Chapter 1
Introduction: The Vulnerability and Transformation of Indonesian Peatlands

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Abstract Tropical peat swamp forests that started to experience fires in the 1960s in Sumatra and in the 1980s in Kalimantan are now seriously degraded in many places in Indonesia. But from a longer perspective, we can see the tropical peat swamp forests' resilience and adaptation. There have been several reports on how deep local knowledge has helped curb further degradation of these forests. Large-scale commercial logging had been undertaken in the Riau area in Sumatra in the 1860s; however, no serious peatland degradation and large-scale fires were reported until the end of the colonial era. Truly serious degradation started only in the middle of the 1980s when large-scale drainage systems were created to support the extensive cultivation of oil palm and timber plantations. Serious fires broke out in 1997, and in 2015 at the time of El Niño. Today only 18.4% of total peatlands in Indonesia are undisturbed natural peatland forests. We also find several initiatives to restore

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degraded peatlands. For one thing, the government has established the Peatland Restoration Agency (BRG) to coordinate the acceleration of peatland restoration and promote the welfare of local people in the peatland area. For another, international organizations, companies, nongovernment organizations, and local communities also have started their respective programs to rehabilitate the peatlands. Such developments can be interpreted as attempts at transformation, that is, the creation of a fundamentally new system in response to ecological, economic, or social (including political) conditions that render the existing system untenable. This volume intends to reshape the discussion on peatland degradation and regeneration with the ideas of vulnerability, resilience, adaptability and transformation, and deepen the understanding of degradation and regeneration.

Keywords Tropical peat swamp forest · Vulnerability · Resilience · Adaptability · Transformation

1.1 Introduction

Tropical peat accumulation was a primary feature of the Holocene, as well as of the last glacial period. Peat accumulation in most tropical coastal areas in Southeast Asia commenced around 4000–5000 BP (Page et al. 2006; Anderson and Muller 1975). The subcoastal and inland peatlands in Borneo date back to the late Pleistocene (ca. 29,000 BP) (Page et al. 2006; Anshari et al. 2001, 2004).

Tropical peatlands store a huge amount of carbon. Tropical peatlands may account for only 10–12% of the global peatland resource by area, but owing to their considerable thickness and high carbon content, they store between 50 Gt and 70 Gt (16–21%) of peat soil carbon, or about 2–3% of the carbon stored in all soils globally (Page et al. 2002, 2006).

Tropical peat swamp forests in their natural state make an important contribution to regional and global biodiversity (Andriesse 1988; Page and Rieley 1998) providing a vital, but undervalued, habitat for rare and threatened species, especially birds, mammals, reptiles and freshwater fish (Ismail 1999; Thornton et al. 2020). "Until recently, peat swamps were assumed to be hostile, acidic places where the biodiversity was low." "Officials and developers argue that there is no point conserving the swamps because there is 'nothing' there. These places don't have big, sexy animals, but in almost all cases, when they say a place is species-poor, they're wrong" (Dennis and Aldhous 2004, pp. 396, 398). Posa et al. (2011) documented 1524 plant species in peat swamp forests in Southeast Asia, of which 172 were endemic species, and 219 species of freshwater fish of which 80 species were endemic.

Peatlands have been exploited for a long time, starting with small-scale clearing and collection of nontimber products by local people. Fisheries, small-scale shifting cultivation and rubber cultivation provided principal sources of livelihood for local people (Furukawa 1992). Commercial logging has also taken place in Riau, Sumatra, Indonesia, since the middle of the nineteenth century but did not seriously disturb the peat swamp forest ecosystem (Mizuno et al. 2021). The exploitation of peatlands for the purpose of oil palm and timber since 1980s, however, accompanied by construction of large-scale drainage projects, has seriously degraded peatlands, resulting in burning and abandonment by settlers.

1.2 Vulnerability of Peatlands

Peatlands ecosystems are vulnerable, especially to the changes wrought by construction of large-scale drainage systems (Mizuno et al. 2016). This book, which is the result of over 12 years of peatlands research conducted by Japanese and Indonesian scholars from a range of natural and social science disciplines, describes the many dimensions of vulnerability, resilience, adaptability, and transformation of Indonesian peatlands social and ecological systems.

In principle, peatlands are not suitable for cultivation because once exploited, they show characteristics of acid sulfate soil, as well as subsidence, disappearance and degradation (Furukawa 1992, pp. 25–31). Nevertheless, Indonesian peatlands have been the object of numerous exploitation or development policies. The construction of drainage systems has caused significant CO_2 emissions (Jaenicke et al. 2008) arising not just from the decomposition of peat (Agus et al. 2010) but also from the fires that have become common in the newly-desiccated landscapes (Page and Hooijer 2016; Purnomo et al. 2017, 2019). As reported by Page et al. (2002), during the 1997 El Niño event, 0.73 million hectares of peatland were burned. Haze from the peatland fires spread to neighboring countries (Varkkey 2013), causing health problems among local populations (Uda et al. 2019; Marlier et al. 2019). Emissions from deforestation due to drainage and fires have been the single largest source of greenhouse gas (GHG) emissions from land use in Southeast Asia. Total carbon loss from converting peat swamp forests into oil palm production zones is 59.4 ± 10.2 Mg of CO_2 per hectare per year during the first 25 years after land-use cover change, of which 61.6% is emitted from peat. Of the total amount (1486 ± 183 Mg of CO_2 per hectare over 25 years), 25% is released immediately from land-clearing fire (Murdiyarso et al. 2010).

Almost every form of peatland development has to some extent involved drainage of the peatland itself and/or its surrounding area (ASEAN 2007). Traditionally, farmers developed relatively small and closed-ended canals for drainage. Over the years many more canals were constructed for logging activities, both in order to drain peatland soils and to facilitate transport of the harvested logs. More systematic drainage began in the mid-1990s, led by the Mega Rice Project (van Beukering et al. 2008; Wösten et al. 2008) and companies establishing acacia and oil palm plantations (Wösten et al. 2008). Evers et al. (2016) have criticized the proposition that drainage-based agriculture can be a component of sustainable tropical peatland development. They argued that even where current guidance and/or policies are implemented to monitor water table depths (WTDs) and limit development to only certain proportions of peat domes, such "sustainable" practices inevitably result in significant GHG emission, long-term subsidence of peat soils, significant flooding in Southeast Asian coastal peatlands, as well as significant losses of biodiversity. The race to catalogue biodiversity before it disappears is particularly intense in the peat swamps, which are vanishing at a frightening rate (Dennis and Aldhous 2004).

1.3 Resilience and Adaptation of Peat Swamp Forest

Peat swamp forests can instead be a showcase for social and ecological resilience and adaptation. Resilience here refers to the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity. We therefore understand resilience as the capacity to change in order to maintain a relatively consistent identity. Adaptability (adaptive capacity) here refers to the capacity of actors in a system to influence resilience (Walker et al. 2004; Folke et al. 2010).

Momose (Momose 2002; Momose and Shimamura 2002) has vividly portrayed sustainable use of mixed peat swamp forests along riverbanks of the Kampar River in Riau Province. People in such areas have traditionally lived in close relationships with mixed peat swamp forest. Their material interactions involve hunting, gathering of many food and utilitarian species, and agriculture, especially swidden cultivation of rice. Spiritually they rely, for example, on the healing powers of plants and herbs found deep in the forest. They possess a rich knowledge of the local landscape and of the networks of trade, marriage, and migration that have sustained local lifeways. Such networks ensured that village peoples successfully adapted to environmental and social changes through time, including population increase, and avoided overexploitation of mixed peat swamp forests. The Malay people of this study have pushed into the frontier of the tidal zone, engaging in fishing, intensive agriculture, and the use of mixed peat swamp forests of the area. They extended their traditional networks into cities via trade. These linkages can be thought as relieving population pressure on peatlands.

Before the introduction of large-scale commercial logging, timber plantations, and intensive oil palm plantations there were no reports of serious damage from fires. The traditional *Ongka* logging (a method of logging using wood rails and sleighs) observed by the local people did not have the technical capability to rapidly expand the logging area, so there was some balance maintained between logging and tree growth (Momose 2002). The peat swamp fires began in the 1960s in Sumatra and then in Kalimantan in the 1980s. During periods of drought, such as in El Niño years, large fires broke out. In Kalimantan, large fires flared for the first times in 1982, 1992, and 1997, even though there had been severe droughts in 1962, 1964, and 1973. On the other hand, in Sumatra, peatlands became more sensitive to autumnal drought after 1985, as there were no significant fires documented between 1960 and 1984 (Field et al. 2009).

In Riau, Sumatra, where our studies were mainly concentrated, numerous large-scale fires were recorded since the early 1980s (Kieft et al. 2016). The mega-fires of

1997–1998 were the biggest fire events in Riau (and Indonesia). The Riau fires were attributed to the large-scale exploitation of peatlands to meet demand for peatland commodities such as oil palm and timber for pulp and paper (Saputra 2019).

This history of exploitation or peatland use demonstrates that the peat swamp forest was resilient at least until the 1960s. For example, during 1860–1940 there were thriving *Panglong* (logging) businesses in the Riau peatland area. *Panglong* was the main business in Riau and Riau islands in Sumatra, run by Chinese businessmen based in Singapore. Chinese laborers were recruited mainly from Singapore. Charcoal-making businesses run by local people were included in *Panglong* (Pastor 1927). The amount of timber logged in 1927 was 450,000 m^3—the largest haul in the Netherlands Indies timber industry (Jelles 1929). There were concerns about depletion of timber resources at the time, but no reports of serious peatland degradation or peatland fires (Sewandono 1937).

Page et al. (2009) argue that the livelihood activities of the Dayak people in Kalimantan and the Malay people in Sumatra have been ecologically compatible with maintaining peatland natural resource functions with only limited and localized damage. There is evidence that peatland ecosystems could accommodate small-scale agriculture, sago planting, nontimber product collection, and fisheries throughout the colonial era (Reep 1907; Mizuno et al. 2021). Since 1965, however, the peat swamps in those areas have been subjected to rapid land-use changes and degradation as a result of transmigration (both spontaneous and officially-sanctioned), large-scale logging (legal and illegal), the establishment of oil palm plantations, decreasing rotation of timber plantations to supply the pulp and paper industries, and fire. By 1988, more than 93% of the peat swamp forests of Sumatra had been degraded, leaving only a few areas in primary ecological states (Page et al. 2009).

Today, peatlands in Indonesia are seriously degraded. According to Uda et al. (2017), of the total 14,915,000 hectares of peatland, undisturbed natural peatland forest comprises only 18.4% of the total, while disturbed natural forest amounts to 24.7%. Meanwhile degraded peatlands, including abandoned land, account for 26.9% of the total, oil palm forests 16.2%, and acacia plantation forest 16.2%. Of the remaining 24.5%, 6.2% is comprised of dry agricultural land, 2.4% of wet rice field, and there are a number of other uses.

1.4 Transformation-Peatland Restoration

To be sure, there have been many peatland restoration efforts. Rewetting has been given priority; canal blocking (Applegate 2012; Ritzema et al. 2014) and hydrological restoration have been discussed (Jaenicke et al. 2010). Rewetting is the key for rehabilitation, and paludiculture (Uda et al. 2020)—the practice of crop and timber planting on wet soils—must be undertaken on rewetted peatland. In her report on the developments of paludiculture, Tata (2019) reported that it was difficult to maintain water levels required by paludiculture, and that lower water tables led to subsidence and increased carbon emission. Dohong et al. (2018) discussed the technical aspects of peatland restoration, focusing on hydrological and vegetational restoration.

The Peatland Restoration Agency (*Badan Restorasi Gambut*, BRG) was established by presidential decree in 2016 to coordinate the acceleration of the restoration of peatlands and promote the welfare of local people in the peatland area. The BRG has advocated the 3R program—Rewetting, Revegetation, Revitalization of Livelihood. The 3R program has been implemented at Desa Peduli Gambut (Peatland Care Village). Today a number of 3R trial areas have been established in order to popularize the program. Studies show that these trial areas, for example in the sago palm area in Kepulauan Meranti District, Riau Province, are still limited in scope, however (Ehara et al. 2018).

There are also several peatland restoration initiatives led by international organizations, the private sector, and nongovernment organizations. Companies that secured ecosystem restoration concessions have attempted gradual revegetation in deforested areas, assisted natural regeneration, rewetting, community-based fire prevention, and established an agroecological farmer school (Darusman et al. 2021). They have also introduced a new method of rewetting called "stock-based water management," which functions like an irrigation system for the paddy field. This system is designed to achieve a high level of water retention in the ecosystem (Kato et al. 2021).

Such developments can be interpreted as attempts at transformation, that is, creation of a fundamentally new system in response to ecological, economic, or social (including political) conditions that render the existing system untenable (Walker et al. 2004; Folke et al. 2010). From our perspective on peatland ecosystems and livelihoods, this new system should not degrade peatlands and must create a sustainable ecosystem. It should guard against peatland fires and revive local livelihoods.

Transformations can be seen to consist of three phases (Olsson et al. 2004; Folke et al. 2010): (1) being prepared for, or even preparing, the social-ecological systems for change; (2) navigating the transition by using crisis as a window of opportunity for changes; and (3) building resilience of the new social-ecological regime. Transformational change often involves shifts in perception and meaning, social network configurations, patterns of interaction among actors, including leadership and politics and power relations, and associated organizational and institutional arrangement (Folke et al. 2009, 2010; Huitema and Meijerink 2009; Smith and Stirling 2010). The new system, once established, should have resilience and adaptability as described.

The current 3R program may thus be viewed as a kind of preparation for the socio-ecological system to come, or as a way of navigating the transition by making use of a crisis as an opportunity for change. Both the Indonesian government and president have repeatedly emphasized the importance of taking care of the peatlands and the urgency of fire prevention in peatland landscapes. The BRG diffused the idea through its Desa Peduli Gambut (Peatland Care Village) and MPA (*Masyarakat Peduli Api*, Fire Care Community) program, which will be explained in volumes to follow.

The peat swamp forest may have been resilient in the past, but as mentioned it is still vulnerable today. Transformation to a newly resilient socio-ecological state might depend in part on the lessons of peat swamp forest life that lasted for thousands of years. At present, the peatlands are facing a crisis, but there are reasons for hope in the resilience and adaptability of the new system, such as the people's initiatives to curb fires or trials in developing a new paludiculture, or tapping into local knowledge about the peat swamp forest to keep the ecosystem sustainable.

While there are numerous studies on peatland degradation and restoration from various viewpoints such as carbon emission, fire, haze, water management, revegetation, and restoration, an integrated idea toward understanding, reconstructing, and reshaping the issue of peatland degradation and regeneration is still lacking. Our long-term research project, therefore, presents an integrated approach to transformation of peatlands, investigating what "resilience" of peat swamp forest means from the perspective of ecological science, social science, and cultural livelihoods. Our project is fundamentally concerned with local knowledge on the resilience of the peat swamp forest, and works together with Indonesian scholars and communities in order to articulate the many dimensions of transformation of degraded peatlands.

1.5 Structure of the Book

The present volume discusses vulnerability, resilience, adaptability, and transformation. Part one focuses on social and ecological vulnerability. Chapter 2 by Mizuno et al. explicate the dynamics of vulnerability of the peat swamp forest in the research village of Tanjung Leban, Bengkalis District, Riau Province. The former local population comprising Malays had established convivial interactions with the peatland ecosystem. However, especially after an acacia plantation was established in the area, peatland fires began to break out. As a result, people turned to logging the peat swamp forest, and land they cleared was subsequently distributed among local people. Along with the development of the settlement and the increase in the number of migrants, people have acquired land through clearing, inheritance, and purchase, and began to secure land rights through letters of certification issued by village authorities. Those lands without letters tend to be abandoned after experiencing fires, on the other hand, lands with letters to certificate land rights tend not to be abandoned, although those land also experienced (some time repeated) fires.

Chapter 3 by Fujita et al. argue that peat swamp forest vulnerability can be understood in part through study of its bird population. Contrary to earlier assessments, Fujita et al. demonstrate that peat swamp forest has a high species variety and overall number of birds. Acacia plantation forests tend to have low numbers of birds, while intermediate zones of rubber forest and village forest have middle-level frequency of bird appearance. These data show the vulnerability of the acacia forest, and some degree of adaptability in the rubber and village forests, hinting at the new regime of transformation from the viewpoint of biodiversity.

Chapter 4 by Samejima et al. take a very similar approach, but this time from the perspective of mammals. Their study shows that the frequency of mammal presence in the peat swamp forest and the acacia forest follows a similar trajectory: high in peat swamp forest and low in acacia forest. This study therefore also points to the resilience of the peat swamp forest and the near term vulnerability of the acacia forest.

Chapter 5 by Saptomo et al. show that CO_2 emission from bare peatlands is affected by temperature and soil humidity. Lower temperature and higher soil humidity lessen CO_2 emission. Soil humidity is not easily controlled, and rainfall has a clear influence. This study therefore demonstrates the vulnerability of bare peatlands.

While all the foregoing papers demonstrate the resilience of the peat swamp forest and vulnerability of peatlands, especially after degradation or the spread of the acacia forest, the next three papers emphasize the peat swamp forest's resilience and adaptability. Chapter 6 by Kok-Boon Neoh et al. discuss termites in degraded and abandoned peatlands. Even as local people wage war against termites, which are typically seen as pests, the insects play a potentially important role in peatland restoration. Owing to the unusual peat ecosystem, highly acidic, anaerobic, and sensitive to fire and other weather conditions, earthworms are nearly absent from disturbed peat. Termites are therefore seen as a potential major soil engineer—if their services could be harnessed efficiently. To ensure the survival and growth of planted trees, farmers can take into account species selection and wood resistance to termite attacks. Otherwise, sustainable pest management and preventive measures should be devised before termites become a serious threat to newly planted trees. Local knowledge can harness termite power as an engine of resilience in degraded peatlands.

Chapter 7 by Suzuki discusses timber processing and retailing in Pekanbaru, Riau Province, Indonesia. Timber supply has changed along with its sources—from the peat swamp forest to the village forest and acacia plantation. The timber processing industry is quite flexible in this way. From hardwood timber to village forest timber such as Mahang, and Acacia, the source tree species have changed. Some molding mills and timber kiosks cope, depending on the pulp and paper companies. This is because it is easy to process and retail timber under company management, without any permission from local governments. On the other hand, the other molding mills and timber kiosks sell timber to local people and the government. They transform their management to adapt to the current situation of timber shortage, such as changing timber species from hardwood to softwood, selling any kind of lumber to retain timber size, and so on. This flexibility in the timber processing industry and retail businesses can be considered adaptability, and it might very well support the timber supplied by future paludiculture in the peat swamp restoration forest.

Chapter 8 by Gunawan et al. discuss the biomass and carbon restoration of the peat swamp ecosystem. It compares biomass and carbon storage among the peat swamp forest, exploited forest, and wind-disturbed forest. The amounts of biomass and carbon storage were higher in the peat swamp forest, followed by logged forest and wind-disturbed forest. Of the peat swamp forest tree species, growth rate of

Cratoxylum arborescens was highest, and followed by *Tetramerista glabra*. Some typical canopy species of peat swamp forest such as *Tetrameristra glabra* and *Palaquium burckii* are promising in their use to rehabilitate logged-over forest areas. These data show the possibility of reforestation with peat swamp forest tree species. On the other hand, carbon storage underground was quite high among any kind of peatland, natural forest, logged-over forest, wind-disturbed forest, oil palm forest, acacia forest, and rubber garden. In this case, it is important to avoid fires that could release carbon that is stored even in degraded peatlands.

The next four papers consider transformation of the peatland ecosystem. Chapter 9 by Sutikno et al. discuss water management for integrated peatland restoration. This study of water management was conducted at the Pulau Tebing Tinggi Peatland Hydrological Unit (PHU) with the purpose of peat rewetting and supporting revegetation efforts and revitalization of livelihood. The canal block constructions, paludicultures, and aquacultures were the integrated activities conducted to support peatland restoration. Two types of canal blocks constructed from wood and vinyl sheet pile were introduced in this pilot project. Four key parameters indicating progress in peatland restoration were monitored periodically, including water table, land subsidence, emission, and vegetation growth.

Chapter 10 by Tata presents the case for plant genetic diversity in peatland restoration. To achieve the target of peatland restoration with species survival rate of 90%, there must be a sufficient quantity of quality planting stocks to ensure genetic value and plant health. The strategy should involve various seed combinations, including not only local species but also those native to other similar environments. The planted jelutung in Jambi and Tumbang Nusa, Central Kalimantan, showed no loss of genetic diversity. Plants in those areas could be used as a source of seeds for peatland restoration throughout both provinces. Villagers with seedling nursery businesses should be made aware of the potential risk of genetic drift if they are collecting seeds from a few individual trees and limited populations. Strategies of seed sourcing should be introduced to farmers so that they are aware of the importance of genetic diversity in peatland landscape restoration.

Chapter 11 by Widyatmoko discusses Indonesian Sustainable Palm Oil Certification (ISPO). There are many ISPO holders among companies, but quite a few are found in small farmer communities, as small farmers are also encouraged to get the certificate to promote sustainable palm oil production. This study points out the difficulties that farmers face in getting the certificate and their various efforts to overcome these challenges, such as the support of local governments, companies, and community initiatives. Obtaining land title is of paramount concern, as are land conflicts that spring from questions of the legitimacy of the legal documents. The forest/timber certificate is among the important issues in peatland transformation (Carlson et al. 2018; Ehrenberg-Azcárate and Peña-Claros 2020). This study also examines the process of ISPO acquisition by small farmers in Riau.

As a whole this book hopes to shed light on the developments in peat swamp rehabilitation, and the way they contributed to transformation and regeneration of peatland landscapes through the integrated lens of vulnerability-resilience-adaptability-transformation.

Future volumes in this series will discuss other important aspects of peatland socio-ecosystems—governance, public health issues related to haze, the history and social perspectives of peatland societies, the impacts and implications of meteorological phenomena, and peatlands as they relate to the national and international economies. These discussions will be related to the shifts in perception and meaning, social network configurations, patterns of interaction among actors, and associated organizational and institutional arrangement. The authors look forward to publishing their findings on these aspects soon.

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