Amphibious Land Repair

Restoration, Infrastructure and Accumulation in Southeast Asia's Wetlands

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ABSTRACT: Amphibious landscapes, wetlands such as coasts, mangroves, peatlands, and deltas, have seen a recent surge in large-scale restoration efforts. This article examines this trend in Southeast Asia, reviewing the history and contemporary dynamics of wetland restoration in the region. Drawing from literatures on the political ecology of restoration, infrastructure studies, and the financialization of nature, we understand wetland restoration as a form of repair to highlight it as a socio-political process. We conceptualize restoration as *infrastructural land repair*, the process of restoring dynamic ecosystems for specific anthropocentric and economic aims, mediated through an amalgam of expertise, technology, and finance. We reveal how restoration can function as a socio-ecological fix, maintaining the same political-economic systems that initially caused wetland degradation. Finally, we identify a need for three areas of scholarship to be expanded on how restoration unfolds in practice within the SEA context, which will be crucial to informing more reparative forms of restoration.

KEYWORDS: accumulation, infrastructure, repair, restoration, socio-ecological fix, Southeast Asia, value, wetlands

The year 2021 marked the beginning of the UN's Decade of Ecosystem Restoration, an initiative focused on rehabilitating and protected ecosystems across the globe to counteract climate change (Waltham et al. 2020). A crucial focus of restoration efforts centers wetlands, which include marshes, swamps, bogs, coasts, river basins, deltas, and mangrove ecosystems. As an amphibious landscape, they defy typical categorization, not fitting neatly into the category of water or land (Jensen 2017). Following decades of drainage, deforestation, and agribusiness development over the past few decades, Southeast Asia (SEA) has become a hotspot of large-scale wetland restoration as part of the global momentum toward restoration. There are over two million square kilometers of wetlands in SEA, including over 60 percent of the world's tropical peatlands and 42 percent of global mangrove ecosystems. Coastal wetland areas make up the highest proportion of wetlands in SEA, followed by inland wetland areas (Liu et al. 2022). An estimated 54 percent to 87 percent of global wetlands have been lost since 1900, with the highest rate of loss in Asia: over 80 percent of Southeast Asian wetlands are already degraded or threatened by conversion to agricultural development (Davidson 2014; Hughes 2017). Wetlands are sometimes flooded and sometimes dry, with burps of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) as rising and falling water levels expose soils to air, emitting

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gasses into the atmosphere. Wetlands perform essential ecosystem roles, including water filtration and regulation, carbon sequestration, sea-level regulation, and biodiversity. They provide critical habitat to diverse species, such as migratory birds (Hughes 2017; Yong et al. 2022). They are no less important for the livelihoods and culture of local communities.

In SEA, wetlands are drained for oil palm and pulpwood plantations, flooded for rice cultivation, or converted to shrimp ponds. In manipulated wetlands, the ecosystem's hydrology is often damaged through canal construction that prevents seasonal water flux (Nugraha et al. 2022). A key objective of wetland restoration is thus hydrological rehabilitation, which dams the canals or re-establishes channels to allow water to flow freely, cycling nutrients through the ecosystem and preventing greenhouse gas emissions. Efforts toward more holistic forms of forest restoration, rather than forest reclamation, began in the region around the early 2000s. These recent projects in SEA are part of a global restoration effort centering the transformation of unproductive and degraded landscapes into functional ecosystems. Ecological restoration was originally defined by the Society for Ecological Restoration in 2004 as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Allison and Murphy 2017: 1).

Ecological restoration as a practice and concept is not new, originating after World War II but gaining prominence in the late 1990s and early 2000s and stemming from the discipline of conservation biology and the fields of landscape and restoration ecology (Higgs et al. 2014; Martin 2022; Palmer et al. 2016). In the last two decades restoration has become a frontier of environmental conservation (Chazdon et al. 2017), the growing 'restoration agenda' central to efforts making environmental management economically profitable (Elias et al., 2021) Many restoration programs and projects around the world are focused on restoring forest ecosystems through tree planting and other greening approaches (ibid, 2021), including stream and river ecosystems (Lave 2021; Smith et al. 2014), coral reefs (Braverman 2018), and desert and grassland ecosystems (Chiquoine et al., 2024).

Recently, as rising temperatures and increased drought wrought by a changing climate have further altered wetlands' biogeochemistry and function (Salimi et al. 2021), greenhouse gas emissions from many degraded wetland ecosystems have increased. As such, global attention has turned to wetlands' potential to act as a "nature-based solution" for climate change mitigation through their capacity for rehabilitation and thus reduced greenhouse gas emissions (Kolka et al. 2016; Siman et al. 2021; Thorslund et al. 2017). In SEA, wetland restoration projects include large-scale peat swamp and mangrove restoration in Indonesia, seagrass meadow planting in the Philippines, and delta rehabilitation projects across Vietnam, Thailand, and Myanmar (Dohong et al. 2018; Rifai et al. 2023; Sidik et al. 2023; Tinh et al. 2022). In urban areas, this is often under the title of blue or green infrastructures, which consist of natural ecosystems implemented to mitigate climate change impacts, such as flooding and elevated air temperatures (Ghofrani et al. 2017). Moreover, restoration requires considerable amounts of capital. A recent study by Imperial College Business School, for instance, shows that ecosystem restoration across SEA requires at least two hundred billion dollars, necessitating the private sector's investment to reach this amount (Holtedahl 2023). Following similar trends toward the financialization of forest and biodiversity conservation (Fletcher 2020; Kay 2018), framing wetlands as nature-based solutions through their restoration enables the restoration process and outcome to bear economic value, leading to wetlands' financialization, such as through blue carbon credits generated by mangrove restoration.

This critical review surveys recent literature on wetland restoration in SEA, contributing to a growing body of critical social science scholarship that examines the practices, processes, and politics of restoration (Brock 2023 Clay 2019; Elias et al. 2021). Our review includes literature from the social sciences as well as the natural sciences, engineering, and environmental policy. Given the striking recent finding that ecosystem restoration "did not result in faster or more complete recovery than simply ending the disturbances ecosystems face" (Jones et al. 2018: 1), it is paramount to understand why restoration projects continue to proliferate. Much critical restoration scholarship has emphasized restoration projects in the Global North (Breslow 2014; Brock 2023; Klein et al. 2022); this review expands the geographical scope of this literature, turning toward the Global South to focus on wetland restoration in SEA. Following recent scholarship that has theorized restoration as "repair" to think through its relation to capitalism (Huff and Brock 2023), race relations (Barra 2021), and its potential for alternative forms of environmental relations (Usher 2023), we understand recent wetland restoration projects as forms of repair to unpack restoration's political dimensions. We extend recent work that has connected nature-based solutions and infrastructure (Lock 2023), arguing that wetland restoration in SEA functions as a form of what we term *infrastructural land repair*, or the process of restoring dynamic ecosystems for specific anthropocentric and economic aims, mediated through an amalgam of expertise, technology, and finance.

In what follows, we advance repair as a socio-political process and offer an overview of critical work that engages nature as infrastructure to highlight the role of maintenance and repair. In section two, we summarize the history of restoration in SEA, tracking how earlier forms of forest restoration inform recent efforts toward wetland restoration. We then interrogate how wetland restoration efforts in SEA produce wetlands as a form of infrastructure to outline a political ecology of wetland restoration in SEA, drawing on literatures on the political ecology of restoration, infrastructure studies, and the financialization of nature. We find that considering restoration as infrastructural repair encourages new ways of thinking about land valuation and revaluation amid rapid environmental change. Moreover, by examining the political limitations of repair, the increasing financialization of these land repair projects may function as a socio-ecological fix. This trend renders degraded wetlands as sites of re-accumulation from their initial extraction for capital-intensive agribusiness and then through ecosystem repair itself, or what Amber Huff and Andrea Brock (2023) call "accumulation by restoration." In reflecting on the possible political and economic implications of the growing financialization of wetland restoration in SEA, we also identify a gap in the literature on how financial instruments, actors, and tools work in SEA wetland restoration. Finally, we suggest that recent scholarship on "reparative climate infrastructures" may provide a justice-centric form of financial engagement in future SEA restoration projects.

Theorizing Restoration as a Mode of Repair

Across the critical social sciences, scholars have shown how the concept of repair unsettles and re-configures, intervenes and re-constructs. In science and technology studies (STS), repair is central in drawing attention to maintenance practices that prevent breakdown. Steven Jackson (2014), for instance, identifies repair as the fulcrum between an always almost-falling-apart world and a world of re-invention and new possibilities. Jackson defines repair as how "order and meaning in complex sociotechnical systems are maintained and transformed, human value is preserved and extended, and the complicated work of fitting to the varied circumstances of organizations, systems, and lives is accomplished" (ibid.: 222). In this sense, repair is distinctly temporal or, in the words of Jackson, "an inescapably timely phenomenon, bridging past and future in distinctive and sometimes surprising ways. . . . It accounts for the durability of the old, but also the appearance of the new" (idem: 223). Central to this definition is how repair offers the means to either reconceptualize and re-configure systems or maintain the status quo. Paying attention to repair means noticing the often-invisible practices that maintain systems but also paying attention to the processes of breakdown and degradation that necessitate repair (Ramakrishnan et al. 2021). Central to work on repair in STS is the understanding that practices of maintenance and repair are embedded in socio-political worlds that hold distinct visions for the future (Denis et al. 2015).

Political ecologists have invoked the concept of repair to understand the tensions and possibilities embedded within imaginaries, objectives, and impacts of restoration: in other words, the politics of repair. They see repair as inherently political because it either constructs something new or maintains the present (Usher 2023). For some, repair can perpetuate current systems, preventing new ways of living with nature (Wakefield 2020). Other work has examined the economic dimensions of repair, underscoring what James Fairhead, Melissa Leach, and Ian Scoones (2012) call the "growth economy of repair," which enables nature to be valued for both its use and its potential for repair (Huff and Brock 2023). Sarah Knuth (2019) describes new economies of repair in her work on decarbonization through urban retrofitting, showing how retrofitting is a green gentrification scheme cast as a market-based solution that reframes environmental problems as untapped economic frontiers. Knuth reveals how such retrofitting efforts require "not just potentially profitable urban repair today but large-scale urban maintenance into the future" (2019: 490), highlighting the uncertainty associated with repair. Huff and Brock (2023) have conceptualized restoration as repair to develop their concept of "accumulation by restoration," referring to when nature becomes "valued not just for its use but also for its potential for repair or restoration" in the shift from a conservationist "mode of production" toward "a growth economy of repair" (ibid.: 2113). They note that repair is a discourse that advances a vision of ecological improvement, intervening in perceived crises to "neutralize" harm while obscuring the latent power dynamics involved in the practice of repair itself.

The dominance of natural capital accounting that privileges economic relations over alternative forms of socio-environmental relations is not inevitable (Usher 2023). Recent scholarship has offered a vision of alternative socio-natural relations formed via differing engagements with ecological repair, moving beyond techno-managerial anthropocentric visions (Barra 2024; Osborne et al. 2021; Webber et al. 2022). As Mark Usher writes, "restoration can therefore encourage humans to recognize that worlds can be arranged differently and composed otherwise" (2023:1257). Monica Patrice Barra (2024) also adopts an hopeful vision of repair. By engaging Black feminist geographies, Barra develops the concept of restoration through her work on coastal restoration in Louisiana, revealing how Black coastal communities "re-route hegemonic ideologies of ecological crisis away from a zero-sum game that pits acres of wetlands gained or lost against frontline communities, and toward the protection and sustainability of Black life and ecologies" (2023: 3). Webber et al. (2022: 937) cite the Black radical and abolitionist traditions to conceive of repair as the undoing of institutions that have been eroded through colonialism, slavery, and capitalism. Invoking the concept of reparations, the authors link repair and reparative framings of justice. In this way, recent work on repair demonstrates how repair as a practice that can be used in breakdown to generate new possibilities. Such insights are fruitful in attending to ways the financialization of restoration can be reconceived (Lamont et al. 2023), becoming closer to what Tracey Osborne et al. describe as "a culture of equity-based earth stewardship and a radically transformed relationship to the planet based on care and reciprocity" (Osborne et al. 2021: 6). In their overview of how restoration can become more effective, equitable, and transformative, Osborne and colleagues argue that restoration initiatives should promote regenerative outcomes by treating not just the symptoms but also the root causes of landscape degradation.

Nature as Infrastructure: Nature-Based Solutions and Ecosystem Services

The wetland restoration efforts surveyed in the following section repair degraded landscapes to improve ecosystem function like water and carbon cycling, climate regulation, and biodiversity conservation (Tomscha et al. 2021) such as in peatland restoration (Bonn et al. 2016). Recent scientific work has shown that wetland restoration may lead to increased carbon sequestration and reduced methane emissions due to wetlands' distinctive hydrology (Valach et al. 2021). Many SEA wetland restoration projects thus emphasize the climate mitigating services of restoration. Increasingly, this co-beneficial process has been framed by policymakers and restoration projects in terms of nature-based solutions or natural-climate solutions (Rifai et al. 2023; Tan et al. 2022). Nature-based solutions (NbS) are defined as "working with and enhancing nature to help address societal challenges" (Seddon et al. 2020: 85) and expanding on efforts towards integrating ecosystem services to adapt to the impacts of climate change (Alexander et al. 2016; Colls et al. 2009; Escobedo et al. 2019).). Ecosystem services, meanwhile, refer to "the aspects of ecosystems utilized (actively or passively) to produce human well-being" (Fisher et al. 2009: 645).

Critical social scientists often argue that nature conceptualized this way is "out there," separate from society, upholding the age-old and contentious nature-culture bifurcation and its complex and dynamic processes reduced to a specific good or service that can be "put to work" for anthropocentric purposes (Besky and Blanchette 2019; Welden 2023). Such a conception of nature obscures how humans themselves are a part of ecosystems, shaping and influencing environmental change. Importantly, this framing of nature as a "service" is evocative of exchange-values and is used to justify nature's valuation, part of a neoliberal toolkit that centers market relations in environmental management, turning natural processes into discrete financial commodities (Bigger et al. 2018; Dempsey 2016; Sullivan 2018). Nature's "services," like carbon sequestration, are measured and made commensurable to financial value through complex accounting so they can be marketed to investors (Huff 2023; Kolinjivadi et al. 2019; McElwee 2017). This neat packaging of "services" that can be measured and valued is emblematic of the production of nature, facilitating capital penetration into nature itself (Bryant 2018).

Scholars have also reflected on how nature's "work" is harnessed to deliver specific ecosystem services and outcomes for human communities and is used as a natural infrastructure (Besky and Blanchette 2019; Carse and Lewis 2017; Hetherington 2018; Ojani, 2022; Wakefield 2020). In contrast to technical approaches to infrastructure in ecology and conservation science discussed later in this section, this scholarship is informed by STS, which embeds infrastructure in social, technological, and material contexts (Larkin 2013; Star 1999). As Ashley Carse (2016) describes, infrastructure is a plastic term that has multiple definitions and meanings. However, for the purpose of this article, we understand infrastructure to mean not just systems or structures but also the relationships that constitute those structures, which bring them into existence or maintain their presence. As Lauren Berlant (2016) says, infrastructure is the lifeworld of structure.

This scholarship on nature as infrastructure understands that nature is formed in relation with humans, modified through human labor for a particular objective or purpose. It is not just an already existing infrastructure (Hawkins and Paxton 2019; Ojani 2022; Wakefield 2020). As Carse describes in his work on the Panama Canal, "as infrastructure, nature is irreducible to a non-human world already 'out there'. It must, in its proponents' terms, be built, invested in, made functional, and managed" (2012: 540). Ultimately, as "out there" nature is expected to provide ecosystem services, capitalist values are inscribed into the landscape, becoming infrastructure for one system of production, rather than other possibilities. Will Lock (2023) describes how engaging NbS follows the framing of the natural world as a form of infrastructure. While not every wetland restoration project in SEA treats wetland ecosystems as a "nature-based solution," we see efforts that harness nature's processes through the act of restoration as strong examples of Sara Nelson and Patrick Bigger's *infrastructural nature*, or "the policy approaches, scientific practices, discourses, and investment strategies that make ecosystems legible, governable, and investable as systems of critical functions that sustain and secure (certain forms of) human life" (2022: 88, see also Dempsey 2016; Li 2014; Sullivan 2018). As Lock describes, "infrastructural nature can be seen as an ideological underpinning of nature-based solutions as they are emerging in practice" (2023: 4). Turning the natural world into infrastructural nature imbues it with the same predictability and measurable value that is in the built environment.

Such is the case for Southeast Asian wetlands. Infrastructural framings of wetlands within the science and policy communities see wetlands as ecosystem services, often framed as pre-existing "blue" or "green" infrastructures (Cardoso da Silva and Wheeler 2017). Like other infrastructures, these become visible only when they are not functioning as expected (Larkin 2013; Puig de la Bellacasa 2014). However, envisioning wetlands as infrastructure is also a political process. Understanding wetlands as services for human needs amplifies an anthropocentric relation to ecosystems. Moreover, as critical work on ecosystem services has shown, "infrastructuralizing" nature maintains capitalist socio-natural relations, enabling their valuation and commodification (Carse 2012; Dempsey and Robertson 2012; Kull et al. 2015). We follow recent critical scholars (Nelson and Bigger 2022; Wakefield 2020) in contending that wetlands are not simply pre-existing infrastructures but are made into infrastructural nature through the process of repairing both the terrestrial and aquatic features of wetlands to perform specific ecosystem services. We expand upon scholarship on green and blue infrastructures in Southeast Asia, which has examined the active construction of physical infrastructure in SEA urban wetlands, such as the Jakarta Seawall (Colven 2020). By developing Atsuro Morita's (2016) argument on infrastructuring amphibious space beyond construction of "aquatic infrastructures," we focus on how wetlands themselves are organized into ecosystem services through restoration. Drawing from the literature on nature as infrastructure, we define *infrastructural land repair* as the process of restoring dynamic ecosystems for ecosystem services, mediated through expertise, technology, and finance. In Southeast Asian wetlands, these purposes include climate mitigation, such as carbon sequestration in peat swamps and methane reduction in mangrove ecosystems, as well as climate adaptation, including water cycling for flood prevention in deltas and sea level rise in seagrass ecosystems.

Since the early 2000s, engaging nature as infrastructure has become ubiquitous in ecology and conservation science, subverting common conceptions of infrastructure such as roads, canals, and electric grids. Natural infrastructure utilizes ecosystems and their components, such as wetlands, forests, rivers, dunes, and reefs, as a metaphor to deliver a diverse array of services typically provided by constructed or engineered materials or structures (Escobedo et al. 2019). This concept has been articulated in the recent proliferation of related scientific terminology such as NbS, green, blue, and ecological infrastructures within environmental management and policy (Cardoso da Silva and Wheeler 2017). Following suit, wetland ecosystems in Southeast Asian landscapes are often framed as natural, green, or blue infrastructures (Hamel and Tan 2022; Rifai et al. 2023; Uy and Tapnio 2021). Green infrastructure refers to the purposeful design, restoration, enhancement, or strategic implementation of forested and terrestrial urban environments to deliver environmental services, such as managing stormwater, enhancing air and water quality, and mitigating urban heat, among other urban services (Cardoso da Silva and Wheeler 2017). For example, green infrastructures such as rain gardens or roof gardens are now used in urban planning to address stormwater pollution and flood management (Twohig et al.

2022). Blue infrastructures function similarly but focus on freshwater and marine ecosystems and are designed to manage and utilize water resources (Cardoso da Silva and Wheeler 2017). Living oyster reef shorelines are used in coastal management to respond to sea-level rise and increasingly powerful storm surges, or wave action that causes coastal erosion (Wakefield 2019). By understanding wetland restoration as a form of infrastructural land repair, we describe in the following sections how the processes of restoration can maintain the political-economic systems that resulted in wetland's initial degradation.

Restoration in Southeast Asia

In this section, we examine the history of restoration throughout SEA. Restoration projects are simultaneously increasing in number and changing geographies, moving from forest ecosystems to include wetlands. We detail this shift and then provide an overview of recent wetland restoration projects.

From Reforestation to Landscape Restoration

The practice of environmental restoration has a longstanding history in SEA, initially with a focus on the region's highly biodiverse forest ecosystems. Regarded as the oldest remaining tropical ecosystems in the world (MacKinnon et al. 1996), Southeast Asian forests consist of mixed deciduous types, including teak and evergreen dipterocarp forests, and extensive areas of montane, mangrove, and peat swamp forests (Appanah et al. 2015). Since the 1980s, logging for export, state-led agricultural land conversion, plantation development, and forest fires were, and continue to be, significant drivers of forest loss across SEA (Imai et al. 2018; Tsujino et al. 2016). As work in political ecology has demonstrated, these drivers of deforestation are rooted in histories of colonialism (Bryant et al. 1993). European scientific forestry practices became ubiquitous across the region's colonial forestry ministries and remained after independence in nations including Myanmar (Bryant 1993), Malaysia (Peluso and Vandergeest 2001), Indonesia (Peluso 1993), the Philippines (Pagunsan 2023), and even in Thailand, which notably avoided colonization (Lohmann 1993). Under colonial economic logic, timber was extracted from forests as a source of state revenue, leading to the expansion of state control into upland and forested areas.

Restoration in SEA has deep roots in colonial forestry. Early restoration in the region began in the mid-1800s with scientific forestry in colonial state-led efforts toward forest reclamation, or the replanting and reforestation of previously logged or degraded forests (Appanah et al. 2016). Ruel Pagunsan (2023) describes how post-WWII reforestation efforts by the Bureau of Forestry in the Philippines were shaped by colonial science. Shaped by extractive economies, early reforestation efforts were predominantly concerned with the ongoing economic potential of forest resources (Bryant et al. 1993). Thus, scientists and states emphasized monocultural replanting of exotic species with clear market value, such as pine, eucalyptus, or acacia (Lamb 1994). In Burma for instance, the *taungya* system for actively reforesting areas under shifting cultivation with teak was first introduced under the British in 1856 (Wohlers 2019). The system has since been widely used across SEA (Appanah et al. 2016).

Post-colonial Southeast Asian forest restoration initiatives have taken the form of state, non-governmental organization (NGO), or corporate-led reforestation programs or re-greening initiatives following traditional forest plantation schemes. The focus on replanting instead of full rehabilitation of an original forest ecology (Lamb 1994) was due to the difficulty in quantifying the extent of forest degradation in contrast to the relatively easy quantification of deforestation and subsequent tree replanting. These compensatory plantations were also employed across SEA to offset the decline in timber output from natural forests; pulp and timber companies financed the seeds and inputs (Buergin 2016). In the 1980s the Thai Royal Forestry Department addressed deforestation in Northern Thailand from logging for woodchips by establishing eucalyptus plantations financed by pulp-and-paper corporations (Puntasen et al. 1992). This reforestation project led to vocal farmer opposition over land tenure and a thirsty ecology of non-native eucalyptus forests, which drained the water table and soil moisture levels, jeopardizing local farming livelihoods (Barney 2004; Lohmann 1993). In Myanmar, the 1991 Wasteland Law led to rapid development of rubber plantations, through which reforestation was used as a form of agricultural expansion and paved the way toward high-input, capital-intensive agricultural production (Woods 2012). In the 1990s, the Vietnamese government followed suit, launching two forest restoration programs: Program 327 and the Five Million Hectares Reforestation Programme (5MHRP), which tripled the plantation forest area in Vietnam (McElwee 2009). In Indonesia, reforestation also has an extensive history. From the 1960s to 2015, 150 official forest reforestation projects were implemented across four hundred locations throughout the nation (Appanah et al. 2015). However, despite these projects, deforestation continued, and forests did not return to their original ecological composition (Sharma and Yonariza 2021). Across the region, many of these initiatives continue today.

Landscape restoration projects in SEA began in earnest in the early 2000s. The World Wide Fund for Nature (WWF) and the International Union for Conservation of Nature (IUCN) defined Forest landscape restoration (FLR) as "a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes" (Appanah et al. 2016:2). This move toward FLR followed global shifts in forestry management away from plantation models toward social forestry (ibid). While reforestation through tree replanting is still practiced in SEA, FLR programs continue to grow in Thailand (Sapkota et al. 2021), Indonesia (Van Oosten et al. 2014), and the Philippines (Mukul et al. 2016). More recently, restoration projects across SEA have centered wetlands, which we examine in the following section.

A Survey of Contemporary Wetland Restoration in Southeast Asia

From the peatlands of Indonesia (Dohong et al. 2018), floodplain systems of the Mekong Delta across Vietnam, Cambodia, and Thailand (Nguyen et al. 2016), high-altitude headwaters of the Ayeyarwady in Myanmar (Gruel and Latrubesse 2021), seagrass ecosystems of the Philippines (Rifai et al. 2023), and Inle Lake's watershed in Myanmar (Pradhan et al. 2015), wetlands across SEA are now the focus of a variety of restoration efforts, including large-scale, NGO-driven, state-led, and corporately funded initatives. Wetland drainage and degradation in the region is still driven by extractive industries, such as logging (Hughes 2017), hydrodam development (Cho and Qi 2023), the rapid expansion of oil palm plantations (Dohong et al. 2017, oil and gas drilling (de Jong and Nooteboom 2010), agricultural conversion for shrimp aquaculture and rice paddies (Gerona-Daga and Salmo 2022), as well as urban development. Degradation is further exacerbated by climate change and extreme weather events such as drought, sea-level rise, and tropical cyclones (Gopal, 2013). As a result, livelihoods and cultural heritage have been lost, water tables contaminated (Cochard 2017), the biodiversity of the region has taken a hit (Hughes 2017), and there has been a substantial loss of ecosystem services important for climate functions (Gopal 2013). In response, restoration efforts across the region seek to repair, and even enhance, these climate functions, making wetlands into NbS. At the 2016 Ramsar Convention of Wetlands, the Indo-Burma Ramsar Regional Initiative (encompassing Cambodia, Laos, Myanmar, Thailand, and Vietnam) formulated the first regional approach to wetland governance (IUCN 2022; Liu et al 2022). This initiative is informed by the expansive wetland work across the region. In this section, we offer a survey of these restoration efforts in Southeast Asian wetlands.

Peatlands

SEA's tropical peatlands, found in low-lying areas of Indonesia and Malaysia, which are home to over 40 percent of the world's tropical peatlands, are rapidly disappearing (Dohong et al. 2017). Peatlands consist of waterlogged, partially decomposed vegetation, extending up to 20 meters deep in certain areas. The majority of Indonesia's peatlands are considered disturbed or degraded, directly or indirectly impacted by canal drainage for large-scale agriculture (Page and Hooijer 2016; Uda et al. 2017; Yuwati et al. 2021). Following drainage, dry peatlands undergo microbial oxidation and become flammable, both processes of which emit enormous amounts of carbon dioxide (Page et al. 2022; Turetsky et al. 2015). The Indonesian state began draining peatlands in the 1990s for large-scale rice estates. Drainage accelerated in the early 2000s as the state gave land concession licenses on peatland to oil palm and pulpwood companies (Goldstein 2016). Some of the most severe peat fires in the country's history occurred in 2015, as El Niño-fueled drought left peatland across Sumatra and Kalimantan highly flammable (Kiely et al. 2021). In response, then-President Joko Widodo pledged to restore 2.2 million hectares of peatland by 2020 by creating a national-level Peatland Restoration Agency (*Badan Restorasi Gambut*) to spearhead the task (Goldstein et al. 2020). The BRG was limited, however, to implementing restoration in peatlands that fall within the state's direct jurisdiction, which excludes many peatlands that are in corporate agribusiness concessions.

The core objective of peatland rehabilitation is to prevent fire and oxidation—thereby mitigating carbon emissions—through hydrological management by blocking drainage canals, introducing new vegetation, and preventing fire (Monteverde et al. 2022, Yuwati et al. 2021). Successful rehabilitation in peatlands is challenging because of their complex hydrology, the variability of precipitation by season, and the fluid movement of water within swamp layers (Sutikno et al. 2020). Repairing drained peatlands' hydrology requires heavy machinery to dig and construct canals, ditches, drains and dams, which reduces surface run-off and increases water storage capacity within canals (Ritzema et al. 2014). After rewetting (Dohong et al. 2018, Terzano et al. 2022) there is often the planting of seedlings and transplants (Graham et al. 2017). Peat rehabilitation requires scientific expertise (Tan et al. 2022) and labor to drive machines, plant saplings, and oversee nurseries (Wiesner and Dargusch 2022). It also requires substantial capital investment (Hannson and Dargusch 2018). Some attempts at peatland restoration have been supported through the Reducing Emissions from Deforestation and Degradation (REDD+) initiative, which was introduced by the United Nations Framework Convention on Climate Change in 2007 (idib). REDD+ encouraged wealthy countries to fund developing countries' forest conservation and restoration projects as carbon offsets (Sayer et al. 2021). Multinational corporations such as Asia Pulp and Paper (APP) have undertaken peatland restoration efforts in their concession areas while other Indonesian companies, such as PT Rimba Makmur Utara, have obtained concession licenses for peatland restoration in Sumatra and Kalimantan with financing from donors and investors (Barbier and Burgess 2021; Jong 2023; Leo et al. 2024; Miller 2022; Sari et al. 2021).

Despite substantial financial and time investment in peatland restoration in Indonesia, the government's ambitious restoration hectare goal has not been met. This failure may be because most peat restoration projects do not fundamentally address the broader drivers of degradation such as drainage and ongoing agribusiness production on peatlands by corporations (Goldstein

2020; Wicaksono and Zainal 2022). Recent evidence from Greenpeace SEA has revealed that corporate restoration concessions such as APP have breached their restoration targets in their concessions, calling into question the efficacy of concession-based peatland restoration (Jong 2023). Successful efforts have centered community-led approaches, which Dilva Terzano and colleagues (2022) have termed the "5-r" approach, embedding community participation across all stages of peatland restoration, including rewetting, fire reduction, revegetation, revitalization of local livelihoods, and reporting and monitoring. Such an approach is crucial in moving peatland restoration past the "business as usual" scenario, where restoration fails to address the root cause of degradation (Girkin et al. 2023).

Deltas

SEA's deltas provide critical ecosystem services, livelihoods, and resources to millions of people particularly in the Mekong Delta (Li et al. 2017). With headwaters in the Tibetan Plateau, the Mekong River winds through Southwest China, Myanmar, Laos, Cambodia, and Thailand, before fanning out in a delta in Southwest Vietnam. Water intensive agricultural practices, like paddy farming and shrimp aquaculture in Thailand and Cambodia (Tromboni et al. 2021), the future development of hydropower dams in the region (Arias et al. 2014, Yoshida et al. 2020), and deforestation across the region (Li et al. 2022) threaten the tributaries of the river basin. This compounds water stress on the floodplains of the Mekong Delta, one of the largest deltas in the world. Conceptualized as a "hydro-agricultural machine" (Biggs et al. 2009: 216), the delta is an agricultural powerhouse due to its rich alluvial soils. For over one thousand years the delta has been modified for transportation, and later for the construction of large-scale canals and drainage systems for agriculture in the mid-nineteenth century by French colonizers, which the central government expanded after independence (Biggs et al. 2009). Since the mid-1970s, state-led irrigation and land reclamation for rice production has dramatically altered the delta's hydrological regime. One of the most populated regions of Vietnam due to the success of alluvial rice agriculture, the Mekong's transformation into a rice bowl has shortened the flooding period of the Mekong from 12 months to 4 to 6 months and caused increasing salinity levels (Le et al. 2018; Nguyen et al. 2016). By the early 2000s, only 1.5 percent of the Mekong's wetlands existed in their natural or semi-natural state prior to rice intensification (Nguyen et al. 2016).

Delta degradation and climate change exacerbate flooding, sea-level rise, and storm surges in the region, causing saltwater intrusion into groundwater systems as well as significant outmigration from the delta, which can lead to geopolitical conflict (Beban and Gorman 2015; Xiao et al. 2021). In turn, restoration efforts seek to restore ecosystem services for climate functions. While most delta projects have been NGO- and state-funded, the large-scale projected future expansion of delta restoration will also be corporately financed (Canning et al. 2021; Correa and Jansen 2021; World Bank 2020). The private equity firm Mekong Capital, for instance, is raising two hundred million dollars for Mekong restoration projects focused on the regeneration of forests (Ngui 2023).

Like restoration projects in peatlands, delta restoration establishes pre-disturbance hydrological functions, including constructing dikes and canals to retain monsoon rainwaters, which maintain moisture levels in seedling nurseries (Beilfuss and Barzen 1994). Maintaining hydrological balance maintenance is a complex technological system, referring to the hydraulic network of canals, flood embankments, sluice gates, and pumping stations (Staveren et al. 2018). Restoration research projects in the delta have examined the construction of bamboo T-Fences and dikes for breakwaters (Albers and Schmitt 2015) and structural protection measures against erosion used to stimulate hydrodynamics and maintain shoreline integrity, which reduce wave stress and increase sedimentation (ibid.). Delta restoration also includes the revegetation of native plant ecosystems (Tinh et al. 2022), which shape the hydrodynamics and sediment transport of the Mekong Delta (Fagherazzi et al. 2017). Beyond the Mekong, other smaller deltas in SEA are undergoning vegetative restoration, including in the Red River Delta in Northern Vietnam (Long et al. 2021) and in the Mahakam Delta in Indonesia (Powell and Osbeck, 2010).

Mangrove Ecosystems

Over 30 percent of the world's coastal mangrove ecosystems are in SEA (Friess et al. 2016) with 20 percent of the global total in Indonesia (Sasmito et al. 2023). Mangrove ecosystems consist of mangrove trees, their carbon-rich anoxic soils, and the dynamic flows of brackish water that provide nutrients and moisture to a variety of species that inhabit mangroves' bulbous roots. The rate of mangrove degradation in SEA is among the highest in the world. As with other forms of wetland conversion, mangrove deforestation drivers include land use change for agricultural development, including rice paddies and oil palm plantations, and aquaculture development, such as shrimp and fish farming, as well as logging and timber production, oil and gas extraction, and urban development (Richards and Friess 2016). Early revegetation efforts in the region included mangrove timber stock replanting in the Philippines in the 1930s (Walters 2003) and mangrove seedling planting in 1978 in Agent Orange-impacted areas in Vietnam (Veettil et al. 2019).

Recently, mangrove restoration is moving from plot-based reforestation (direct planting) towards incorporating hydrological rehabilitation and ecological engineering (Gerona-Daga and Salmo, 2022; Ellison et al. 2020). While direct planting is still the predominant form of mangrove restoration, new mangrove restoration projects are integrating hydrological rehabilitation and coastal engineering methods to re-establish hydrological balance. We see this as connected to the growing new paradigm of mangrove governance (Sidik et al. 2023), which frames Southeast Asian mangrove and seagrass ecosystems as "blue carbon," or natural-climate solutions that can store atmospherically significant amounts of carbon (Alongi et al. 2016, Friess et al. 2022; Macreadie et al. 2021). According to Gerona-Daga and Salmo (2022) Indonesia leads in studies on hydrological rehabilitation methods, this can include making physical changes to the ecosystem to encourage tidal inundation or change surface elevation (Oh et al. 2017), while studies in Vietnamand Malaysia, incorporate coastal engineering such as constructing sea dikes and breakwaters or making use of groins, mollusks, and bamboo fences (Albers and Schmitt 2015;Nguyen et al. 2022; Phong 2022).

In many instances, mangrove restoration has encountered challenges due to governance issues, lack of community engagement and inadequate hydrological preparation (Friess et al. 2016; Mursyid et al. 2021; Sasmito et al. 2023; Suyadi et al. 2023). In the Philippines, large-scale mangrove plantation schemes using only one species of mangrove tree have failed due to the inability to achieve the correct estuarine conditions for the saplings and the lack of post-planting management plans (Barnuevo et al. 2017). In Indonesia, issues in scientific knowledge transfer to local communities has challenged project implementation and results (Dharmawan et al. 2017). Nevertheless, attempts at mangrove restoration continue to expand, including Singapore's OneMillion Trees initiative in the Sungei Buloh Wetland Reserve and Kranji marshes (Parks 2019). This increase is driven by rising policy interest and scientific evidence for the potential of blue carbon (Gerona-Daga and Salmo 2023; Sidik et al. 2023; Thorhaug et al. 2020). For example, Indonesia's mega-restoration project, Mangroves for Coastal Resilience, aims to rehabilitate 630,000 hectares of mangroves by 2024 (World Bank 2022). Such restoration efforts are bolstered by the financial promise of blue carbon markets (Friess et al. 2022).

Seagrass

The growing popularity of blue carbon has also drawn attention to seagrass restoration in the region as a potential nature-based solution to mitigate climate change and repair coastal infrastructures (Rifai et al. 2023; Stankovic et al. 2021). Seagrass restoration initiatives in SEA are more limited than mangrove restoration even though the region has the highest diversity of seagrass diversity and habitat types in the world (Fortes 2018; Fortes et al. 2018). The seagrass habitats found in SEA exist within shallow, partially enclosed coastal systems as well as in expansive estuaries (John et al. 2023). These areas experience significant daily and seasonal changes, such as light availability and salinity due to tidal fluctuations (Fortes et al. 2018). The distribution and health of seagrass meadows have suffered across the region due to increasing global temperatures from anthropogenic climate change, eutrophication from dredging, pollution from sewage, mine tailings, and thermal effluent, and an uptick in coastal development (Sudo et al. 2021).

Much of the research on seagrass restoration has been in the Philippines, home to the largest extent of seagrass in SEA (Fortes 2018). During the early 1980s, the government of the Philippines sought help from the Food and Agriculture Organization to explore the possibility of restoring seagrass in the country (Paling et al. 2009). To achieve this, an international consultant was appointed to facilitate a technology transfer initiative, introducing techniques for seagrass restoration, and conducting a trial transplantation program, which had limited success (ibid). The most effective way to promote seagrass recovery is by addressing the root causes of disturbance (Talbot and Wilkinson, 2001). However, this approach can be challenging, particularly in cases where limited resources hinder comprehensive environmental management changes. As a temporary measure, they suggested that transplanting seagrass and implementing artificial seagrass projects could offer short-term solutions (ibid). In the early 2000s, the Philippine National Seagrass Committee (PNSC) was established to overseeall activities related to seagrass and specifically, the UNEP/GEF South China Sea Project's goal of restoring 80 percent of the region's seagrass cover to the previous 1995 level (Fortes, 2018). More recently, interest in seagrass restoration as a nature-based solution is also ramping up elsewhere in the region, including in Indonesia (Rifai et al. 2023) and Vietnam (Veettil et al. 2022), due to the framing of seagrass ecosystems as blue carbon. This has opened new opportunities for finance and is growing private investment and financial interest in seagrass restoration projects (Stankovic et al. 2021, Friess et al. 2022, Macreadi et al. 2021).

The Political Ecology of Southeast Asian Wetland Restoration

Conceptualizing restoration as infrastructural land repair reveals that it is a social and political process. As wetland's ecological systems are repaired to a specific baseline (Ureta et al. 2020), this re-orders ecosystems services for precise climate configurations (Ramakrishnan et al. 2021). Such repair efforts aim to rehabilitate ecosystems to a previous environmental condition, as an anticipatory form of environmental governance (Hirsch 2020). However, as the previous section chronicles, such efforts continue to meet significant challenges, both in restoring ecosystems and in preventing the continuation of the original form of degradation. Thus, the process of wetland restoration in SEA often maintains the larger political-economic system that precipitated its degradation. Moreover, new efforts towards wetland restoration in SEA produces wetlands as NbS, turning the restoration of the very degradation that contributed to the climate crisis in the first place into new economic possibility. In this final section, we interrogate infrastructural land repair, first through examining repair's process and then by unpacking repair's political implications.

Infrastructural Land Repair: Experts, Technology and Finance

Infrastructural land repair involves a range of actors including humans (scientists, farmers, governments, investors) and nonhumans, such as abiotic (water, climate, and soil) and biotic entities (plants and animals). Interactions between them are mediated through experts, technology, and finance and restore both the terrestrial and aquatic features of wetlands, producing wetlands as green and/or blue infrastructures to enhance specific ecosystem services. Here, we examine how expertise, technology, and finance maintain the political-economic status quo in the face of ecological crisis.

Expertise: Who?

The global governance of wetland restoration involves a range of actors, working across national, international, and intranational scales to facilitate the rehabilitation of wetland ecosystems. Key international actors include the United Nations Environment Programme (UNEP), which recently declared the international Decade of Ecosystem Restoration, Wetland International, IUCN, WWF, Environmental Defense Fund, The Nature Conservancy (TNC), and the World Bank, to name a few prominent examples. Inter- and intra-national efforts toward restoration are shaped by the Ramsar Convention, an intergovernmental treaty established in 1971 signed by 168 nations designating wetlands as crucial sites for biodiversity, conservation, and facilitating international cooperation toward sustainable wetland use (Stroud et al. 2022). The Ramsar Convention marks the only multilateral environment agreement on a singular ecosystem type.

The United States, as a center of restoration ecology (Martin 2022), has been a critical location for the expansion of wetland mitigation banking (Lave and Doyle 2021) overseen both at state levels, and at the federal level by the Environmental Protection Agency (EPA), US Fish and Wildlife Service (USFWS), the National Park Service, and the US Army Corps of Engineers. The Natural Resources Conservation Service manages the Wetland Mitigation Banking Program. Across Europe, the European Union has contributed over 23 million euros to the expansion of waterLANDs restoration project, funded through the EU Horizon 2020 Green Deal Call 7.1, aimed at enhancing wetland carbon storage and tailoring financial solutions for wetland restoration (WaterLANDS 2024). In China, the National Wetland Conservation Program, which began in 2003, is the largest wetland rehabilitation program in the world. It is largely funded by the Chinese central government and managed by the Office of Wetland Conservation and Management of State Forestry Administration (Liu and Ma 2024). In SEA, central NGO actors include the World Bank, United Nations Development Program (UNDP), TNC, WWF, Wetlands International, the Asia Foundation, The Wildlife Conservation Society, Birdlife International, and Conservation International. Most recently, the World Resources Institute, established the Southeast Asia Climate and NbS (SCeNe) Coalition at COP28. This coalition "aims to democratize access to knowledge, technical assistance, and climate finance so that frontline organizations (FOs) across SEA can engage in NbS projects with full awareness and consent." The main output of SCeNe is their NbS Tool, signaling the rising interest in directing carbon investor funds toward FOs in SEA. While Chinese assistance in nature-based solutions play a role in SEA (Zhu et al. 2024), we find a clear gap in the literature chronicling the extent and specifics of Chinese investment in the financing of SEA's wetland restoration.

Wetlands for NbS is influential in international and national policy circles (Hamel and Tan 2022; Ureta et al. 2020; Wang et al. 2022), because of the authority of scientific expertise that is facilitated by the capacity of science to "travel" (Shapin 1998). Such expertise is produced by formally trained scientists, engineers, or environmental analysts and refers to the authority that delineates overall restoration plans and procedures, not the physical labor of restoration itself.

Wetlands do not pre-exist as infrastructures. They are actively framed as such through scientific expertise, which is then upheld and circulated in policy circuits (Goldstein 2016). The physical act of wetland restoration, however, can require re-engineering the landscape's hydrology which determines the amount and frequency of water available in a landscape (Nugraha et al. 2022; Tien et al. 2021). Hydrological restoration also draws on ecological engineering to ensure wetlands' capacity to enhance ecosystem services. For example, Noralene Uy and Chris Tapnio (2021) invoke studies from ecological engineering to conceptualize the potential for seagrass and mangrove restoration as blue/green infrastructure in the Philippines. Moreover, the recent interest in seagrass and mangrove ecosystems as NbS (Lima et al. 2023; Rifai et al. 2023; Stankovic et al. 2021) has focused on their carbon sequestration capacity above other ecosystem and cultural roles, whereby the ecosystems are primarily understood through their capacity to hold atmospheric carbon.

Investigating how expertise is mobilized in wetland restoration raises questions: one, how are wetlands conceptualized as degraded (who defines restoration?), and two, how are they managed (restoration by whom?). Ecological restoration is an extension of green environmentalism, the conception that Nature can be returned to its original "baseline" through careful human management if this process is overseen by rational and objective experts (Lorimer 2017). For instance, in Benjamin Thompson's (2018) work, he describes the structure, specificity, and elaborate degrees of expertise governing mangrove restoration in Thailand. Since 2004, mangrove management has been carried out by the Department of Marine and Coastal Resources, which is divided into over 45 technical "substations," each having a Mangrove Management Unit. In the case of the Mekong Delta, Jacob Weger (2019) describes how expertise "draws together networks of actors via shared interests and interpretations" through translation, and how expert knowledge travels across scales of analysis and intervention. Sarah Moser and Emma Avery (2021) demonstrate how expertise is mobilized in the new Forest City eco-city development project in Malaysia, which was built on reclaimed land and is constituted of four artificial islands along the strait of Meleka on top of one of the largest seagrass beds in Malaysian territorial waters. They show how the eco-rhetoric of Chinese property developers maintains a form of "green" identity that claims to "bring the symbiotic coexistence between city and nature to a new height" (ibid.: 2) despite the questionable ecological impact of constructing a city on such a biodiverse ecological habitat. They also demonstrate how this normative and apolitical discursive framing may mask the multi-scalar politics of Forest City, instrumentalizing urban greening for Chinese economic, territorial, and geopolitical goals.

Restoration as a NbS render wetlands technical (Li 2007). Ecological engineers, scientists, and technocrats define ecological baselines, creating their metrics of comparison and facilitating restoration management. This is a form of "stewardship from above" (Huff and Brock 2023: 10), which centers simplification, standardization, and technification. Expert scientists translate the complexity of wetlands into discrete variables that can be measured, modeled, mapped, and managed by transactional units, legible to financial and insurance markets (Goldstein 2020), supposedly securing the future by maintaining the present. This renders complex ecological functions and individuals into standardizable, legible, and quantifiable units (Nelson and Bigger 2022). Benoit Ivars and Jean-Philippe Venot (2019: 1040) describe how expertise can create new imaginaries of wetlands, making Myanmar's Ayeyarwady Delta into a "global wetland," for example, for worldwide relevance that requires generic research and governance approaches.

Through technical expertise, dynamic wetlands are parceled into their ecosystem services: complex processes of gaseous exchange become reduced to carbon cycling, for instance. Such expertise can privilege scientific knowledge of an ecosystem over other lay, local, or Indigenous conceptions (Braun 1997). Recent critical work is beginning to examine the local knowledge of wetlands (Gorman 2023), but there is a dearth of scholarship on local perceptions of wetland restoration in SEA. Such expertise is also shaped by economic ends. As Goldstein (2016) describes, peatland scientists' role in restoring degraded peat swamps in Indonesia delegitimated corporate attempts toward agricultural land development but validated peat restoration in service of carbon sequestration for carbon markets, embodying a *carbon-ontology* (Krzywoszynska and Marchesi 2020) of peat swamps. Experts oversee, and influence, the technologies, and the ways that technologies inform wetland restoration.

Technology: How?

An array of technologies shapes wetland restoration, reworking wetlands into green/blue infrastructure. As infrastructure studies makes clear (Star 1999), infrastructures are never built from scratch but rather are installed on and in existing land and ecosystems. Technologies restore wetland's ecological base to perform as infrastructure, digging, draining, and dredging to release the wetlands intrinsic ecological functions. These technologies are simultaneously physical and nonphysical. Physical technologies range from the cranes, trucks, and excavators used to encourage tidal inundation, alter surface elevation, and dig canals to the sea dikes, breakwaters, groins, mollusks, and bamboo fences constructed to encourage tidal inundation or change surface elevation, used to manage the moisture regime (Nugraha et al. 2022). In Morita's (2016) examination of how the Chao Phraya Delta in Thailand was made into aquatic infrastructure, he describes irrigation technologies that managed the flow of water in the delta to reduce flooding. Anja Nygren and Anu Lounela (2023: 297) describe how, through the processes of "dredging, draining, drying, sedimentation and salinization," these technologies over-emphasize the hydrological components of wetlands. This privileges a water-centric conception of wetland ecosystems that obfuscates issues of land tenure and control, exacerbating local environmental vulnerabilities.

Nonphysical technologies refer to both the digital technologies and technologies of governance to restore wetlands into infrastructures. Restoration scientists and policy experts use a range of digital technologies—GIS, satellite imagery, remote sensing, and component surveys—to develop the *idea* of wetlands as infrastructures, and which can enumerate, monitor, and track the ecological services that wetlands provide, such as carbon. In Indonesia's peatlands, Goldstein (2020) shows how satellite imagery and remote sensing creates new volumes of governable space. This process is an example of what Tania Li (2014) describes as statistical picturing: using technologies, land can be assembled into a new form and valued. The technologies of governance that restore wetlands into infrastructures include institutional arrangements, legal frameworks, and political systems that invoke restoration as an NbS solution. These technologies, or what Li (ibid.) calls "inscription devices," restructure the social relations of wetlands, expanding its network of actors and the wetlands' perceived potential for value.

As Huff and Brock (2023) have noted, restoration necessitates new technologies of inscription, such as satellite imagery and remote sensing, to track and quantify repair and thus enable financial valuation. Rini Astuti (2020: 284) describes how restoration in Indonesia's peatlands requires new technologies of governance, which produce new spatio-ecological units such as "peatland hydrological unit, peatland ecosystem function and peat dome peak." Such units manipulate dynamic ecosystem processes so they can be legible to capital. Such technologies are becoming central to the restoration for mangrove and seagrass ecosystems as well, with the use of aerial drone imagery to quantify the potential carbon stocks of coastal ecosystems (Fakhrurrozi et al. 2023; Kidangoor 2023). However, the use of such digital technologies is often for processes that preclude easy quantification, such as carbon sequestration potentials. As Goldstein (2022) has described in the example of peatland restoration, these scientific uncertainties can be incompatible with financial uncertainty, creating a feedback loop of data collection that stalls the investment and thus success of these restoration projects.

Finance: Why?

In reviewing scientific and critical social science literature on wetland restoration in SEA, we find that framing restoration as a NbS, as blue/green infrastructure, or as a bundle of discrete ecosystem services, is generating new financial engagement with wetland ecosystems. This offers novel ways for wetlands and their ecological processes to be useful to capital. *Infrastructural land repair* revalues the land, labor, and capital that has been eroded by monetizing the use-value of each within repair through the expertise, technologies, and finance that underpin restoration. In this way, wetland restoration is undertaken to "to address crises brought about by patterns of capital accumulation and uneven development, such as environmental degradation, changes in labor markets, and an unwillingness by actors to absorb costs of producing negative environmental externalities" (Cohen and Bakker 2014: 133). Indeed, the growing financialization of wetland restoration in SEA demonstrates this. With the increase vision of peatland restoration as a NbS (Strack et al. 2022; Tan et al. 2022), peatland restoration efforts in Indonesia have been seen as a new possibility for innovative climate finance, in large part due to its climate services (Bonn et al. 2016; Sari et al. 2021). The influence of finance within peatland restoration includes private investment in peatland restoration via restoration concessions (Buergin 2016; Miller 2022) as well as REDD+ financing for carbon mitigation (Pham et al. 2021). In mangrove and seagrass ecosystems, the blue carbon framework offers the potential for new carbon marketing in developing the financial frameworks and mechanisms to implement blue carbon finance (Friess et al. 2022; Sidik et al. 2023), with SEA poised to be a global leader in Blue Carbon due to its high mitigation potential (Macreadie et al 2021). In 2023, the World Economic Forum (2023) signed the first partnership on blue carbon with the Indonesian government, to support efforts to scale up blue carbon finance. In the Mekong Delta, efforts toward climate adaptation and resilience are capital-intensive, and development projects rely on donor-driven climate finance to construct green infrastructures (Chandrasekharan Behr et al. 2020; Thomas 2023).

Such examples of financialization exemplify how restoration in SEA can act as a socio-ecological fix under capitalism (Castree and Christophers 2018; Ekers and Prudham 2017), consistent with James McCarthy's (2015: 2495) definition of a socio-ecological fix as "something that directly engages with and resolves, mitigates, or postpones a structural impediment—including any environmental one—to sustained capital accumulation." Capitalism creates barriers to its own future, in this case the degradation of wetlands through extractive industries, and thus, market-based solutions enable capital's own expansion (Buscher and Fletcher 2020). Wetland restoration in SEA can thus be a socio-ecological fix for capital, which requires sinking large-scale, long-term investments into landscapes (Ekers and Prudham 2017) and takes considerable time (Bayraktarov et al. 2016). Through the speculative practices (Bodin et al. 2022; Dressler et al. 2018) and possibilities of financing ecosystem repair, wetland restoration in SEA may enable degraded wetlands to become economically viable once again. While a socio-ecological fix is, by definition, capital invested in new locations or industries (Ekers and Prudham 2017), wetland restoration in SEA functions not just as a mechanism for accumulation but might also become a form of *re-accumulation,* generating second order "value from ruin" in the same landscapes left degraded by first-order capitalist extraction (Dressler et al. 2018; Knuth et al. 2019). Green and climate finance in SEA thus uses wetland restoration projects to provide ecosystem services, invoking an "economy of repair," in which "nature becomes valued not just for its use in production or recreation, but also for its repair or restoration" (Huff and Brock 2023: 16). As Huff and Brock (2023) warn, this may lead to "accumulation by restoration," whereby nature is rendered re-investable through the financialization of its repair (Canning et al. 2021; Knuth et al. 2019). However, while the literature we reviewed does outline the increasing role of finance in wetland management, there are few empirical examples discussing the specific mechanisms of financial accumulation through which wetlands are restored. While conceptual framings, including Huff and Brock's (2023), are helpful in offering a theoretical framework for understanding efforts like Blue Carbon as well as other carbon credit schemes engaged in SEA wetland restoration, more case-based, empirical work is needed to delineate how and to what ends, exactly, restoration enables new forms of capital accumulation in SEA.

The Limits of Repair: Maintaining Disrepair?

The process of infrastructural land repair is clearly political. As a novel socio-ecological fix, it upholds existing socio-ecological systems and relations, building the social, political, and economic scaffolding for wetland restoration while simultaneously obscuring the political backdrop of repair. Infrastructural land repair offers wetlands as a solution to wetland degradation—and the current climate crisis more generally—in a way that precludes larger systemic analysis or reform. As Erik Swyngedouw (2010: 222) argues, socio-ecological fixes "make sure nothing really changes. Stabilizing the climate seems to be a condition for capitalist life as we know it to continue." This form of repair perpetuates the status quo, upholding and expanding the political-economic system that culminated in wetland disrepair in the first place, while forging new inroads for capital accumulation as outlined in the previous section.

Thus, restoration in this sense, could be seen as an example of what Julie Guthman calls the *limits of repair*: maintaining a system amidst continuous change and crisis. She warns this form of repair could cause iatrogenic harm, whereby the solution itself exacerbates the very problems it is meant to resolve, as "problems arise along how the cures actually work" (2019: 23) This raises questions about how this process, through its financial potential, might result in land grabs and dispossession (Barbesgaard 2018) or, as we see in some cases in SEA, undermine the initial goal of ecosystem restoration itself. Despite ambitious wetland restoration efforts in SEA, much restoration still has not yet achieved its goals of either restoring ecosystems or enhancing ecosystem services. Restoration could therefore be emblematic of what Stephanie Wakefield and Bruce Braun term the *katechon*: "the permanent management of the present to hold back forces of change" (2018: 203). The katechon wards off chaos in a continual loop of crisis and risk management. In the katechon, there is no promise of a different future, possibility, or an end to this loop. The chaos of the climate crisis is created by the same order the katechon upholds.

However, this does not have to be the case for infrastructural land repair. Noel Castree and Brett Christophers (2018) offer a cautiously optimistic reading of ecological fixes and outline the potential for finance to rebuild alternative, less extractive systems, for instance. Webber et al. (2022) expand on this notion, outlining possible financial contours of reparative climate infrastructures. Ultimately, as wetland restoration efforts in SEA continue to proliferate, it is clear more critical social science research is needed to examine how it unfolds and to elucidate its larger political implications.

Conclusion

In this article, we chronicled the recent trend of wetland restoration in SEA in peatlands, deltas, mangrove, and seagrass ecosystems, identifying how restoration is used to ensure specific ecosystem services for climate mitigation and adaptation. We suggest that restoration takes the form of *infrastructural land repair*, the process of restoring dynamic ecosystems for specific anthropocentric and economic aims, and parcels ecosystems into discrete ecosystem services through the expertise, technology, and finance that underpin restoration efforts. We underscore that, in general, wetland restoration in SEA maintains the same political-economic systems that resulted in wetland degradation in the first place. We also examined how restoration functions as a socio-ecological fix, highlighting the need for research that examines the growing world of restoration finance to ascertain if restoration by accumulation is already underway within SEA wetlands. As the United Nations recently issued a declaration for a global decade of restoration, wetland restoration worldwide is poised to expand (UN 2024). SEA is thus a valuable context to learn from. While there is much scientific scholarship on wetland restoration in SEA, there is less research from critical social scientists, which is needed to examine the social, political, and economic implications of such projects.

Following this review, we propose three ways we would like to see this literature move forward in the SEA context. First, while there is an abundance of scholarship that critiques financial tools and mechanisms theoretically, there remains a substantial need for critical scholarship that unpacks how financialization unfolds in practice through restoration efforts. Second, there is a lacuna in scholarly literature that examines the infrastructural labor required to enact restoration, including who is doing the physical repair, where they are coming from or located, and their remuneration (Randle 2022; Stokes et al. 2024). This is important, as insights into the labor of restoration is vital to understanding how restoration revalues land. Third, while much of the critical literature on restoration elucidates how repair may perpetuate injustice, we see a space for work on SEA wetlands that theorizes and reviews forms of repair that offer more reparative environmental futures (Webber et al. 2022). Indeed, repair is theoretically rich due to its double-sidedness (Corwin and Gidwani 2021; Jackson 2014): in the act of repair there is also the hope for other, more caring socio-natural relations. In the US context, there is a growing literature on reparations and reparative forms of restoration, the possibilities of constructing "restoration otherwise" from the ruins of climate change (Barra 2024; Usher 2023). As wetland restoration continues to scale up across SEA and draws increasing attention of the financial sector, there is a clear need for scholarly work on and from the region that attends to how restoration can be engaged as a truly reparative climate solution.

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