and mechanization, the total land drained for cultivation promptly increased from 349,000 ha in 1879 to over 2.4 million ha by 1929 (Pasquier 1930; Hickey 1964; Biggs et al. 2009) and dredged 165 million cubic meters in volume of earth (Pasquier 1930), which resulted in irreversible changes to the delta's landscape, ecology, and society (Miller 2003; Biggs 2004; Shannon 2009; de Nijs and Shannon 2010). To fulfill this mission and provide labor for plantations in MD, an average of 73,000 people moved into reside along the new canals per year (from 1881 to 1921) (Biggs 2010). Consequently, this era was likely a frontier boom of migrants making a new Great South March in the late nineteenth and early twentieth centuries (Miller 2006; Biggs 2010). As a result, the population of under 500,000 in 1869 increased to almost 4 million people by 1930 (Rambo 1977; Biggs 2004; Biggs et al. 2009).

The French colonial government launched a primary strategy of development in Mekong Delta that was focused on military and navigation objectives. Within this scheme, agricultural production was largely neglected (Miller 2006). By 1930, after more than 30 years of new waterway construction and opening up of the MD, the colonists realized that the watercourse could be used for both navigation and agricultural cultivation, so the strategy of reshaping the delta shifted toward agricultural industry development. The main focus during this new era was securing substantial increases in rice production through infrastructural development (Cleary 2005) involving a grid of irrigation and drainage canals with large pumping stations and flood gates (Biggs 2005). The dredging was aimed at producing a more rigorous and micromanaged hydraulic system for enhancing intensive agriculture (Biggs 2005; Evers and Benedikter 2009).

The draining of swamp forest, and the alteration of such a large part of the delta, caused significant deterioration of the delta's ecology and had serious repercussions, forcing thousands to abandon their fields and causing social unrest (Biggs 2004). The fall of French colonial regime by 1945 was in-large part a result of these social and environmental incidents. Instead of reshaping the MD landscape and draining the wetland to build an endless horizon of rice, the delta modification project severely destroyed the ecology of the wetlands, and left the delta as treeless horizons of "abandoned lands" (Biggs 2004). The excavation program and infrastructural maintenance works were virtually halted during "Transition stage." The delta's landscape became severity and parts of the delta's degraded land were gradually restored as wetland (Biggs 2004) (Fig. 2).

1931–1953: failure remedy of past waterway construction—the development of scientific casier model

In response to the complex crisis comprised from free fall in rice export prices in 1930, combined with several floods induced an agricultural crisis, the colonial ideas about landscape and agricultural development in the MD were to focus on development of new casier model—an encasement of land and people within a surrounding flood dike. French engineers and scientists adopted the Northern Vietnam traditional agriculture, of which landscapes subdivided into so many cells of dikes and canals. They used the term casier to describe this case-like landform. Tonkinese (the Northern people of Vietnam) immigrants and local workers together had dredged a grid of irrigation canals 13 km by 3 km, with mechanical dredges, maintained with diesel water pumps. In this project, along with dredging new primary grid of irrigation canals, many intersectional canals were dug that divided the delta's landscape in a terrestrial "chessboard" (Biggs 2004, 2010, 2011).

According to Biggs (2010), the dredging contracts of the French colony extended from 1893 to 1951. However, the economic crisis in 1930s along with the escalation of the anticolonial war (1945–1954), undermined the construction of new canals. In 1939, the French engineers abandoned the construction of casiers as military forces fought for control of the territory (Biggs 2011) and there was little maintenance of the network (Shannon and de Nijs 2011). Until being overthrown in 1945, the colonial government carried out just a few small settlement projects in Long Xuyen Quadrangle—the western region of MD (Biggs 2005). The colonial government was soon reformed, and the MD then became a battle ground again. Subsequently, the delta's infrastructure and landscape were severely deteriorated after a long time of no repair (Biggs 2004).

1954–1974: delta-wide development under the American tutelage and war-torn damage

The main policies for the MD in this period focused on "permanent implantation" (Biggs 2010) of people to the rural areas and "Green revolution" for improvement of rice production. At the end of French regime, an immense delta's wetland area was abandoned with a number of incomplete canal excavation projects. To protect the delta from insurgence and a scramble for land, the political priority of the South Vietnamese government was to expand settlements to the more isolated regions of the delta to reclaim wasted land by adopting a *casier*-style resettlement system, similar to that proposed by the French (Biggs 2010). The wetland destruction was enabled through a

variety of legislative and policy instruments. One of these was the establishment of "Agrovilles" or "strategic hamlets" in the "no man's land" abandoned by the French to concentrate on the rural population (Biggs 2004, 2010).

Having failed to develop a systematic understanding of the whole delta, the Americans along with international consultants, conducted a series of scientific studies for further understanding of MD hydrological landscape and biodiversity. In accordance with suggestions from these studies, to sustain the rural livelihood and reinforce the Agroville policy, the Southern government had promoted the Green Revolution as the onset of modernization of agricultural industry with an array of activities of introduction of new technologies, including high-yield varieties of rice, chemical fertilizers and pesticides, mechanized land preparation and portable diesel pumps (Miller 2006; Vormoor 2010). In addition to these changes, by late 1970s, the dredging and draining of the delta were recommenced to control water flow in and out of the delta (Evers and Benedikter 2009). Unfortunately, with the escalation of the war the program was seriously interrupted regardless of its positive contribution to agricultural improvement. In addition, the MD's landscape was dramatically impacted by the Green Revolution and driven by land uses changes and rapid infrastructure development for improvement of agricultural practices (Can et al. 2007) (see further explanation in the fifth stage).

In addition, the war profoundly altered the physical landscape of the MD. When it came to increasingly technical involvement and physical construction of the USA in 1965, the dredging programs drastically expanded through mostly for isolated military base projects and alongside new highways. In 1960s, as the presence of US forces abruptly increased in the southern Vietnam, the MD landscape changed dramatically with the widespread excavation of canals and the construction of airstrips, highways and military camps (Biggs 2004). From 1961, the wetland was also transformed during wartime through the use of chemical defoliants, causing extensive damage to swamp forest and other ecological losses. Of the total 800,000 hectares of wetland in POR, 325,000 hectares of forest was cleared or drained. Furthermore, herbicides and napalm bombings damaged an estimated 4.9 million hectares of forest, of which 124,000 hectares of mangroves and 27,000 hectares of *Melaleuca* forests were lost (HCL 1998; McElwee and Horowitz 1999; Binh et al. 2005).

1975 to the present: closing off the delta after united nation

In the fifth periods, the MD underwent two phases (1975–1985 and from 1986 to present) of reconstruction immediately after the Vietnam war finished, and the economic boom era of agriculture and aquaculture. The Vietnamese government had restructured the agricultural production by applying two major policies in the former stage (i.e., infrastructure and economic development; and agriculture collectivization and state control), with three activities (i.e., establishment of new economic zones; population mobilization and rehabilitation; and clearing land for agriculture), while in the latter stage, three significant policies (i.e., intensity and extensive rice and aquaculture development; water control and flood regulation; and wetland conservation establishment) with three main activities (i.e., construction and expansion of canals; soil reclamation; and large-scale construction of canals, dykes, and roads) were implemented for further exploitation of the lucrative resources of the delta. Subsequently, more than 1 million hectares of wetland was drained and converted to cultivated land during this phase (Fig. 2).

Destruction caused by the war (1954–1975) seriously strained Vietnam's economy. After reunification in 1975, the economy of Vietnam has been plagued by enormous difficulties in production. Worse, the country's critical agricultural infrastructure had been badly damaged. The market economy was completely changed to a socialist-planned economy characterized by agricultural collectivization and state control of commodity production (Beresford 1989; Fforde and de Vylder 1996). Furthermore, from 1976 to 1980, the state policy designated to establish New Economic Zones (NEZs), which covered the MD (Hill 1984). The new settlers were given financial incentives to settle and drain areas for crop production in different regions of the MD that had suffered degradation during wartime and had been excluded from regular agricultural cultivation (Hill 1984; Kono 2001). The collectivization, however, led to food shortage in the whole region in late 1970s (Pingali and Xuan 1992).

The steadily increasing area of land available for agriculture and aquaculture in Vietnam since the introduction of "DoiMoi" policy (*or economic reform*) in 1986 has come from draining (Hill 1984) and converting many of the swampy marshes and forests of the western part of the MD into shrimp ponds (de Graaf and Xuan 1998; Benthem et al. 1999). The delta suffered more anthropogenic damage in the 1980s and early 1990s (Hashimoto 2001; Kono 2001; Le Meur et al. 2005) when large-scale construction projects for draining wetland (Hoa 2008) were undertaken to intensify rice production (Truong and Nguyen 2002; Miller 2006; Le et al. 2007; Binh 2010) and aquaculture (Trung et al. 2006; Nhan et al. 2007; Binh 2010). This development has been in line with the Mekong Delta Development Program proposed in 1968 (Biggs 2004), with the objective being to "close off" the delta to floods and saline water intrusion to make the farming systems less dependent on natural conditions and expand multiple cropping to former

flood-prone and brackish areas, thus reversing the phase of "opening up the delta" (MRCS/WUP-FIN 2007).

The rapid expansion of rice production based on the natural resource exploitation in the fifth stage has made the MD become the "Rice bowl." The MD's extraordinary economic growth had contributed to an exit from a long-term food shortage country in late 1970s and made it become a significant economic region of Vietnam since 1989. Until 2009, the MD produces annually more than 20 million tons of rice, and an approximate of 5 million tons of fish and shrimp for domestic consumption and export (Fabres 2011; Lan 2011). However, the "Rice bowl" was established on the back of the degradation and removal of natural *Melaleuca* swamp and coastal mangrove ecosystems.

During the fifth periods, all canals, agriculture land, and population of MD dramatically increased [i.e., 15,000 km of main canals were constructed (Vietnam-Netherlands Corporation 2011), agriculture land expanded to an estimate of 3 million ha, and population increased to 17.26 million people (Fig. 2)]. This intensification of human activities had negative impacts on the wetlands' environment of the MD when more wetland and natural resource was intentionally drained and diminished.

The drivers of wetland loss

Wetland loss or degradation is the result of the interaction of a wide range of social and economic processes. Frequently cited anthropogenic causes of wetland loss and degradation include wetland drainage and conversion for crop production, aquaculture, conversion for logging, construction of canals, dykes, and dams and urbanization, e.g., (Moser et al. 1998; ME Assessment 2005).

Based on the history line analysis summarized in Fig. 2, and framework for identifying proximate causes and underlying driving forces of wetland conversion proposed by Geist and Lambin (2002) and van Asselen et al. (2013), we identified seven primary variables which closely connected the wetland loss and degradation in the study area [i.e., resettlement and economic development policies; population growth and urbanization; demand for food and reclaiming wetland for agriculture, construction of canals, construction of dykes flood protection systems; expansion of travel systems (waterway and roads); and exploitation of wetland natural resources]. Proximate causes are human activities or immediate actions which directly caused wetland conversion such as expansion of arable land and urban land. Infrastructure construction (e.g., roads, dams, canals, dyke constructions) and reclaiming wetland for agriculture were the other important proximate causes of wetland conversion. Population growth and economic growth were the most important underlying driving forces of wetland conversion. The causal loop diagrams of the natural wetland loss were developed from seven identified variables that presented major relationships (Fig. 3). These variables included the factor that drive the primarily natural swamp *Melaleuca* ecosystem, an endemic wetland of the MD, to be mostly destroyed. Figure 3 shows two different periods that drove the changes of the MD's wetlands [i.e., period before 1975 (Fig. 3a) and period after 1975 (Fig. 3b)].

In the period 1816–1974, six of the identified variables (except the variable construction of dykes flood protection systems) drove wetland loss and degradation (Fig. 3a). The policies of settlement and economic development were the primary indirect (underlying) drivers, while agricultural growth and expansion, the availability of wetlands and their natural resources for exploitation, canal construction and infrastructure development, and other related factors can be categorized as direct (proximate) drivers. Building canals directly impact the wetlands by draining water and clearing forest for agriculture activities. The canal networks facilitated further wetland drainage and population growth. At the beginning stage of exploiting the MD, manpower played a vital role in land conversion, until the period of French colonization, where machines became available for digging and dredging the canals. Thus, primary wetland loss was increased significantly with the mechanization and technological development of canal construction.

The variables in the period after 1975 were the same as the previous period, except that there were two additional variables: "constructed dykes and flood protection systems" and "constructed canals." Theses constructed systems were aimed at regulation of water and the prevention of early floods in depression areas to meet the demand of intensive and extensive rice production. The dyke and canals systems in the coastal areas played a vital role both in prevention of salinity in the water supply for agriculture. In addition to roads, dyke systems also function as inter-province travel systems. Both of the constructions of dykes and flood protection systems became the strong drivers of significant change in the area (Fig. 3b). Furthermore, they enabled further development of travel systems throughout the delta in comparison with early periods. Throughout the MD, canal webs constitute an important trade route connecting the delta to markets and seaports. Due to an increasing population and increasing trade volumes from agriculture, road transportation was gaining importance and increasingly needed. The more the demand for land for infrastructural development, the more wetland was drained and converted to other land use types.

Much work has been done to develop assessment techniques that provide early warning of wetland degradation

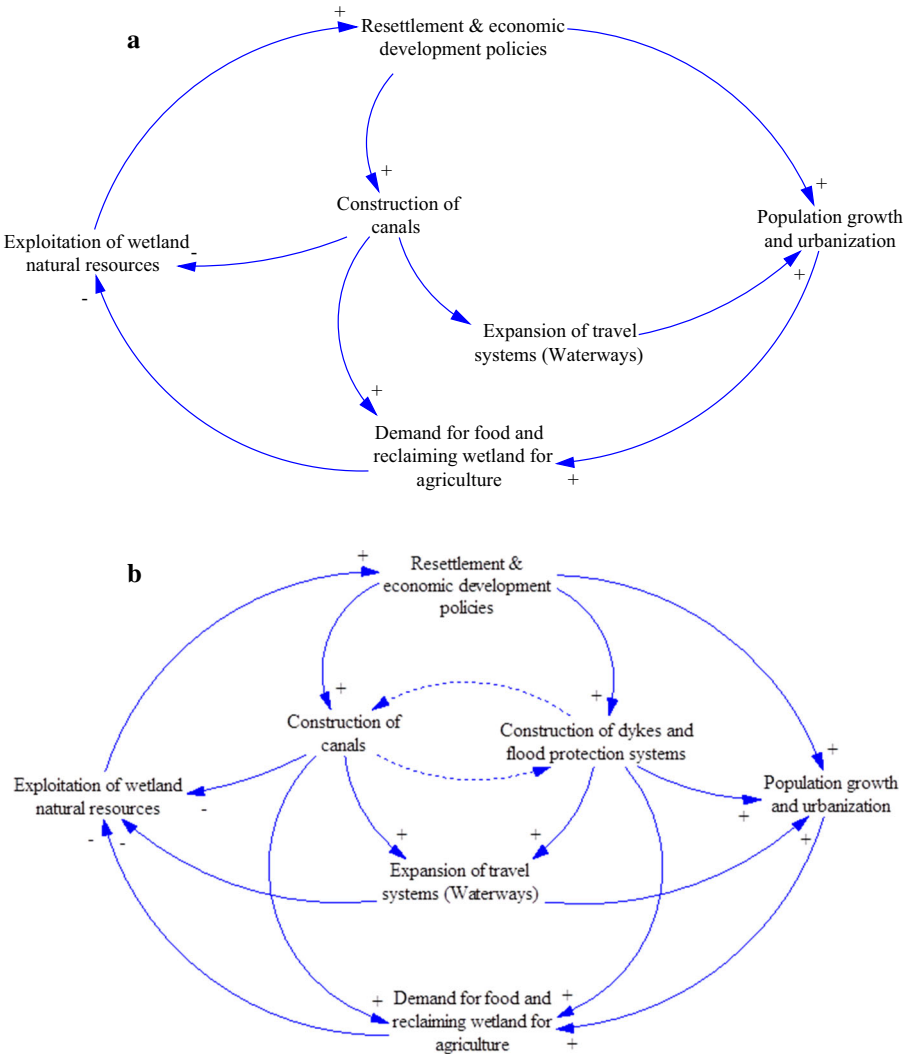

Fig. 3 Causal Loop Diagrams of the factors driving natural wetland ecosystem loss and degradation that transformed the Mekong Delta history between 1816 and 2013 (**a** for the period before 1975, **b** for after 1975)

[i.e., a set of pressures that impact on tropical wetland has been studied and identified (Finlayson and Moser 1992; Whigham et al. 1993; Moser et al. 1996)]. The pressures on wetland loss and degradation can be classified as "proximate" and "primary" drivers. According to Finlayson (2003 p. 15), "Proximate drivers" are various, of which the drivers relate to land use change (i.e., clearance, drainage, and infilling) that are similar to the results of this study. Furthermore, van Asselen et al. (2013) conducted a global meta-analysis of the drivers of wetland loss and postulated that agricultural development was identified as the main proximate cause, and economic growth and population density were the most frequently underlying forces.

To tropical wetlands, the assessment of primary drivers or underlying causes of wetland loss are undermined and insufficient. According to Hollis (1992) and Kotze et al. (1995), the underlying causes are largely socioeconomic and policies. As presented, we argue that the policies were the primary driver led the loss of wetlands in the study area. In addition, an array of primary drivers were identified [i.e., demographic change; economic change (including globalization, trade, market and policy framework), social and political change (including governance, institutional and legal framework), technological change, and lifestyle and behavioral change (Millennium Ecosystem Assessment 2003)]. Furthermore, the causes of wetland loss and degradation need to be considered at two levels [i.e., the drivers that cause a direct loss of wetland and those brought about by external changes beyond the wetland (Moser et al. 1998)].

Ecological transformations and the development of wetland conservation in MD

Early colonial and nineteenth-century Vietnamese records describe the forests as being composed of the flood-tolerant species of cajeput (*Melaleuca cajuputi*) and mangrove (Biggs 2004, 2010). Despite extension of new canals and

expansion of agricultural plantations under the French colonial era in the 1920s, the elimination of vast areas of natural wetland forest by wetland dredging and conversion served as the primary catalyst for environmental change in the Delta's recent past. A reported 2.5 million cubic meters of wood per annum (from 1880 to 1910) was extracted, with approximately five thousand hectares of forest disappearing each year (Biggs 2010). However, the actual destroyed forest areas were probably much larger due to the settlers using fire to clear land when establishing rice plantations and the cutting permits from colonial government for charcoal supplying to steam-powered ships (Biggs 2011).

During the war time (1945–1975), the MD's physical landscape and forests were heavily fragmented and annihilated by artillery and chemical defoliants (Sluiter 1993, p. 148). There are a few studies that have looked at the environmental damage of the Vietnam War in the MD (Egler 1968; Westing 1971). It is estimated that half of the 2500 sq. km of *Melaleuca* swamp forests and 27,000 ha of mangroves were defoliated in the delta during the war. Some of the most heavily sprayed areas were the mangrove forests along the coast the U Minh forest on the Ca Mau peninsula, and the Plain of Reeds area of the upper delta (Thomas 1974).

Before the war, most parts of the broad depression and the plain of reeds (mainly consisting of *Melaleuca* forests and swamp grasslands) were not inhabited and not utilized for agricultural purposes due to their infertile soils and specific hydrologic conditions. However, in recent decades, since the expansion of canals to the solitary coupled with the policy of resettlement, in both regions under the socialization program of agrarian issues, a large number of migrants were mobilized to reclaim these two regions to establish rice-producing farms in both regions (Tanaka 1995). During 1980s, 700,000 ha *Melaleuca* forests in the Plain of Reeds (Shulman 2002) and 10,000 ha of lowland (Tanaka 1995) were converted to rice farms.

Mangrove forests in the MD used to cover more than 250,000 ha (Hong and San 1993). War, forest fire, logging for fuel wood, and other human activities have resulted in the reduction in mangrove forests in the MD. After the war (1975–1983), mangrove forest area was lost due to timber exploitation (207,798 m^3) and charcoal production (23,030 ton) (Hong and San 1993). The expansion of irrigation systems to the coastal area coupled with the growth of shrimp cultivation also resulted in loss of coastal wetland and mangrove forest (Powell et al. 2011; Cosslett and Cosslett 2014). By the late 1990s, mangrove forests were cleared for shrimp farming in many areas (Hong and San 1993; Hong 2004). This clearing occurred against a backdrop of significant social, political, and economic reform, as well as economic development and integration into the global economy. From 1983 and 1995, 5000 ha of mangroves in Kien Giang province were cut each year (Joffre and Schmitt 2010), and approximately 37,500 ha of mangroves in Ngoc Hien district (former of Ca Mau province) were converted to shrimp ponds rice farms (Binh et al. 1997; de Graaf and Xuan 1998). It is estimated that the mangrove forest area in the MD declined from 117,745 to 51,492 ha between 1983 and 1995 (Hong and San 1993; Phuong and Hai 1998).

Prior to 1989, knowledge about wetlands in Vietnam was rather limited. The economic development had come at an environmental cost and the MD had been dealing with growing evidence of wetlands environmental damage and degradation. In the mid-1980s, a policy process was put in motion to address the country's serious environmental problems and rapidly diminishing resource base. The National Conservation Strategy (1985) outlined the nature of the environmental challenge or "crisis" confronting Vietnam. The National Plan for Environment and Sustainable Development (1991–2000) further built on the initiative of the National Conservation Strategy to propose a comprehensive, integrated approach to sustainable development and the actions, policies, legislation, projects/programs and organizational structures, necessary to achieve sustainable development.

The significance of wetlands conservation has long been recognized in Viet Nam—evidence by the countries joining of the Ramsar Convention on Wetlands in 1989. Since then there has been growing recognition of the critical importance of Viet Nam's water-related resources and the role of wetlands in maintaining these. Some external agencies (e.g., WWF, CARE International, and IUCN) are working with the Vietnamese government to encourage a more participatory approach to conservation governance. Since Vietnam became a member of the Ramsar Convention, the number of legal documents on conservation of natural resources and wetlands has increased and the regulatory scheme has become more comprehensive. Although policy and legislation on wetland conservation governance strongly promoted wetland protection and management, and some institutions were established with an array of national wetland conservation strategic planning implementation capabilities under the Ramsar Convention, the management of wetland sites in Vietnam still comes under the remit of many different levels of Government and Ministries. This often leads to a great deal of bureaucracy (Fig. 4), top-down management and conflicting management policies (Torell and Salamanca 2003; Cai et al. 2005).

In the MD, reforestation of *Melaleuca* has been taking place in former unproductive state farms since the late 1980s. This scheme had successfully restored about 7600 ha, consisting of 3000 ha of regenerating *Melaleuca* and swamp grassland (Van Der Schans 2006) in POR to

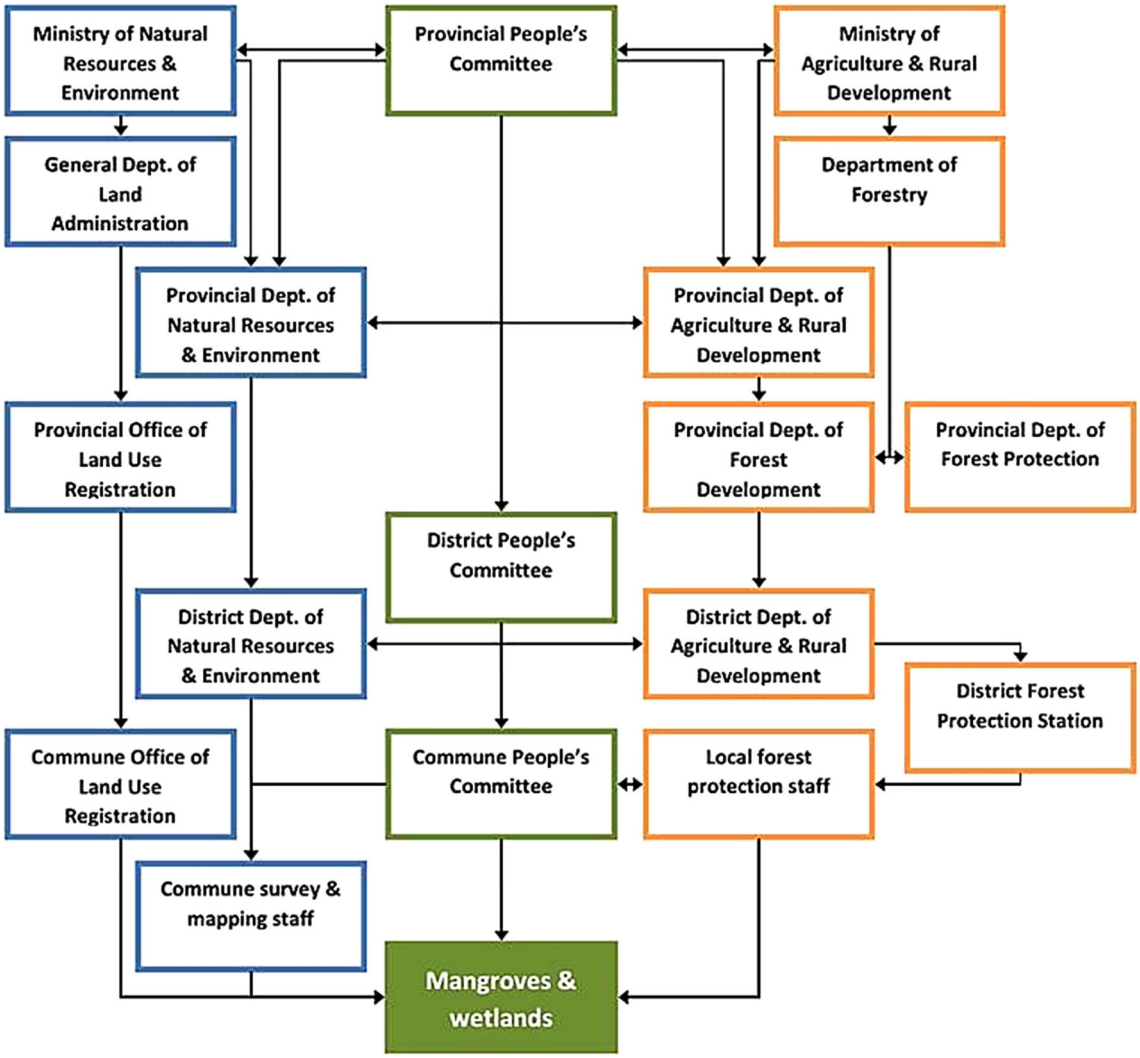

Fig. 4 Redundant and conflicting government institutional structures responsible for mangrove management in Vietnam [*Source*: Hawkins et al. (2010)]

become the Tram Chim National Park (TTCNP) (Nguyen and Wyatt 2006). The first national park was declared in 1998 for the last remaining remnants of freshwater wetland habitat in the MD. Several foreign-funded projects for rehabilitation of mangrove areas were established under the Mekong Delta Master Plan (1993) during the 1990s (Benthem et al. 1999). In the coastal delta, Mui Ca Mau National Park (MCMNP), consisting of 41,862 ha of mangrove forest and shore was established in 2003 which has a core protection of 13,400 ha of mangroves (Sam and Hong 2003; Tinh et al. 2009). Striking example of successful restoration was the case of Can Gio mangrove forest which covered more than 40,000 hectares. The Can Gio ecosystem was almost completely destroyed during the Second Indochina War (1965–1969) by chemical agents and bombing (Ross 1975; Hong and San 1993; Hong 2001, 2004). After the war, the landscape of Can Gio was barren with approximately 10,000 ha of barren, 4500 ha was invasive of palm *Phoenix paludosa* and fern *Acrostichum aureum*—only 5600 ha were cultivable (Nam et al. 2014). In 1978, an extensive reforestation program was undertaken by the Forestry Department. The reforestation program aimed at restoration the mangrove ecosystem previously destroyed by herbicides, establishing mangrove plantations for sustained production of fuel wood, charcoal and poles and improvement in local inhabitants livelihoods (Nam and Sinh 2014). By 1996, nearly 35,000 ha of mangrove forest had been replanted in Can Gio (Tuan 1997); of these, about 20,000 ha are now successfully rehabilitated (Hong and San 1993; Nam and Sinh 2014). The reforestation effort brought vast ecological improvement to the mangrove environment and its associated biodiversity. The forest supplies construction wood, fire wood, fish harvests, crab harvests, clam and oyster harvest,

as well as indirect values such as storm and erosion protection, water filtration, and carbon sequestration. The mangrove forest area of Can Gio Biosphere Reserve has high biodiversity with more than 200 species of fauna and 52 species of flora, which was declared as a World's Biosphere Reserve by the UNESCO on January 21, 2000 (Tuan and Kuenzer 2012).

Conclusions

Over the centuries, infrastructure development has considerably altered and fragmented the natural environment of the MD. Many of the environmental problems resulting from these activities can be considered as a consequence of the failures to recognize the delta as a socioecological system. Recently, Käkönen (2008, p. 205) stated that the "development in the MD of Vietnam has been very dynamic in the recent past, and currently it stands at an interesting crossroads." The historical review presented in this manuscript describes the dynamics of wetland conversion in the MD from the colonial period to recent times (2000s). It provides an overview of how the delta's wetlands were transformed in different periods, and analyzes the driving forces of wetland loss and the underlying causes that derive from the differing policies of political regimes. Five stages with seven variables of MD wetland conversion and degradation were identified and analyzed in detail the linking of anthropogenic process and other socioeconomic impact on wetland loss. Seven variables of MD wetland conversion were identified. The policies of settlement and economic development were the primary indirect (underlying) drivers, while agricultural growth and expansion, the availability of wetlands and their natural resources for exploitation, canal construction and infrastructure development, and others related factor of wetland destroy were categorized as direct (proximate) drivers. Intrinsically, the delta has a complex and dynamic ecology and hydrology. The management of wetlands reflects the socioeconomic drivers at a particular time. The anthropogenic modifications of the landscape compounded escalating risks from floods and saline intrusion throughout the MD. The inconsistent policies of different government regimes over time have greatly complicated the management and conservation of the wetlands as these policies might raise the conflict between different land use actors and activities. Coupled with the pressure from increasing demand of lands for socioeconomic and demographic development, the threats of remaining natural wetland loss in from failures of land reclamation and the effect of climate change are becoming more visual. We now need to take a holistic approach to wetland management in the MD that includes a better understanding of the implications of past decisions on wetland loss.

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