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Wetland Management, Development, and Degradation: A Comparative Study of the South Vietnamese Mekong Delta and the Mozambican Zambezi Delta

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Abstract

As has been made evident by a plethora of research on the environmental histories of territories within the Indian Ocean World (IOW), the exploitation and commodification of natural and human environments that was introduced by European imperialists in the colonial era has contributed significantly to the destabilization of local ecologies. By presenting a comparative analysis of two natural monsoon-based wetlands in the IOW – the Mekong Delta in Southern Vietnam, and the Zambezi Delta of Northern and Central Mozambique – this article contends that imperial strategies of wetland development and models of hydraulics control have contributed significantly to modern and post-modern wetland degradation and unsustainability. It will demonstrate how the replacement of colonial management with that of centralized governmental control within both Vietnam and Mozambique continues to aggravate this environmental crisis due to their respective tendencies to prioritize economic profit over environmental necessities. The destabilization of these natural wetland environments over the past two centuries has contributed to increases in various undesirable consequences: food insecurity, disease, ecological species endangerment, irregularities in rainfall, intense fluctuations of seasonal monsoons and El Niño South Oscillation (ENSO), as well as dangerous vacillations between periods of drought and flooding. As climate change continues to disrupt our natural world, and as local governments continue to favour short-term economic initiatives that disregard environmental repercussions, IOW wetlands and the valuable ecosystems within them risk becoming obsolete.

KEYWORDS: WETLAND ECOSYSTEMS, ENVIRONMENTAL DEGRADATION,
CLIMATE, RAINFALL, DISEASE, COLONIZATION,
EAST AFRICAN HISTORY, SOUTHEAST ASIAN HISTORY

Representing only 6% of the earth's surface, wetlands are among the most valuable, diverse, and productive ecosystems in the natural world.[1] Throughout the Indian Ocean World (IOW),[2] the development, expansion, and subsequent evaporation of several wetland environments rely on seasonal monsoons and precipitation patterns. The annual cycle of monsoons and wetland expansion has become entrenched in the surrounding population's harvests, cultural practices, and traditions. For thousands of years these annually recurring trends enabled the implementation of sophisticated agricultural schedules by native peoples, allowing them to harness their shifting natural environment.

Despite obvious benefits of wetland preservation on human societal development, the appreciation of these productive ecosystems is often forgone in favour of economic biases. Human desire to control wetlands as a means to promote maximum crop yield has resulted in unsustainable tactics of mass draining, irrigation, and other forms of hydraulic infrastructure – actions which have increasingly become detrimental to the preservation of biodiversity and regional sustainability of these often swampy habitats. Strategies of agricultural development that were introduced in the colonial and post-colonial era have gradually shifted the respect for and adaptation to wetland habitat fluctuations into an attempt to distort seasonal monsoon patterns through technological manipulation. Hydraulic infrastructure poses threats of endangerment to thousands of unique botanical and animal species throughout the IOW wetland environment; threats which increase along with environmental unpredictability associated with climate change.

European models of wetland development and hydraulics, and their general lack of understanding of monsoon-based traditional agriculture, have ultimately resulted in mass wetland

[1] Robert Costanza et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature*, 387 (Solomons, MA: University of Maryland; Center for Environmental and Estuarine Studies, Zoology Department and Institute for Ecological Economics, 1997), 256.
[2] IOW: term referring to regions within African, Asian, and Australian continents that are impacted by annual monsoonal patterns.

degradation throughout the previously colonized IOW. Thus, solutions implemented based on Western initiatives to mitigate impacts of seasonal variations of precipitation throughout the colonial era ultimately had negative consequences for local ecosystems. Through the comparative analysis of two natural monsoon-based wetlands in the IOW –namely the Mekong Delta, and the Zambezi Delta – this essay will discuss the extent to which wetland development models and hydraulics control, either enacted or inspired by Western strategies, have contributed to wetland degradation. This essay argues that while European models of development were alien to the realities of monsoon-based agriculture of native populations, and were largely implemented as a means of maximizing commodity production with lucrative ends, the centralized control that has replaced Europeans throughout the post-colonial era has had a similar effect on ecological degradation.

This paper develops the aforementioned argument by first providing regional and climatic context to both the Mekong and the Zambezi Delta's. Second, it presents a historical review of regional instabilities and the mechanism of imperial control and development in both regions. Next it reviews the environmental consequences affecting both regions by examining the agricultural, social, and ecological impacts of these strategies. Finally, it demonstrates future environmental developments which are likely to hinder both regions as the negative effects of climate change become increasingly evident within Delta ecosystems.

Geographical Context: Continental Southeast Asia's Mekong River and Southern East Africa's Zambezi River

Geography and Monsoons in the Mekong River

The Mekong River runs 4,200 kilometres from the Plateau of Tibet to the South China Sea. Carrying an average of 475 cubic kilometers of water per year – this massive river meanders through continental South East Asia. From the highlands of Tibet, the Mekong river flows through the Yunnan Province

in China, the border regions of Myanmar, and thereafter enters Thailand, Laos, Cambodia, and Vietnam. Prior to entering Southern Vietnam, the river divides into nine low-lying distributary channels known as the "Mekong Delta."[3] Measuring approximately 200 km, the Mekong Delta (MD) is one of the largest delta systems in the world. It covers 49.5 thousand km of territory – of which 74 % is located in Vietnam, the remaining 26% in Cambodia.[4]

The entire Mekong River basin is dominated by two monsoons: the North East and the South West. The South West Monsoon produces the rainy seasons between June and November and is characterized by heavy and frequent precipitation, high humidity, peak cloud coverage, tropical temperatures, as well as river flooding and increased river flows.[5] By contrast, the dry seasons brought forth by the North East Monsoon between December and May, produces little precipitation and lower humidity.[6]

The dry season is often accompanied by saline intrusion in the coastal regions.[7] Saline intrusion, or salinity, refers to the build-up of salt in soil, eventually resulting in salt levels that are toxic to plants. At the point of intersection between the Mekong Delta and the South China Sea, there is an intermingling of the river's freshwaters with the salty sea water.[8] During the dry season in particular, salt water is able to creep up on Mekong Delta rivers and tributaries, often encroaching as much as 70 to 80 kilometers inland.[9] Sea water is thereafter absorbed by plants and groundwater of the region (saline intrusion), impacting both ecosystems and aqua systems alike.

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[3] Pamela McElwee and Michael M. Horowitz, *Environment and Society in the Lower Mekong Basin: A Landscaping Review* (New York, USA: Institute for Development Anthropology, 1999), 10.
[4] Hoang Huu Nguyen et al., "A review of the drivers of the 200 years of wetland degradation in the Mekong Delta of Vietnam," *Regional Environmental Change* 16, 8 (2016), 2303.
[5] McElwee and Horowitz, *Environment and Society*, 19.
[6] Ibid.
[7] Mira Käkönen, "Mekong Delta at the Crossroads: More Control or Adaptation?," *Ambio*, 37, 3 (2003), 206
[8] McElwee and Horowitz, *Environment and Society*, 27.
[9] Ibid.

Societies residing in the Mekong Delta incorporate the river into every aspect of life. The Mekong River has been manipulated as a service of transportation, communication, and food production, and also serves every day uses which even includes drinking water.[10] Comprising 12% of the national area, the Delta is home to of 22% of the national population –approximately 16.365 million people – 82.5% of whom reside in rural areas (c.2016).[11] The Delta comprises generally fertile and alluvial soils, which play an important role in agricultural and aqua-cultural production in Vietnam.[12] But large scale canal and dike construction over the past two centuries have dramatically changed the basins. More recently, these projects have made the Mekong Delta one of the most populated regions in Vietnam, increasing communication, commercial trade, and tourism, as well as creating a 'rice bowl.' The Mekong Delta produces over 50% of the nation's rice yield, contributing over 30% of national GDP circa 2016.[13] However, the exploitation of the Delta region has changed natural hydrological, ecological, and morphological processes– contributing greatly to wetland degradation in the Delta.[14]

Geography and Monsoons in the Zambezi Delta:

Similar to the Mekong River, the Zambezi River is also recognized for its multi-national presence and productive capacity. As the fourth longest river in Africa, the Zambezi River and its tributaries flow through parts of Zambia, Angola, Namibia, Botswana, Zimbabwe, Tanzania, Malawi, and Mozambique - where it empties into the Indian Ocean via seven tributaries that make up the Zambezi Delta sub basin.[15] Measuring approximately 2,575 km from its Zambia highland source to the Coastal

[10] Käkönen, "Mekong Delta at the Crossroads," 205.
[11] Nguyen et al., "A review of the drivers," 2306.
[12] Ibid., 2303.
[13] Ibid.
[14] Ibid.
[15] Jonathan Lautze et al., eds. *The Zambezi River Basin: Water and Sustainable Development* (New York: Routledge Publishing, 2017), i.

Delta in Mozambique, the total area of the river basin is inhabited by approximately 40 million people, representing 1/3 of the total population of the river's eight riparian countries.[16] A unique and often underemphasized feature of the Zambezi River is that it traverses some of the world's least developed countries throughout the entirety of its length. Thus, its highly variable climate has frequently led to devastating cycles of floods and droughts that have crippled societies and economies throughout the region.[17]

The Zambezi River Basin experiences an intercontinental tropical climate that is controlled primarily by the movement of the Inter-Tropical Convergence Zone (ITCZ). Defined as a belt of low pressure which circles the earth near the equator, the ITCZ acts as an axis between highly pressurized winds in the Northern and Southern Hemisphere.[18] This clash of winds often generates vigorous thunderstorms over large landlocked areas, drastically affecting rainfall during wet seasons between October and April.[19] Meanwhile, the dry season, spanning the period between May and September, remains relatively stable, although its minimal precipitation is often a risk for drought and forest fires.

Droughts in Southern Africa are most correlated with warm phases of El Niño South Oscillation (ENSO). Defined as a routine climate pattern occurring when Pacific Ocean surface temperatures rise above normal levels for an extended period of time, ENSO results in a brief period of warming around the world and shifts weather patterns spanning global continents. [20] ENSO's impact on Zambezi riparian countries can have devastating effects. Most communities residing along the river depend on Zambezi water sources for drinking, bathing, agriculture, and other basic needs of domestic

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[16] Xueliang Cai et al., "Availability and Use of Water Resources," in *The Zambezi River Basin*, eds. Lautze et al., 7
[17] Ibid., 2.
[18] Sharon E. Nicholson, "The ITCZ and the Seasonal Cycle over Equatorial Africa," *American Meteroroological Society* (2017), 337.
[19] Cai, "Availability and Use of Water Resources," 10.
[20] Kevin Byrne, "What is El Niño," AccuWeather Inc. (2019). [Accessed on December 9, 2019]. https://www.accuweather.com/en/weather-news/what-is-el-nino/70005474

life. Thus, droughts eliminate relatively safe water supplies, often pushing native communities towards stagnant pools ripe with illness and disease.

The Lower Zambezi, or the Zambezi Delta, located in the low coastal lands of Mozambique, commences 145 km from the coast and spans 230 kilometers of the Mozambican coastline.[21] The Zambezi Delta, consisting largely of low-lying swampy depressions and wetlands, was once rich with alluvial soils which contributed to relative regional agricultural success for decades. The predominant vegetation of the region is a mixture of woodlands, savannah, grasslands, mangrove forest, and coastal dunes.[22] However, as will be discussed in the following sections – colonial models of development have significantly hindered regional fertility.

Historical Review of Wetland Development: Western Influence, Wetland Management, and Instability

Mekong Delta Society: Wetland Development Schemes and Management

Human attempts at wetland accommodation and control throughout the Mekong Delta were a slow historical process. From the beginning, the extent of ecological development in the region was focused on increasing rice yields. According to Vietnamese legend, rice was a gift from the gods who had taken pity on the misery of men.[23] During the 10th century Great March South,[24] land shortages and overpopulation in the Red River Delta – the Vietnamese territory's previous metropolis of rice

[21] Paul Przyborski, "Zambezi River Delta," EOS Project Science Office, NASA (Winter 2013). [Accessed on December 10, 2019]. https://earthobservatory.nasa.gov/images/82361/zambezi-river-delta
[22] Aurélie C. Shapiro et. al., "The Mangroves of the Zambezi Delta: Increase in Extent Observed via Sattelite from 1994 to 2013." *Remote Sensing Journal, MDPI,* (2015), 16505.
[23] Thimothee Janssen, dir., *Inside Rice: A grain of culture* (New York, NY: Filmakers Library, 2006).
[24] During the Great March South, Vietnamese and Chinese peoples residing around the Red River Delta began to migrate southwards, occupying territories controlled by the Cham and Khmer Kingdoms. According to the research of Dr. David A. Biggs of the University of California, the Mekong Delta region itself was not occupied until the 1600s when Chinese and Vietnamese settlers from the surrounding area of Bien Hao, near current day Ho Chi Minh City, migrated and began to develop the Mekong Delta (Nguyen, 2016. pp. 2304-2305)

production – resulted in the southward migration of Vietnamese masses towards the productive plains of the Mekong Delta.[25] The Vietnamese thereafter began comparing their country to a yoke of production – represented by a man carrying a bamboo stick with a basket of rice on each side. One basket signifies the Red River Delta in the North, the other the Mekong Delta in the South. [26] Thus, it became the man's responsibility to support the rice of both Deltas, and develop those Deltas by all means necessary.

In 1816, the Nguyen Dynasty launched central policy programs to expand Delta settlements and reclaim land. At the time, the Mekong Delta consisted of 130km of canals, 3100 km^2 of rice land, and contained approximately 50,000 Vietnamese settlers. Those statistics increased exponentially with the arrival of French settlers around 1866 – marking the commencement of la mission *civilisatrice*.[27] The French restructured swamps and marshes in the Mekong Delta, establishing a system of control and taxation of local peoples and resources.[28] After Vietnam's official recognition as a French colony in 1886, the French shifted their approach towards more economic objectives of water management – employing blueprints for drainage and irrigation to support the construction of a mono-cultural area of rice cultivation in the Delta.[29] To manage newly created plantations and maintain production levels, approximately 73,000 people were forced to relocate to the South each year between 1881 and 1921.[30] Thus, the Mekong Delta population increased from less than 500,000 people at the beginning of French rule in 1869, to nearly 4 million people by 1930.[31]

[25] Vietnamese forcibly occupied Mekong Delta territories. These territories were previously controlled by the Cham and Khmer kingdoms. (Käkönen, "Mekong Delta at the Crossroads," 206).
[26] Ibid.
[27] Nguyen et al., "A review of the drivers," 2305.
[28] Käkönen, "Mekong Delta at the Crossroads," 206.
[29] Ibid.
[30] Nguyen et al., "A review of the drivers," 2306.
[31] Ibid.

The French focused on four major activities to tame the delta: water drainage and open land creation for settlement and agriculture, the expansion of canal networks; the expansion of navigation networks; and the expansion of rice production.[32] However, by the 1930s , the draining of swamp forests and digging of canals had caused significant deterioration in the ecology of the Delta, forcing thousands to abandon their rice fields and spurring mass social unrest as a consequence of overcrowding and overexploitation of the remaining fertile areas. French economic biases in the Delta modification project were readily apparent to the Vietnamese population. The Vietnamese witnessed their social and national needs being neglected by their French government in favour of global demand for rice. Despite the region's recognition as a major source for global rice exports, Vietnamese people struggled to feed themselves, resulting in social and political polarization and conflict.[33]

French mishandling of the Delta contributed to the Vietnamese famine of 1944-1945 – during which approximately 2 million Vietnamese people starved to death. Having collaborated with the Japanese Axis government during the Second World War (WWII), Vichy France hoarded Vietnamese rice intended for shipment to Japan – neglecting the starving constituents of their Vietnamese colonial holding. Ruthless harvest schedules resulted in the mass destruction of wetlands spanning the colonial state, leaving vast areas of the Mekong Delta temporarily abandoned and barren.[34] The fall of the French colonial regime was in a large part due to these social and environmental predicaments.[35] Despite attempts to maintain control through new ecological strategies that emerged during the late 1940s and early 1950s – the French found themselves unable to prioritize the development of Mekong Delta when confronted with the mass social unrest under which the Vietnamese population rejected French authority, culminating with the Indochina War.

[32] Nguyen et al., "A review of the drivers," 2306.
[33] Käkönen, "Mekong Delta at the Crossroads," 206.
[34] Nguyen et al., "A review of the drivers," 2305.
[35] Ibid., 2306.

By 1954, with Cold War politics already heavily entrenched into the Vietnamese political realm, the U.S. government entered South Vietnam as the region's advisors to achieve democracy – a political pursuit that was accompanied by the promise to tame the tumultuous social and environmental conditions present in the Mekong River basin. While 1957 establishment of the Mekong Committee[36] (MC) provided the Delta with the allusion of regional security, the newly established South Vietnamese government, the Republic of Vietnam (RVN), focused on internal development. The Mekong Delta Development Plan (MDDP) was inaugurated as a U.S.-South Vietnamese initiative which promoted agricultural development through water control infrastructure.[37] Based on the irrigation plans of the 1933 Tennessee Valley Authority,[38] the MDDP addressed the major inhibitors to crop yields such as flooding and salinity intrusion. The plans ensured the construction of seasonal dams to control water extremes throughout the Delta, permitting the installation of rice farming systems which remained independent from seasonal conditions, and thus were capable of yielding double or triple harvests per year. Ultimately, the MDDP had the hopeful intention of feeding, employing, and pacifying the Mekong Delta population, dissuading them from insurgency attempts against the government in Cold War Vietnam.[39]

The plans inaugurated in the 1960s under the MDDP, although not fully realized due to mass regional conflict of the US- Vietnam war, have served as a baseline for agricultural intervention used

[36] Mekong Committee: Composed of four riparian states – Cambodia, Laos, Thailand, and South Vietnam – was inaugurated to ensure cooperation between these four non-communist states with regards to Mekong development plans and strategies against the spread of the communist ideology (Tuyet L. Cosslett and Patrick D. Cosslett, "The Mekong Committee 1957-1975," *Water Resources and Food Security in the Vietnam Mekong Delta*, Natural Resource Management and Policy 44, (2013)).
[37] Käkönen, "Mekong Delta at the Crossroads," 206.
[38] Tennessee Valley Authority (TVA): A New Deal program established in 1933 which provided jobs and electricity to the rural Tennessee River Valley spanning seven states in the south. Improved the navigability of the Tennessee river through flood control; the reforestation of marginal lands, taught farmers new techniques to better maintain their crops and increase annual harvests; and constructed energy minded industries, to help stimulate industrial production in the region (Source: Franklyn D. Roosevelt Presidential Library and Museum, "Great Depression Facts," *Franklyn D. Roosevelt Presidential Library and Museum,* (2016). [Accessed on December 11, 2019]. https://www.fdrlibrary.org/great-depression-facts)
[39] Käkönen, "Mekong Delta at the Crossroads," 206.

in Vietnam until today. War in Vietnam, extending between 1945 and 1975, brought significant changes to the Mekong Delta's physical landscape and forests. The increase of US forces led to the widespread excavation of canals, the construction of airstrips, highways, and military camps throughout the Delta.[40] Although little research has been conducted on the extent to which the Vietnam war damaged the environment in the Mekong Delta, we do know that the American war destroyed an estimated 22,000 square kilometers of forests and farmlands through use of herbicides and napalm bombings.[41] In addition to mass ecological destruction, chemical defoliants have also impacted the human population in Vietnam; for example the remnants of Agent Orange[42] still impact 15,000 fourth generation Vietnamese despite its dispersal in the 1960s. The population of the Mekong Delta was and remains the people most vulnerable to this chemical exposure, and their environment continues to suffer.

The post-war era in Vietnam was characterized by reunification and reconstruction. The market economy in the south was transformed into a socialist-planned economy based on agricultural collectivization and state control over commodity production.[43] Between 1976 and 1980, a five-year plan known as The New Economic Zones (NEZ) was instituted by the government. It promoted infrastructural and economic development, and provided settlers with financial incentives to settle and drain areas effected by wartime degradation to stimulate crop production.[44] However, prohibiting private trade decreased access to agricultural technology and reduced rice yields. Collectivization led to food shortages by the late 1970s.

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[40] Nguyen et al., "A review of the drivers," 2307.
[41] McElwee and Horowitz, *Environment and Society*, 53.
[42] Agent Orange: A colloquially named and highly toxic chemical herbicide and defoliant which was dispelled from U.S. fighter plains between 1961 and 1971 to destroy the tree top camouflage that Viet Cong guerilla relied upon for congealment throughout the Mekong Delta and Vietnamese Central Highlands.
[43] Nguyen et al., "A review of the drivers," 2307.
[44] Ibid.

After the 1979 food shortage, a rice priority policy was implemented throughout Vietnam. With the 1986 entry of Nguyen Van Linh into leadership, a more liberal policy/reform of land known as "Doi Moi" was imposed. The introduction of Doi Moi encouraged further drainage initiatives to intensify rice production, and converted many swampy marshes and forests into shrimp ponds.[45] Large scale construction was rooted in the objective of 'closing off' the Delta from floods and saline intrusion, and thereafter completing the process of rendering the Delta independent of changes to natural conditions as was commenced in the 1950s.

Zambezi Delta: Wetland Development Schemes, Management, and Portuguese Control

Unlike the Mekong Delta, the Zambezi Delta had not developed according to native strategies of development prior to the introduction of market economies. Prior to the 12th century, the Zambezi Delta had been sparsely populated. The Delta's geographic location, dividing Mozambique almost exactly in half, had initially been inhabited by fragments of various political groups with vastly disparate languages and cultures.[46] Its land usage consisted of hunting, fishing, and agriculture for local consumption.[47] Between the 12th and 14th centuries, Indian Ocean trade increased demand for products from the regions of the Upper Zambezi, such as gold, ivory, and leopard skins. By the 16th century Portuguese arrival, trade routes into the Mozambican interior were already well established, providing the Portuguese with access to the inner African communities which would soon supply the trans-Atlantic slave trade.

[45] Nguyen et al., "A review of the drivers," 2307.
[46] Newitt, M.D.D., "The Portuguese on the Zambezi: A Historical Interpretation of the Prazo System," *The Journal of African History* 10, 1, (1969), 67.
[47] Richard Beilfuss et al, "Land Cover and Land Use Change in Zambezi Delta," *Zambezi Basin Wetlands Volume. III. Land Use Change and Human Impacts* (Research Gate Publications, 2000), 34.

The ultimate Portuguese acquiesce of control over the Zambezi Delta region began with their annexation of the region in 1629.[48] To maintain control, the Portuguese established a *prazo* system, whereby African settlements along the banks of the Zambezi were placed under the supervision of a Portuguese governor. Developing into a system similar to that of the notorious plantation system in the Americas, the *prazo* system ultimately represents the origins of Portuguese social and political influence over African communities.[49] Towards the end of the 19th century, as the Delta population reached 100,000, cash crops replaced ivory and slaves as the region's principal exports.[50] After losing business ventures to other European colonial powers throughout central East Africa, the Portuguese began centralizing their business endeavours into their colonial holds in Angola and Mozambique.

The Portuguese resorted to cash crop development to bolster its struggling colonial economies. The Portuguese Trading Company at Mopeia established the first opium cultivating plant in the Zambezi Delta in 1870. By 1893, the establishment of the region's first sugar processing plant was established by the soon to be Sena Sugar Estates (circa 1920).[51] Cotton was introduced as a cash crop in 1926, and rice by 1941. At the height of production, regional cultivation represented 346,000 hectares (ha) of the Zambezi Delta wetlands, with the Sena Sugar Estates and other Portuguese owned companies allocating 85% to commercial livestock and cash crop growth.[52] The expansion of Portuguese commercial cash-crop farms resulted in the expulsion of native landowners throughout the delta, pushing native Africans into marginal and barren lands and increasing food insecurity throughout African communities. Between 1930 and the 1970s, native cultivatable land in the Zambezi Delta decreased from 15 ha per family to less than 1 ha.[53]

[48] Newitt, "The Portuguese on the Zambezi," 71.
[49] Ibid, 67.
[50] Beilfuss et al, "Land Cover and Land Use Change," 35.
[51] Ibid.
[52] Ibid, 35.
[53] Ibid.

The end of the WWII was accompanied by the expansion of colonial hydroelectric generation.[54] The looming European energy shortage refocused imperial attention on the manufacturing potential of overseas colonies. These pressures spurred mass hydraulic engineering efforts throughout African colonies. Despite the construction of protective dikes throughout the Zambezi river in the 1920s to reduce widespread flooding of the sugar estates near the Morromeu plantations [55] – initially set at sea level but increased several times after experiencing overflow from floods in 1939, 1940, 1952, 1958, and 1978, respectively (c.2000) [56] – the emphasis of water-manipulation development during the post-war era made previous hydraulic control efforts throughout the Zambezi Delta appear minimal. The sudden dependence on African colonies as a means of bolstering European reconstruction introduced hydraulic development at an unprecedented level throughout the southern half of the continent.

Following a 1949 conference in Johannesburg regarding damming projects along the international Zambezi river, the 1950 Technical Conference on the Development of the Zambezi River culminated with a shared document by Portuguese and British developers regarding water flow management of their respective colonies.[57] The New African Model, akin to American development in the Mekong Delta, was inspired by the development blueprints formulated for the Tennessee Valley Authority; with complete disregard for the divergent landscape and farming techniques of the Zambezi River Delta.

The Zambezi's Kariba Dam (*Figure 1*), located between current day Zimbabwe and Zambia, began controlling hydraulics on the Zambezi River in 1959.[58] Due to the significance of dams as

[54] Kate B. Showers, "Electrifying Africa: An environmental history with policy implications," Geografiska Anneler: Series B, *Human Geography*, 93, 3 (2016), 199.
[55] Beilfuss et al, "Land Cover and Land Use Change," 35.
[56] Ibid pp. 36
[57] Showers, "Electrifying Africa," 199.
[58] Ibid., 199

symbols of state power, large dam construction became pursued by European colonizers across the African continent in an attempt to overpower growing nationalist sentiment among native communities. In addition to creating the largest man made lake in the world (Lake Kariba), the Kariba Dam's water pathways enabled the connection of remote and undeveloped rural sites to urban environments and mines over 500 km away from each other.[59] Further, the dam controlled 50% of the Zambezi runoff into Mozambique.[60] The construction of the Kariba Dam marked the beginning of an era of large scale African hydroelectric development, and reinvigorated colonial endeavors in river basin planning, irrigation, and flood control.[61]

By December 1974, the Portuguese established the Cahora Bassa Dam (*Figure 1*) in Mozambique. The dam was financed by the British after Portuguese consignment to supply the majority of the Dam's electricity to Apartheid South Africa.[62] The construction of the dam hoped to fulfill Portuguese desires to: a) have more influence over flood control, river navigation, and hydropower generation on the Zambezi; b) to establish a navigable channel for trans shipments by deepening existing channels; c) to enlarge the region's agricultural schemes in tributary basins and alluvial plains; and d) to further develop Mozambican mining industries.[63] However, soon after the dam's completion, Mozambique declared independence from the Portuguese, and the significance of the dam as an emblem of Portuguese colonial power collapsed.

After independence, farmers, managers, and technical personnel hired by the Portuguese emigrated from the region, resulting in the subsequent decay of machinery, buildings, plantations, and the loss of massive capital investment.[64] In March 1978, a mass flood claimed the lives of forty-five

[59] Showers, "Electrifying Africa," 199.
[60] Beilfuss et al, "Land Cover and Land Use Change," 36.
[61] Showers, "Electrifying Africa," 199-200.
[62] Ibid. 199
[63] Beilfuss et al, "Land Cover and Land Use Change," 36.
[64] Ibid.

Africans, causing $62 million USD in damage and requiring $40 million USD in aid.[65] The flood displaced 75,000 people, destroyed 18,000 ha of cropland, and resulted in the migration of flood victims into communal state farms, where they subsequently suffered from impoverished conditions, disease, and famine. By the 1980s, Mozambique's civil war was terrorizing delta communities and devastating the natural environment with landmines and poaching raids.

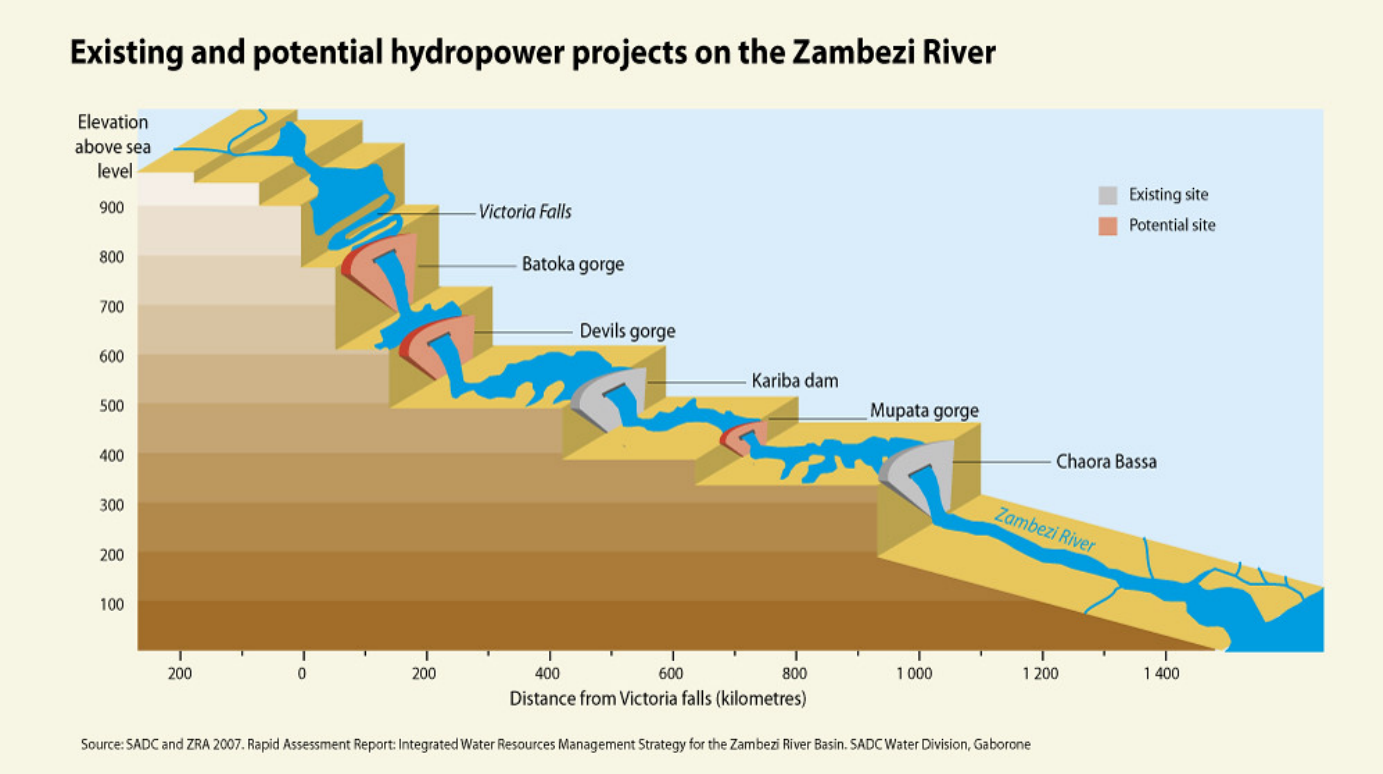

Figure 1: Existing and Potential Hydropower Projects on the Zambezi River
(Source: SADC and ZRA 2007. Rapid Assessment Report: Integrated Water Resources Management Strategy for the Zambezi River Basin. SADC Water Division, Gaborone)[66]

Regardless of the socio-eco-political turbulence of post-independent Mozambique, the Portuguese, imitating their fellow European colonists, maintained domination over the country's largest and most lucrative industries. Thus, the Portuguese indirectly controlled the Mozambican

[65] Ibid.
[66] Accessed on December 11, 2019. https://www.flickr.com/photos/gridarendal/32363493375/in/photostream/

economy, ruling through neo-colonial and neo-imperial tactics and implementing an economic environment of corruption and intimidation upon the new Mozambican government. The Portuguese government's domination over Mozambique's Hydroelectric Generation Station (HCB)— the industry owning and managing the Cahora Bassa Dam – allowed the Portuguese to delegate flood patterns throughout the Zambezi Delta according to the economic interests and energy requirements of the Portuguese and South Africans, without warning or concern for local communities and environments in the Delta below.

Consequences of Mekong Delta Development Strategies:

The manipulation of Mekong Delta wetlands and the rejection of monsoonal patterns for harvests were vital in the creation of the region's 'Rice Bowl.' While the implemented systems have functioned to the advantage of Mekong Delta communities, there are certain risks and consequences that have accompanied the expedited development of the regional environment. The unintended benefits and disadvantages of flood control systems, hydrolysis, and irrigation are explained in the following section.

Flood Control: The Increase of Financial and Food Insecurity Among Poor Delta Dwellers

Flood-control systems such as embankments, high dikes, and sluice gates were constructed primarily between 1997 and 2000 – resulting in the total cultivation capability of three rice harvests per year in over 40% of the province as opposed to the general two harvest system.[67] Mechanisms of water control has also significantly reduced the damage caused by floods to Delta society. Vietnamese officials argue that flood management has upgraded livelihoods and improved working conditions throughout the

[67] Nguyen et al., "A review of the drivers," 2307.

Delta. Further, because of increased demand for agricultural services prevalent during both wet and dry season, employment rates have also increased.[68] However, studies have demonstrated that after a few years, the total yield of the three crop system within diked areas is less than the yield from two crop systems outside due to the reduction of soil fertility.[69] Soil fertility reduction is managed by the increased use of agrochemicals which damages the environment and contributes to the degradation of water quality. Moreover, flood management systems lead to the suffering of poor farmers who had previously benefited from the 'free sediment' residue left over from seasons of flooding. The lack of sediment leads farmers to invest further in agrochemicals, contributing once again to water degradation and further reducing economic sustainability of agriculture among the poor. Poorer peoples residing within the Delta also used to benefit from fishing in flooded fields prior to the imposition of dikes, an activity that had provided some easily accessible food or commercial goods.[70]

Dike-surrounded Vietnamese society has become generally accustomed to their newly controlled environment. However, the impression of complete flood security among the Vietnamese has led to the development of infrastructure that lacks resilience to water damage. The event of unexpected massive flood would incur greater risks and greater losses throughout Mekong Delta communities – floods which are becoming more likely as climate change continues to destabilize weather patterns. In addition, the increased flow velocity created by protection structures leads to bank erosion that destroys streamside vegetation and riverside communal infrastructure.[71]

[68] Ibid., 2307.
[69] Ibid.
[70] Ibid.
[71] Ibid.

Hydrolysis: The Ca Mau Peninsula Development Project and the Competition between Rice and Shrimp

While flood-management strategies span the entirety of the Mekong Delta region, problems of increased salinization predominantly affect Delta's coastal areas and low-lying peninsulas *(Figure 2*). As was recorded in French reports during the late 19th century, the widening of extensive canal networks to facilitate canal navigation, transport, and movement, had the tendency to increase salinization, and thus required further protective infrastructure and hydrolysis. Massive salinity projects were implemented in the 1990s, promoting food security, protecting formerly fresh-water systems from salinity, and transforming brackish water areas into freshwater areas for further cultivation opportunities.[72] Brackish water reduction projects focused on transforming salinity in the provinces of the Ca Mau Peninsula (*Figure.2*). Spanning 450 000 ha of land and requiring the construction of 40 secondary canals (250km), the Ca Mau development project was a major undertaking in which mass amounts of freshwater were pumped into brackish water environments, diluting salt content and contributing to healthier soils and larger crop yields.[73]

The increase of cultivatable lands in Ca Mau, however, increased instability within ecosystems and habitats by reverting salt water environments into those of fresh water, resulting in the decline of aquatic resources.[74] Due to the recent boom in Vietnamese aqua-cultural production and the imposition for new shrimp diversification strategies among shrimp famers, the removal of brackish water reduced grounds available for shrimp farming. Since the transformation of Ca Mau's brackish regions into rice fields, inhabitants of the Ca Mau peninsula have come to rely economically on rice cultivation. Thus, there is an opportunity cost between the two industries as they compete for wetlands, and the hydrolysis

[72] Käkönen, "Mekong Delta at the Crossroads," 208.
[73] Ibid.
[74] Ibid., 209.

of brackish systems creates confrontation between the success of rice yields and shrimp production in various provincial territories.

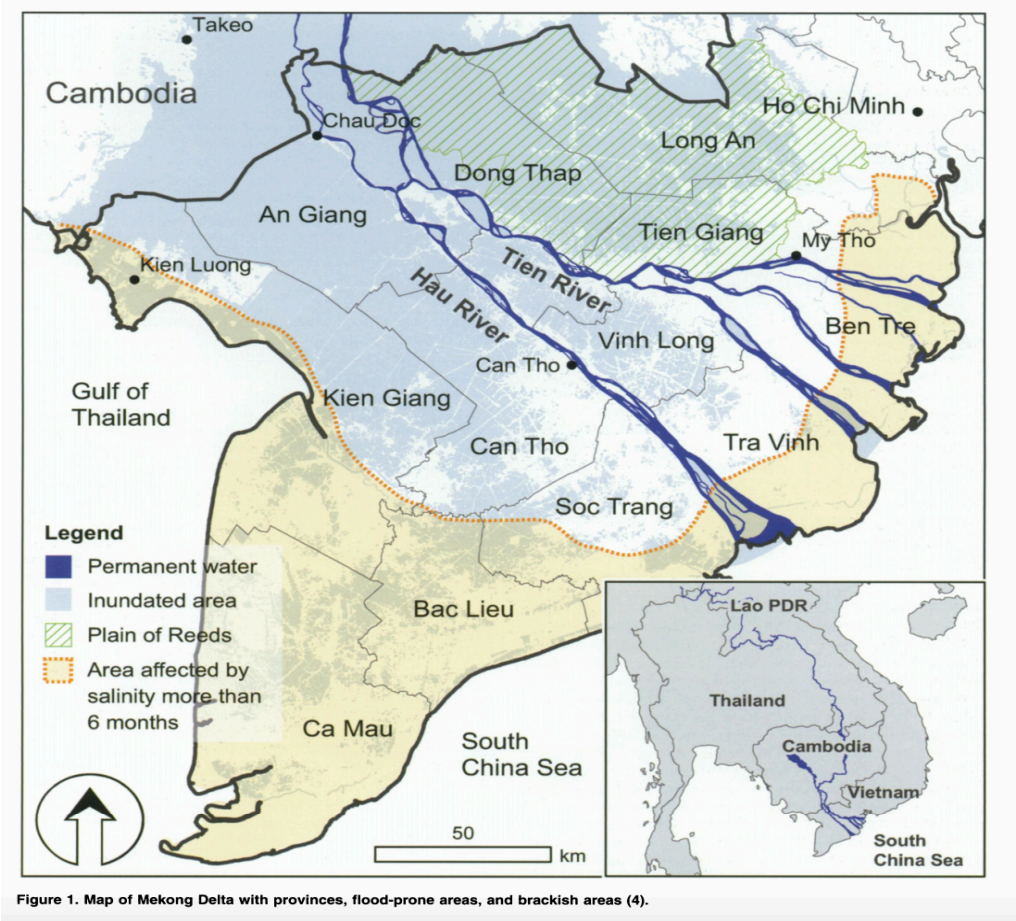

Figure 2: Map of the Mekong Delta with Provinces, Flood Prone Areas, and Brackish Areas (Source: Käkönen, 2003, pp 208)

Irrigation: The Plain of Reeds and Cultural Alienation

Finally, the negative consequences of irrigation and draining strategies of wetland management are most noticeable by examining Mekong Delta's Plain of Reeds. The Plain of Reeds flood plan system covers 10.6% of the delta (*Figure 2*). The region is characterized by its acid sulfate based soils and prolonged inundation, which have rendered the agricultural yield of the region historically low.[75]

[75] Ibid., 209.

Leaching – applying excess irrigation where salt content is high to avoid salt build up in soil –was a hopeful tactic for soil quality improvement. However, it required a large amount of fresh water to be pumped into the Plain of Reeds, contributing significantly to water waste. Although these tactics have increased regional rice yields, they have ultimately resulted in the acidification of water in the region, a phenomenon which is extremely harmful for aquatic life.[76]

By the 1990s, the draining techniques in the Plain of Reeds resulted in almost a complete shift from traditional floating rice cultivation techniques, pushing the population instead towards a short-life rice variety that enabled increased yields and multiple annual harvests. Similarly, the upper Delta's An-Giang province (*Figure 2*) decreased its production of traditional floating rice by nearly 80% in the 1980s, while irrigated rice increased significantly as a response to flood barriers.[77] These changes significantly shifted regional cultural traditions rooted around the ebbs and flows of inundation periods. It was longstanding Vietnamese tradition that dry months were accompanied by periods of rest and family bonding, and the wet season with heavy exertion and productivity. Thus, many Vietnamese societies faced over-exploitation and exhaustion due to new rice cultivation paradigms.

Fishing culture has also shifted significantly due to drainage and hydrolysis of the wetlands – leaving fishermen and fishing villages struggling to maintain their livelihoods. A similar consequence was noticeable after the creation of NEZs in the late 1970s, where ethnic minorities in Vietnam were encouraged to become sedentary in the Mekong Delta, thereby abandoning previous traditions of cultivation and adopting those imposed by relocation projects.[78] Shifting cultural norms throughout the Mekong Delta, in addition to noticeable negative implications of environmental degradation, made rural Delta populations feel alienated from the Vietnamese government and the rest of society.

[76] Ibid., 209.
[77] Ibid., 207.
[78] McElwee and Horowitz, *Environment and Society*, 59.

Agricultural development policies in Vietnam can thus be loosely compared to a means of modern conformity

The commonality between French, American, and Vietnamese agricultural development plans is that each ruling power approached natural resource exploitation from a distant birds-eye view which was guided by a brute desire to control the environment while remaining completely detached from the ecological conditions and mosaic of cultures present within. In the following section, a similar phenomenon will be related to the Zambezi Delta as the detached and centralized control of prominent Portuguese industries and the urban rule of the Mozambican government have analogously disregarded, and thereby alienated, rural populations– contributing to environmental and ecological degradation, as well as communal devastation.

Consequences of Zambezi Delta Development Strategies:

With the exception of Western plantations in the region, irrigation and other hydraulics systems in the Zambezi Delta remain highly underdeveloped. The most important forms of water control throughout the basin are the series of dams that had been constructed by European engineers in the 1960s and 1970s, completely shifting regional dependency away from ITCZ seasonal patterns. The Cahora Bassa altered the geomorphological characteristics of the lower Zambezi valley. Due to Portuguese models of commoditizing water into a valuable export intended for South African mines, cities, industries, and farms, this previously free resource was largely diverted away from the Delta and its 500,000 inhabitants.[79] South African needs came to dictate the timing, duration, magnitude, and frequency of

[79] Allen F. Isaacman and Barbara S. Isaacman, *Dams, Displacement, and the Delusion of Development: Cahora Bassa and its Legacy in Mozambique, 1965-2007* (Ohio University Press, 2013), 123.

water released from the dam, with complete indifference to its effect on agriculture, fisheries, wildlife, and indigenous populations downstream.[80]

The expedited construction of the Cahora Bassa displaced thousands of people from their homelands and submerged 2,739 km^2 of fertile land behind its reservoir. Combined with the widening rivers upstream, and inundation of floodplain habitats, the construction of the Cahora Basin drowned herds of wild animals, flooded entire native communities, and irreversibly transformed or flooded local ecosystems.[81] The new Cahora Bassa lake region pushed communities downstream into already inhabited territories, increasing food insecurity, competition for cultivatable land, and overpopulation. With the closing of the dam gates in December 1974, the river's once powerful velocity during the wet season was reduced to a trickle. The Zambezi decreased from its normal discharge of approximately 8000m^3 to less than 60m^3 per second. This pitiful flow, representing less than 1% of the river's average wet season emission, remained consistent for the following 3 months.[82]

By April 1975, the Cahora Bassa reservoir had already overflowed the dam. The Portuguese operators, recognizing that one of the turbines deep below the surface was slightly defective, chose to remedy the problem by completely opening the dam's turbine and sluice gates – unleashing unprecedented volumes of water on the unsuspecting and unprepared Delta population below.[83] The event, often described by locals as an inland-borne Tsunami, was a flagrant disregard for Zambezi lowland communities, wreaking mass devastation by washing away homes, gardens, and livestock. It signified the general trend of how the dam was going to be managed, without warning, nor any concern for local peoples.

[80] Ibid., 124.
[81] Ibid.
[82] Ibid.
[83] Ibid., 125.

The implementation of Cahora Bassa reduced wet season river flows by 61%; and increased dry season flows by 243%.[84] The disruption of seasonal patterns destroyed the monsoon-based variations that had defined riverine faming systems for centuries. Further, the reduction of flooding throughout the wet season inhibited the replenishment of nutrients in alluvial soils that were relied upon by peasant farmers. As in the Mekong Delta, the reduction of alluvial soils also contributed to soil degradation and lower crop yields throughout the Zambezi Delta. In some regions, alluvial farming effectively collapsed. Further, the sharp reduction in flood volume and the deepening of river channels for ameliorated river transport and navigation contributed to bank erosion and soil salinity.[85] A government survey conducted in 1979 reported that there was an absence of river bed cultivation along the bank of the Zambezi, which had previously been some of the most preferred and cultivatable land among delta farmers.

Unpredictable mass floods caused by random sluice gate releases along the Cahorra Bassa Dam ultimately displaced thousands of delta inhabitants. After suffering from drowned crops and agricultural failure, many villagers began hunting for a more stable environment on higher ground. However, East Africa's erratic precipitation levels often prevented the re-establishment of successful farming systems, and farm mobilization was commonly accompanied by food shortages caused by droughts.[86] Unlike the water management strategies implemented to enhance the cultivation of rice throughout the Mekong Delta, the commodification of water throughout the Zambezi Delta meant that food for native inhabitants was not a priority. Prior to flood-control implementation, households relied on foraging through riverbeds to find roots, tubers, river plants, and berries for nutritional sustenance.[87] However, bank erosion resulted in a decrease of wild foods along the river. For members of the Delta

[84] Ibid., 126.
[85] Ibid., 135.
[86] Ibid., 138.
[87] Ibid.

community that refused to be displaced, food insecurity and loss due to unpredictable floods became embedded into their way of life. For example, in 2008, the area of Chirodzi-Sanangwe, located sixty-five kilometers east of Cahora Bassa, still relied on cultivated fields through risky floodplains for cultivation.[88] They had not had a successful harvest in over a decade.

Sweet potato had been the dominant crop in the delta, growing best in floodplains and inundated gardens. Unfortunately, this generally adaptable crop lost its prevalence throughout the region as pressure from controlled floods washed the crop downstream in lowland areas; and the potato lacked sufficient water to grow in the highlands. Maize was also a cereal crop that lost its prevalence due to the impact of over and under hydration.[89] Shifts in cereal crop dependency for native Delta households resulted in the popularization of cassava (manioc) as a food staple in the region. Cassava is both drought and pest resistant, and it could be used to make porridge or bread. However, despite its high caloric value, cassava is a poor source of vitamins and proteins, and its use as a dietary staple resulted in malnutrition.[90] According to a 2003 study conducted in Mozambique's delta-based Tete Province, almost 10% of the area's total population, and 17.4% of children under 5, suffered from acute malnutrition.[91] Further, findings from a 2002 report demonstrated that women in the Tete Province had the highest rates of malnutrition in all of Mozambique, a fact which was causally linked to the region's increased rates of miscarriages, stillbirths, and gestational mortality.[92]

[88] Ibid., 139.
[89] Ibid.
[90] Ibid.
[91] Andre M.N, Renzaho, "Mortality Rates, Prevalence of Malnutrition, and Prevalence of Lost Pregnancy among Drought-Ravaged Population of Tete Province, Mozambique," *Prehospital and Disaster Medicine Journal* (2009), 28.
[92] Isaacman and Isaacman, *Dams, Displacement, and the Delusion*, 141.

Delta Disease: Prevalent Illnesses in the Wetlands of the Mekong Delta and the Zambezi Delta:

Due to water dependency in both the Mekong and Zambezi Deltas, some of the most frequent ailments and diseases are water related. In the Mekong Delta, mosquito-borne diseases such as malaria, dengue fever, and Japanese encephalitis (JE) rely most importantly on rice-field ecosystems for breeding environments.[93] Canals, inundated areas, and rivers are also ideal habitats for mosquitos. Thus, these mosquito-borne diseases thrive in the region's rice bowl economic model. As seen below in Figures 3 and 4, a study conducted in 2015 demonstrates the geographical areas where malaria and other mosquito transmitted illnesses are most prevalent throughout the Mekong Delta.

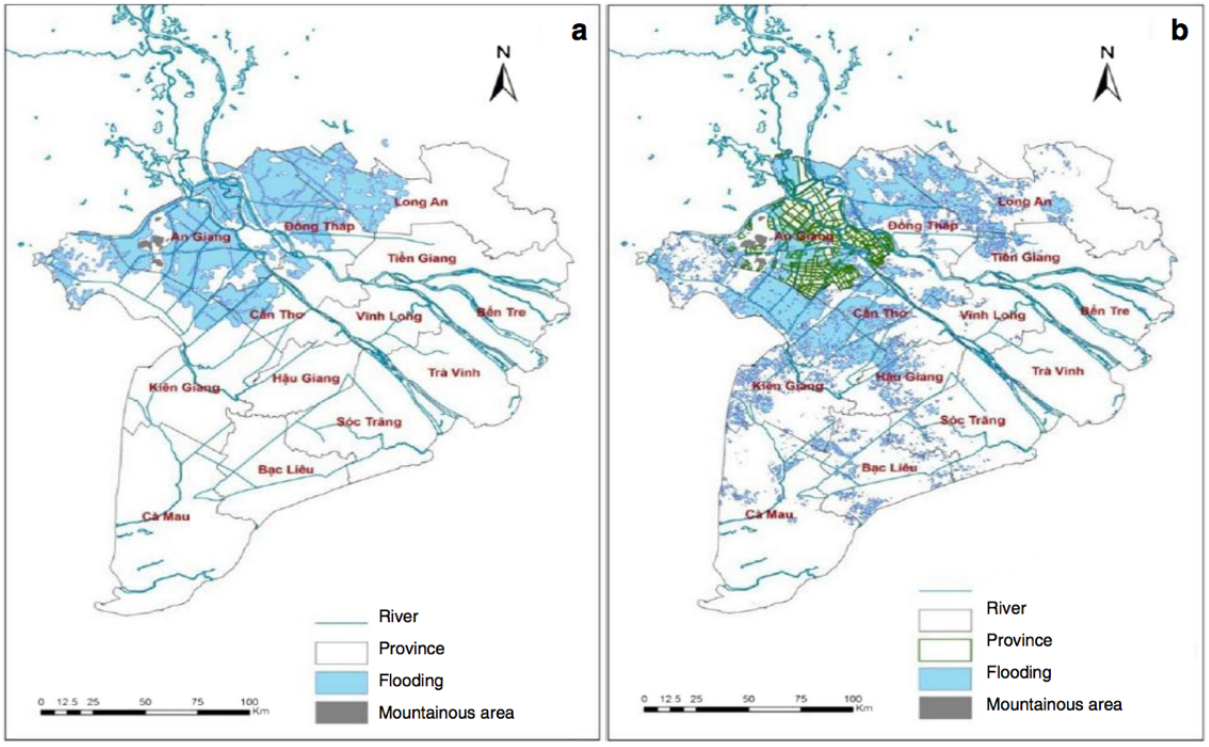

Fig. 2 Flooding maps of the Mekong Delta region in Vietnam (source: Dartmount Flood Observatory 2006; Brakenridge et al. 2011. In: Linh et al. 2013)

Figure 3: Flooding Maps of the Mekong Delta in Vietnam to Determine Ideal Mosquito Habitats (Source: Phung et al., 2015. pp. 859)[94]

[93] Shin-Ya Ohba et al., "Mosquitoes and their Potential Predators in Rice Agroecosystems of the Mekong Delta, Southern Vietnam," *Journal of the American Mosquito Control Association*, 27, 4 (2011), 384.
[94] Dung Phung et. al, "The Spatial Distribution of Vulnerability to the Health Impacts of Flooding in the Mekong Delta, Vietnam," *International Journal of Biometeorol*, 60 (2016), 859.

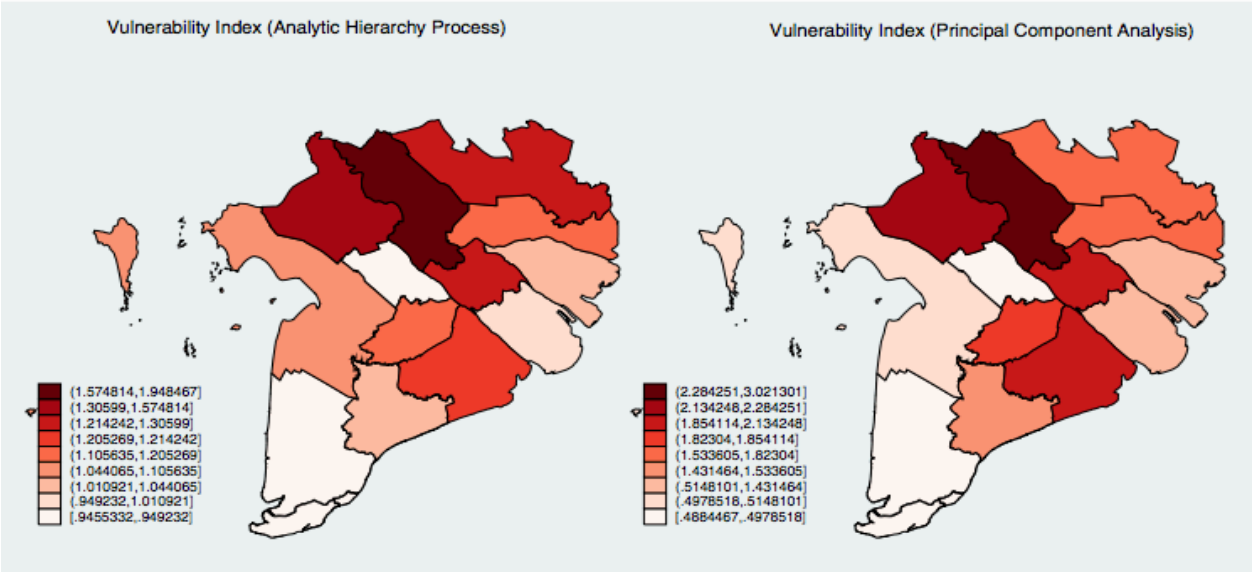

Figure 4: Flooding Maps of the Mekong Delta in Vietnam to Determine Ideal Mosquito Habitats (Source: Phung et al., 2015. pp. 863)[95]

As stated in the study by Phung et. al., "the spatial distribution of health vulnerability … [throughout] … Mekong provinces is comparable to the hazard maps of the greatest flood extent in the Mekong delta." [96] The interior provinces of An Giang and Dong Thap, coloured dark red in Figure 4, are the Mekong Delta provinces with the highest rates of malaria and dengue fever. This is primarily due to the regions' lack of access to health care and insufficient information on methods of prevention for malaria and other mosquito transmitted ailments. Malaria incidences in the Mekong Delta between 1990 and 2014 have decreased in Southern Vietnam from 10 cases per 1000 people (0.01%), to 0.10 cases per 1000 people (0.00001%).[97] However, it must be noted that the aforementioned reference to "Southern Vietnam" includes areas that are outside of the Mekong Delta region as well, meaning that this statistic does not accurately represent the progress existing explicitly amongst Mekong Delta dwellers. Further, as will be discussed below, dysentery, cholera, and other diseases and illnesses

[95] Ibid., 863.
[96] Ibid., 862.
[97] Sandra M. Goldlust et. al, "The Decline of Malaria in Vietnam, 1991 – 2014," *Malaria Journal*, 17 (2018), 4.

related to drinking contaminated water sources are also highly prevalent in regions that rely on surrounding water sources for lifestyle, convenience, and consumption.

Zambezi Delta Diseases:

Shortages of food result in the intensification of strenuous labor, often resulting in minimal and insufficient yield despite exhaustive efforts. This, combined with stress, thirst, and prolonged sun exposure, has the potential to weaken immune systems among Zambezi Delta rural community members; rendering them highly vulnerable to illness and disease. The lack of seasonal flood predictability resulted in vast regions of stagnant, swampy, water. These waterways thereafter become depended upon for bathing, laundry, and drinking, leaving many consumers affected by cholera and diarrhea. According to a report conducted in 2000, rates of cholera within Mozambican society was a severe problem throughout riverine zones, and increased during randomized inundation periods. [98]

Further, while malaria had been a common threat throughout the lower Zambezi Delta valley prior to the inauguration of the Cahora Bassa dam, the increase of stagnant bodies of water created permanent pools serving as fertile breeding grounds for mosquitoes. According to a 2006 report conducted in the Tete Province, malaria, diarrhea, and tuberculosis were the three leading causes of death (61.6%) for adults, and was the second leading cause of death for children under five.[99] Further, cases of peoples infected by schistosomiasis – a disease caused by water-borne parasitic flatworms that burrow under the skin of the unsuspecting bather and thereafter burrow themselves into the urinary tract or intestines – was also increasing in the Tete region, especially among children under five. Thus, the proximity to stagnant water through the Zambezi Delta renders communities vulnerable to diseases and illness that were less prevalent prior to the construction of the Cahora Bassa dam. Ironically, the

[98] Isaacman and Isaacman, *Dams, Displacement, and the Delusion*, 144
[99] Renzaho, "Mortality Rates," 29.

construction of the Cahora Bassa, despite its intention of manipulating the natural environment to human advantage, has provided significantly more assistance to the development of disease than the development of local success.

Case Studies of Regional Ecological Degradation in the Wetlands

While the entire ecological environment of both the Mekong Delta and the Zambezi Delta have been impacted by the human manipulation of seasonal monsoons, the wetland based botanical wonders discussed below are notable for their multi-faceted uses within both delta society and the ecological environment, namely: Malaleuca forests (Mekong), Papyrus swamps (Zambezi), and Mangrove trees.

Malaleuca Forests

Prolonged flooding in the Plain of Reeds (Figure 2) and other regularly inundated wetlands throughout the Mekong Delta contributed to an ecological niche for the growth of Malaleuca forests. Malaleuca forests are a valuable resource to Mekong Delta communities, serving several unique purposes. For example, the plant's secretion of Cajeput oil, while utilized as an anti-irritant or polysporin type ointment, can more importantly can be used as an insect repellent – a vital resource throughout the Mekong Delta malarial zones.[100] Further, Malaleuca roots provide ideal protection for underwater habitats and aquatic life, and for these reasons have been relied upon by Vietnamese fishermen for centuries.[101]

Although inland wild capture fishery remains the most important industry of the region, land reclamation for rice paddies, leaching practices, and heavy use of agrochemicals have devastated Malaleuca forest regions. Malaleuca plants are also exploited for timber and firewood, which, when

[100] Käkönen, "Mekong Delta at the Crossroads," 209.
[101] Ibid.

combined with the water pollutants and water control hazards impacting the region, contributes to significant degradation of these unique trees.[102]

Papyrus Swamps

Similar to the Mekong Delta, the Zambezi Delta supports a great mosaic of wetland vegetation communities, including papyrus swamps. Popularized by ancient Egyptian societies because of its paper-like properties, the Papyrus continues to be frequently harvested as a commonly used material on roofs, and its leaves remain ideal for crafts such as baskets, mats, and ropes. For the natural environment, papyrus swamps provide ideal habitats for birds, fish, and other wetland accustomed life forms, nesting in their leaves and their nest-like roots. The unique ability of papyrus roots to filter sewage allows root dwelling aquatic life to remain relatively undisturbed by regional water pollution. Further, the humid barriers beneath the plant allows it to protect surrounding water from evaporation and stagnation; both useful mechanisms for avoiding water degradation and maintaining a root-based environment that is unconducive for the growth of disease and bacteria.

Overcrowding in cultivable delta lands, deforestation due to overpopulation, and widespread water degradation and pollution has contributed to the significant decline of this previously abundant resource. Recently, conservation attempts have been made by the Mozambican government to preserve what is left of this unique and multi-purposeful form of fauna. For example, the Marroneau Buffalo Reserve, a protective sanctuary established in the 1950s for the conservation of the dwindling Marroneau Buffalo population, has dedicated 160, 000 ha of floodplains to the preservation of papyrus swamps.[103] Moreover, the popularization of environmentalism has sparked an increase in the

[102] McElwee and Horowitz, *Environment and Society*, 45.
[103] Beilfuss et al, "Land Cover and Land Use Change," 35.

inauguration of wetland conservation areas and ecological sanctuaries dedicated to papyrus and other unique East African flora and fauna since the start of the 21st century.

Mangrove Forests

Mangrove forests, present in both Mekong and Zambezi wetlands, also suffer extensively from hydraulic control initiatives and environmental manipulation. Mangroves are commonly located along the continental tropical coasts of Vietnam and Mozambique, respectively home to 32 species and 9 species of this unique plant. Mangroves needs a specific natural environment to thrive, a reality which generally lacks consideration in wetland development plans. An ideal mangal ecosystem needs access to saltwater, protection from excessive wave activity, ocean currents to convey seeds, a certain degree of tidal penetration, and, preferably, a mud substrate bottom. [104]

Mangroves present an ideal resting habitat for seasonal fish and shrimp on their migration seaward. They act as perfect breading grounds, hatcheries, nurseries, and feeding environments for fish in their early stages of life. For these reasons, mangroves are highly depended on by fishermen.[105] In addition to their contribution to aquaculture, mangroves also provide significant shoreline protection from coastal and riverine erosion. They can reduce flooding and storm surges, as well as act as natural sea dikes.[106] Mangroves are also known to reduce saline intrusion in their surrounding areas. Other natural uses of different mangrove species' can be found below in Figure 5.

Like malaleuca forests, certain mangrove plants provide useful remedies to illnesses and diseases prevalent in habitats that are frequently inundated. Despite this array of benefits, mangroves are under significant threat in the Mekong and Zambezi basin.[107]Mangrove forests used to cover over

[104] McElwee and Horowitz, *Environment and Society*, 46.
[105] Ibid., 46.
[106] Ibid.
[107] Ibid.

250, 000 ha of land throughout the Mekong Delta. However, war, forest fires, logging, charcoal production, and other human activities have significantly reduced the presence of the mangrove plant throughout Vietnamese wetlands.[108] The lucrative shrimp farming industry has and continues to rely on mangal environments for ideal shrimp ponds environments, engaging in mass deforestation to use the plant's mud substrate floor and salinized aquatic leftovers as shrimp basins – transforming these environmental metropoles into degraded areas dependent on artificial feeding. [109]

Table 16. Uses for Mangrove Species in Traditional Medicine in the Mekong Delta

Species	Treatment	Part of mangrove used
Acanthus ilicifolius	Rheumatic joints	Leaf
Acrostichum aureum	Wounds and boils	Pounded rhizome
Ceriops tagal	Malaria	Decoction
Clerodendron inerme	Jaundice	Leaf
Heritiera littoralis	Diarrhea	Seeds
Hibiscus tiliaceus	Emollient, diuretic, laxative	Root
Ipomsea pescaprae	Astringent, tonic, diuretic	Plant
Pluchea pteropoda	Headaches	Leaf
Thespesia populnea	Stomach aches	Leaf
Xylocarpus gramtum	Dystentary	Bark
Wedelia biflora	Wounds and cuts	Leaf

Source: Phan Nguyen Hong and Hoang Thi San 1993

Figure 5: Uses for Mangrove Species in Traditional Medicine
(Source: McElwee and Horowitz, 1999. pp. 48-49)

Further, mangrove ecosystems have suffered substantial threat throughout the Zambezi delta due to the reduction in volumes of sediments being transported to the mouth of the Zambezi and throughout riverine estuaries.[110] Mangroves have also succumbed to mass deforestation in the

[108] Nguyen et al., "A review of the drivers," 2310.
[109] McElwee and Horowitz, *Environment and Society*, 49.
[110] Isaacman and Isaacman, *Dams, Displacement, and the Delusion*, 134.

Zambezi, as Delta communities struggle to find sufficient fertile land in the overpopulated semi-stable environments.

While the environmental impacts of the destruction of mangal environments have been made evident, the destruction of mangrove ecosystems have also contributed to cultural impediments for Zambezi Delta communities as well. Herbalists stress that unpredictable and unprecedented river flow patterns, in addition to jeopardizing the growth of mangroves and other plants, are stripping the environment of necessary plant-based remedies. [111] This ecological degradation has contributed to the weakening of indigenous healthcare systems, delegitimizing tribal expertise in natural forms of treatment, alienating tribal communities from traditional forms of healthcare, and removing an often irreplaceable form of medical treatment from areas which have minimal, if any, access to western-modeled healthcare institutions and treatments.

Despite the risks of climate change and unsustainable development projects which threaten the survival of mangal ecosystems in the Zambezi Delta, several efforts have been made to ensure mangal forest preservation in recent decades. According to the Remote Sensory Journal's 2015 report, between 1994 – 2013, the coverage of the total mangrove area in the Zambezi Delta area had increased from 33,311 ha to 37,034 ha; representing an increase of 3723ha of mangal ecosystems.[112] This growth is largely credited to the establishment of protective environments in preservation areas where human impacts are limited, such as in the Marroneau Buffalo Reserve. As seen below in Figure 6, mangrove losses over the aforementioned two decades were primarily along coastal zones, where oceanic pollution and climatic storm surges are most prevalent. Whereas gains are characteristically localized

[111] Ibid., 145.
[112] Shapiro et. al., "The Mangroves of the Zambezi Delta," 16510

in protected inland environments such as newly exposed islands, the banks of small inland streams, and river flats. [113]

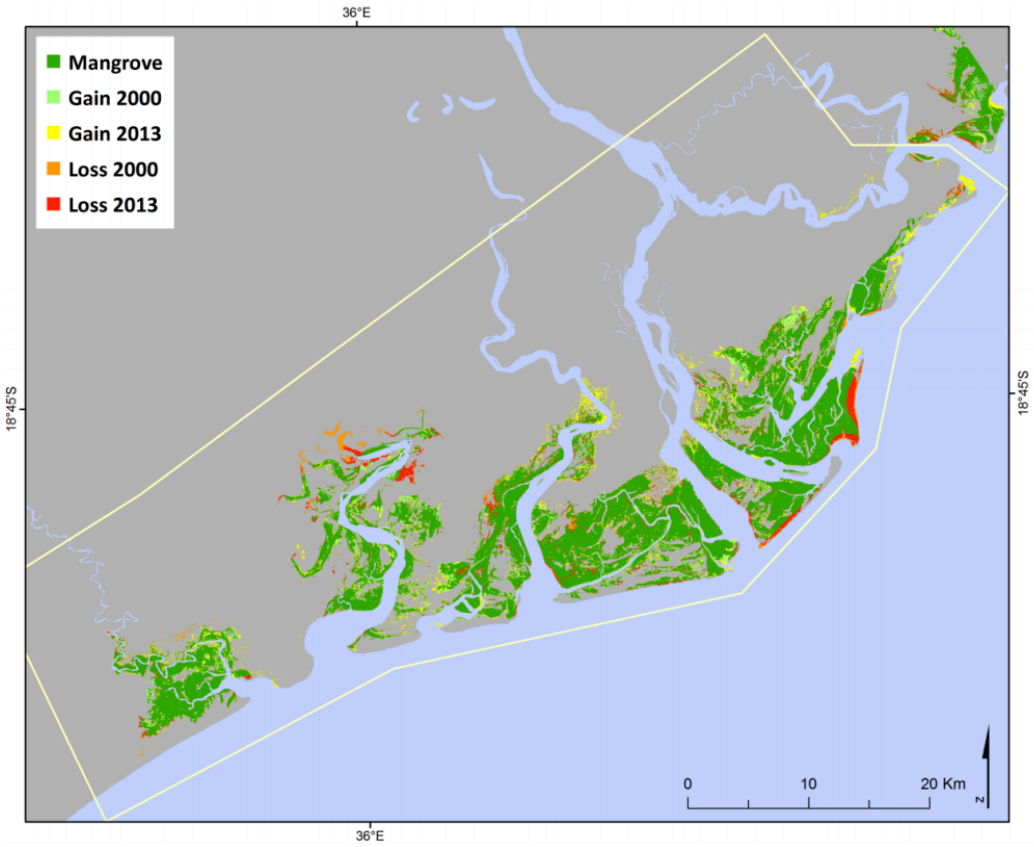

Figure 6. Change in Mangrove Extent within the Zambezi River Delta from 1994 to 2013 detected with Landsat Data
(Shapiro et. al., 2015. pp. 16509)

Climate Change: The Mekong Delta and the Zambezi Delta

Climate change presents obvious obstacles for both Mekong Delta and Zambezi Delta ecology. As the climate continues along its human-caused erratic path, elevated risks of droughts, floods, and natural disasters will follow. The mass use of agrochemicals, ineffective waste disposal systems, and the rise of pollution drifting inland from the South China Sea and Indian Ocean, respectively, is contributing

[113] Ibid.

to an increasingly unsustainable environment for the preservation of these delta ecosystems. For both regions, the expansion of the tourist industry has also become highly problematic. Mass influxes of tourists require Western standards of accommodation, promoting short-term development and infrastructural solutions which contribute to rises in national waste production and environmental degradation. The following section will develop the risks that climate change poses on each region specifically.

Mekong Delta

The Committee for Coordination of Investigations of the Lower Mekong Basin has conducted research in recent years which suggests that any world-wide rise in ocean levels would have detrimental impacts on the region's agricultural and ecological life.[114] According to the 2009 report published by the Ministry of Natural Resources and Environment of Vietnam, sea levels along the coast of Vietnam have increased by 3mm/year between 1993-2008[115] – a figure which is consistent with the global rise in sea level of 1.8 ± 0.5mm/year since 1961.[116] The report also indicates that by 2100 sea levels are expected to increase by an average of 75cm in Vietnam.[117] This estimated rise in sea level would impact the Mekong Delta region by submerging 7580 km2 (19%) of the area – as seen in Figure 7 below.

Other predictions have been that temperature increases could decrease soil moisture and precipitation levels, which would also affect regional stability. The Ministry of Natural Resources and Environment of Vietnam's findings indicate that between 1958-2007, the annual average temperature

[114] McElwee and Horowitz, *Environment and Society*, 23.
[115] Ministry of Natural Resources and Environment, "Climate Change, Sea Level Rise Scenarios for Vietnam," *Ministry of Natural Resources and Environment* (2009), 6.
[116] Ibid., 4.
[117] Ibid., 15.

of Vietnam increased by approximately 0.5 to 0.7 ^{O}C, which has been accompanied by a national reduction in rainfall of about 2%.[118] While predictions pertaining to temperature for the end of the 21st century differ between North and South Vietnam, as well as their respective regions, the South Vietnamese Delta is expected to have an average temperature increase of 2 ^{O}C by 2100.[119] These changes in temperature are anticipated to change Mekong Delta rainfall amounts by an increase of 1.5%.[120]

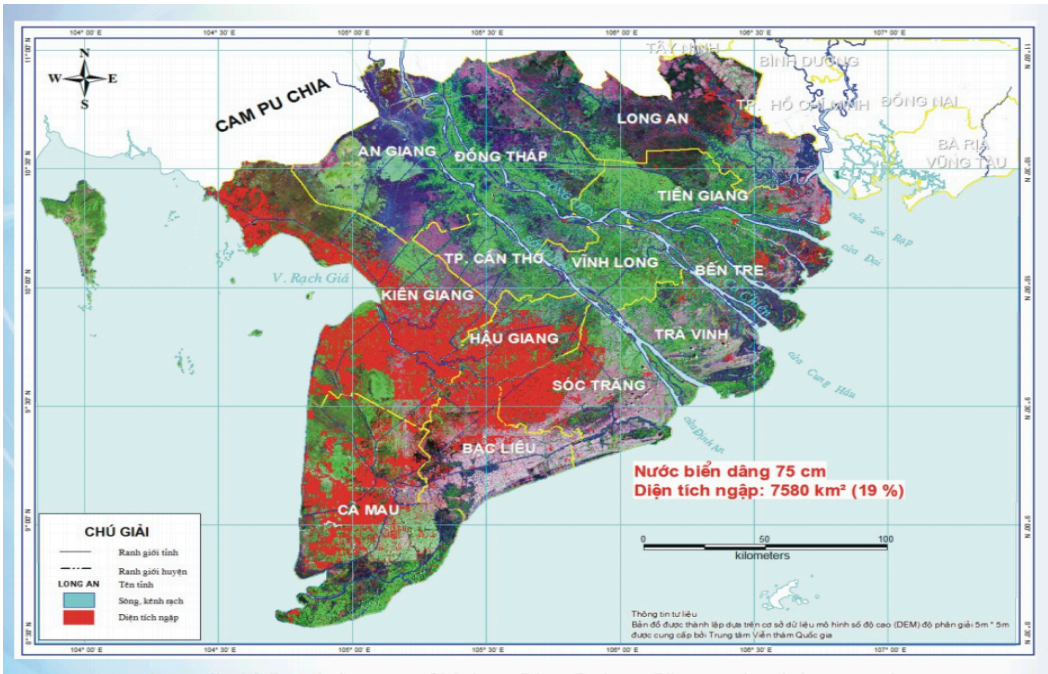

Figure 7: Inundation Map of Mekong Delta 2100
(Climate Change, Sea Level Rise Scenarios for Vietnam, Ministry of Natural Resources and Environment, 2009)[121]

Climate change has already started to impact migration dynamics and environmental displacement. It has exacerbated climatic shocks and environmental stresses which impede on peoples'

[118] Ibid., 4-5.
[119] Ibid., 12.
[120] ibid., 13.
[121] Ibid., 33.

livelihoods, thereby making climate change an ever-increasing driver of the global refugee crises. Environment-based relocation has been noticed among poor fishermen in Ca Mau province, as they face fish stock decline and harsh weather conditions. [122] Further, environment driven migration has also been observed among the people in the Quang Tri Province after suffering repeated crop failure. Environmental migration and government resettlement projects and policies are problematic in the sense that they create vulnerabilities among rural people and communities – especially among women, children, elderly people, and ethnic minorities.[123] While it is argued that migration can reduce the human wrought environmental degradation of a region, it also creates risks of overpopulation in another area; and has the potential to contribute to mass unemployment, resource-based disputes, and social unrest.[124]

Zambezi Delta

Similar risks related to rising ocean levels, overpopulation, and ecological destruction impact the Zambezi Delta region. Recorded shifts in climate have indicated that the mean temperature in Southern East Africa has increased significantly since the end of the 19th century time (Figure 7 & Figure 8). By 2050, the Zambezi Delta is expected to become much hotter and much drier, with a 0.3–0.6^{O}C increase in temperature per decade. [125] This increase in heat would increase evaporation by 10 - 25 %, thereafter

[122] United Nations Viet Nam, "Migration, Resettlement, and Climate Change in Viet Nam: Reducing exposure and vulnerabilities to climatic extremes and stresses through spontaneous and guided migration," *United Nations in Viet Nam* (2014), 1.
[123] Ibid., 25.
[124] Ibid.
[125] Richard, D. Beilfuss and Charles Nhemachena, "Climate Change Vulnerability and Risk," in *The Zambezi River Basin: Water and Sustainable Development*. ed. Jonathan Lautze et. al. (New York: Routledge Publishing, 2017), 50

reducing rainfall by 10 - 15%.[126] Further, annual river flow runoff is predicted to decrease by 15% with every temperature increase of 1 ^{O}C. [127]

The unpredictable extreme weather conditions that arise from climate change are also likely to result in extreme floods and droughts throughout seasonal El Nino oscillations. Continued patters of climate change are expected to reduce agricultural yields and cultivatable lands throughout the region – due either to inundation of drought – contributing to migration of farmers into more fertile lands, thereby resulting in overpopulation, famine, disease, and social unrest. The progression of climate change will also result in increased unpredictability of ITCZ storm patterns and intensities, resulting in heightened tropical cyclones that are likely to affect dam safety, effectiveness, and detrimental levels of flooding.[128] Magnification of the intensity of floods due to cyclone intensification could destroy road stocks, general infrastructure and other means of development-based construction; ultimately having negative implications on region's economic growth.[129] If these levels of temperature increase are attained, the Zambezi region's population and ecology will suffer beyond repair.[130]

Conclusion:

For centuries, the livelihoods and farming systems in both the Mekong and Zambezi deltas relied on adaptation techniques to accommodate changing environmental conditions. [131] However, more recently, the management of environmental factors for development strategies have shifted from adaptation to control, and decisions for said strategies have become more centralized. In Vietnam,

[126] Ibid.
[127] Ibid. pp. 57
[128] Ibid., pp. 60
[129] Channing Arndt and Finn Tarp. "Climate change impacts and adaptations: Lessons learned from the greater Zambezi River Valley and beyond," *Climate Change*, 130 (2015), 4.
[130] See tables in: Beilfuss and Charles Nhemachena, "Climate Change Vulnerability," 54-55.
[131] McElwee and Horowitz, *Environment and Society*, 25.

agricultural modernization for high-yield rice varieties and increased agrochemical use, combined with hydraulic control structures, have all contributed to the productivity of the Mekong Delta. But this mixture of mass environmental manipulation also contributes to the reduction of water quality, increased demand for water, and diminished biodiversity. [132]

Throughout the Zambezi Delta, the legacy of colonial control over social and economic activities remains in neo-colonial strategies of wetland management, whereby Portuguese and South African companies, as well as the Mozambican government benefit economically at the expense of lowland Mozambican natives. The unpredictability of when, at what velocity, and what at volume floods will impact the region have contributed to significant instability, food shortages, ecological degradation, and social alienation among native African communities. Further, diseases borne out of stagnant pools have thrived in these new unstable territories.

Thus, Vietnamese and Mozambican government policies need to be altered with respect to development in ways which accommodates human needs, unique cultural traditions, and the natural environment. Policies for both regions should only be implemented after extensive regional research is conducted. These policies should be approached after hands on experience. There is a need for the reduction of centralized control over policy initiatives in Vietnam, Mozambique, and other developing nations around the world.

Throughout the IOW, ecosystems and aquasystems suffer over the lack of long-term development planning and initiatives which incorporate unique environmental factors into policy making. Recent efforts have been made throughout the region to introduce sustainable models of wetland preservation. Beyond Vietnam and Mozambique, mangrove preservation forests have been introduced in Bangladesh and India, such as the Sundarbans forest reserves of the Ganges Delta,

[132] Ibid.

whereby mangroves are preserved alongside other flora, fauna, mammals, and aquatic life. The provision of these small spaces of sanctuary are attempts at protecting unique environments from the ever-developing world beyond demarcated reserve boundaries. Problematic repercussions of pollution, however, continues to hinder these mangal refuges, as water irrigation systems and natural downstream river flows continues to transport harmful pollutants into these otherwise "pristine" areas

Rice cultivation for international export in the Mekong Delta and the commodification of water at the Cahora Bassa dam above the Zambezi Delta, have significantly skewed perceptions of local needs, diluting them with rates of local profit. Provinces throughout the Mekong Delta and the Zambezi Delta, among throughout the IOW, require policies which focus on regional based development solutions and incorporates knowledge of the land and traditions into its agenda. Significant investment into long term sustainable development goals are needed to be prioritized throughout the IOW. Funding needs to be allocated towards environmental protectionism and climate related risk management strategies today, before climactic repercussions of human short-term development habits become irreversible and ever-more detrimental to the livelihoods of inhabitants throughout the IOW.

Regardless of these aforementioned solutions, the reality of both Vietnam, Mozambique, and most other nations throughout the IOW is that a vast majority of the national population remains impoverished. For nations whose populations still struggles to put food on the table, policies which promote environmental consciousness and native empowerment rarely come to fruition.

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