Chapter 6
Indonesian Peatland Functions: Initiated Peatland Restoration and Responsible Management of Peatland for the Benefit of Local Community, Case Study in Riau and West Kalimantan Provinces

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Abstract Indonesian peat swamp forest ecosystems provide various environmental services, which are important locally, nationally, and globally. However, due to increasing land scarcity, the pressure to utilize them for agriculture is increasing. This chapter focuses on a case study in Riau and West Kalimantan to discuss the socioeconomic and environmental values of peatland through examples of financial analysis and economic valuation and discussion based on fieldwork data. It shows that the opportunity cost of CO_2 emission reductions by conserving peat swamp forests from conversion to oil palm plantation ranged from USD $3.7 to 8.25/t CO_2e, which is far higher than the current registered emission reduction compensation price. Opportunity costs are higher than the carbon market price, and a carbon market is not available currently, especially for peat forest conservation. This chapter clarifies what models are viable taking the case study as a point of departure and calls for urgent development strategies to establish viable compensation alternatives to landholders beyond the carbon market. Peat conservation measures imply high opportunity costs, however indigenous and adaptive plants show economic promise to help further develop markets, paludiculture techniques, and management options to rewet peatlands.

Keywords Initiated peatland restoration · Peatland functions · Riau West Kalimantan · Socioeconomic costs

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Introduction

Tropical peatlands are important for global, national, and local environmental functions and simultaneously, they have come to be appraised for their growing social and economic importance. Among various environmental functions they provide, the capacity to sequester and store high amounts of carbon (C) is the most prominent one. At a global scale, peatlands store an estimated 120 gigatonnes (Gt) of C or approximately 5% of all global terrestrial carbon (Rieley and Page 2005). The 14.9 million ha (Mha) of Indonesian peatlands (Ritung et al. 2011) store about 27 Gt C below ground in the form of peat organic carbon or an average of about 600 t C ha^{-1} m^{-1} (Agus et al. 2013a). In addition to peat soil carbon, peatlands also store carbon in plant biomass, which varies from about 2 t C ha^{-1} in annual crop systems to about 200 t C ha^{-1} in undisturbed forests (Agus et al. 2014a). Peatland carbon storage capacity is also important at a national scale because of high government reliance on peatland as one of the main contributors to a 26% C emission reduction pledge as stipulated in Presidential Regulation No. 61/2011. At a local scale, peat domes, resting on water-tables and fed by rainwater, have a crucial function in hydrological control. They can absorb water up to 13 times the mass of dry peat during the rainy season and release some of this water gradually during the dry season. This helps to mitigate the surrounding areas from floods and droughts (Agus and Subiksa 2008).

Peatlands in Indonesia are an important repository of unique biodiversity, prevent saline water intrusion from the sea into inland areas, and provide a cooling effect in surrounding areas due to high water storage (Parish et al. 2012). Most Indonesian peatlands remained undeveloped until the late 1960s, due to difficulty in accessing them (Kobayashi 2008). They also remained underutilized because of their inferior nature as productive agriculture land, mainly due to low fertility and water saturated conditions (Agus and Subiksa 2008). However, since the 1970s, peat swamp forests have been opened up by logging operations in Sumatra and Kalimantan (Kobayashi 2008). When peat is drained and fertilized, it can support the growth of almost all kinds of crops including vegetable, food, and plantation crops (Agus et al. 2012; 2013b), supporting the livelihood of local people and contributing to the national economy.

Peat swamp forests also possess a unique ecosystem function when they are pristine, but these are fragile and can be rapidly degraded through human activities (Baccini et al. 2012). Researchers have shown how land clearing and drainage network development contributes to their degradation (Page et al. 2011). There are wide potential impacts that may result from the development of peatlands for agriculture and these include soil subsidence, flooding, water shortage and pollution, fires and air pollution, habitat loss and biodiversity change, as well as changes in socioeconomic conditions. The pressure whether to conserve peatland in many cases is as strong as to develop it for agriculture, settlement, and mining purposes. The dilemma that Indonesia and other Southeast Asian nations that possess peat swamp forests face is the pressure to prioritize conservation, whilst not neglecting people's needs to use peatlands for development. Concurrently, time, uncontrolled use, and unwise peatland management practices do pose serious risks to local people, the public at large, and future generations. To respond to issues in Indonesia, this chapter discusses the socioeconomic and environmental values of peatlands and provides examples of financial analysis and economic valuation to conclude with suggestions for a way to balance environmental and economic needs.

Social Functions of Peatland: From Traditional to Intensive Use

Peatlands and people have been connected through intricate histories of cultural development in Indonesia's economy and the different intensity of peatland use is related to time, their vicinity to centers of development, access to capital, and domestic and global market demands on products that can be produced in them. Indonesia's peatland development is a relatively recent development, initially introduced for subsistence farming (Andriesse 1988) and then for plantation crops, annual crops, and multistrata systems. Their use can range widely and they can be a source of raw materials for industry and forestry under large-scale intensive cultivation or be used by smallholders for subsistence as well as commercial crop cultivation. Over the last 20 years, forest areas have decreased to make way for agriculture and other uses, the most important include plantations (oil palm, timber trees such as *Acacia*, rubber and various perennial tree crops), agroforestry, and annual crops (paddy system, vegetables, and cereal crops) (Gunarso et al. 2013). Sago forest plantations can also be found in parts of Papua such as the Mimika area and they require no drainage system or fertilization.

The shift to using peatland for agriculture production has significantly contributed to household, district, provincial, and national level income increases. Among agricultural uses, acreage allocated to oil palm plantation on peatland has increased rapidly from 4% in 2000 to 6% in 2005 to 10% in 2010 relative to the total Indonesian peatland area of 14.9 million ha (Agus et al. 2014a, b). This increase is attributed to the ease of market accessibility and the profitable use of land. Therefore, scholars have noted that abandoning agricultural practices and restoring the land to natural conditions would imply severe socioeconomic consequences (Van Beukering et al. 2008). However, there is no doubt that the uncontrolled use of peatland will degrade the benefits of peat forest environmental services.

Despite intense use in some areas, large areas of peatland have also been abandoned and covered by shrubland due to various reasons including unavailable labor and capital as well as remote locations from markets. Shrub-covered wastelands cover an estimated 22% of the total peatland area (Agus et al. 2014b) and tend to be the origin of many peat fires during the dry season (Agus et al. 2013a).

Subsistence Use of Peatland and Its Transformations

Until the late 1960s, people never lived permanently or cultivated crops regularly on peatlands (Rieley and Page 2005). Those who lived in rural areas depended on forests for a wide range of goods and services and subsequent forest conversion impacted on their livelihoods and culture. Research has clearly shown that when forests are replaced by oil palm monoculture, communities lose access to timber (for construction), rattan, and jungle rubber gardens (Sheil et al. 2009). Many of Indonesia's indigenous people practice shifting cultivation, whereas companies generally prefer hiring migrant workers with backgrounds in sedentary agriculture. This has led to ethnic conflicts between newcomers and indigenous groups (See Anderson 2013). Momose (2002), for example, has revealed that indigenous Malay villages in peat swamp forests along the Kampar River, in Riau Province, conducted agricultural activities such as shifting rice cultivation as well as fishing, hunting, non-timber forest product (NTFP) harvesting, and logging using their local knowledge. Malay people have contended that *ongka*, a traditional way of logging, is a sustainable form of peat swamp forest use. In Kalimantan, the indigenous Dayak people have long depended on natural wetlands, mainly consisting of peat swamps and freshwater swamps, for their livelihood and have engaged in shifting rice cultivation, the harvesting of forest products, and fisheries (Saman and Limin 1999). However, the Malay, Buginese, and Banjarese who live in estuary areas have historically had stronger relations to peatland and pioneered their sustainable use. The Chinese community in West Kalimantan, as well as Banjarese and Buginese in Sumatra, were also among the initiators of peatland use, who were followed later by Javanese and Balinese transmigrants. Researchers have also shown that native Mamuju farmers in West Sulawesi believe that peatland can be adapted for almost all kinds of crops, except for cocoa (Rina und Noorginayuwati 2012). Shallow peats that are generally fertile and suitable for agriculture have tended to be prioritized and their main uses have included swamp paddy systems, fishing, duck rearing, and water buffalo farming. Communities have historically adapted to seasonal water fluctuations and paddy farming has been practiced during the dry season while fishing and duck rearing have been practiced during the wet season. In this way, their management systems are perceived to function in a sustainable fashion. In other words, local farmers have a local understanding rooted in their interactions with their ecological environments and are clearly conscious of the fact that continuous draining and land exploitation will result in subsidence and a decline in soil fertility (Noorginayuwati et al. 2006).

Traditional systems are still maintained in some areas of peatland, although in the last couple of decades traditional farming and gathering have not been the sole sources of income. Increasingly, people have diversified their livelihood activities to work in both the service and commercial sectors as drivers, traders, laborers, and civil servants to increase income. Despite this diversification of income sources, nature-friendly forms of traditional farming have been maintained (Umar et al. 2014) and multiple cropping systems are more sustainable within the ecological conditions that exist (MacKinnon et al. 2000).

Furukawa (1994) has also described the different groups of people who make use of peat swamp forests in Riau province. One group is the Malay people who have been characterized as possessing multiple traditional farming activities that include fishing, hunting, gathering *jelutung* latex and rubber, rice and coconut farming, and nomadic forms of trading. Other immigrant groups such as the Buginese and Banjarese who have occupied the tidal areas of the eastern part of Sumatra, have built rice fields and became permanent residents there.

From the 1970s onwards, transmigrant farmers from densely populated areas of Java introduced more intensive forms of farming. This was partly due to relatively small parcels of land (2.25 ha per household (HH)) they were entitled to, compared to that of local farmers who used to have the privilege to clear and claim the forest and possess a larger share. Lowland rice crop systems were the mainstay among transmigrants and it is usually in rotation with *palawija* (secondary crops such as maize or beans) during the dry season (Noor 2001).

In general, local Banjarese, Dayak, Buginese, and Chinese systems are more diverse, combining annual and perennial crops, compared to transmigrant agriculture systems. Diverse systems such as those traditionally practiced by the Banjarese people have been gradually adopted by Javanese transmigrant farmers as shown by the succession of some of the lowland rice systems and perennial crops such as coconut and a combination of fruit trees with fish ponds in Purwosari, Tamban, and South Kalimantan (Collier 1982; Haris 2001). However, despite a relatively large area of land managed by local people, simple water transportation facilities limit access to markets and thus the management of large areas have been limited by investment and labor availability (Umar et al. 2014). Therefore, with time, traditional systems have incrementally diminished. Within this context, the development of peatland agriculture has adapted to the market and local socioeconomic and institutional capacity that supports economic activities. At present, intensive smallholder vegetable, fruit, and perennial crop farming can be found in peatland areas (Agus et al. 2012). A study by Van Beukering et al. (2008: p. 32) in Central Kalimantan revealed that several factors influence farmers' choice of crop varieties:

- Familiarity with and knowledge about the species. This is especially applicable for rubber as opposed to oil palm;
- Improvement in accessibility to seeds and nurseries;
- Improvement of accessibility to markets;
- Importance of the species for personal consumption (such as rice);
- Availability and size of local markets for alternative crops; and
- Frequency of harvest. Farmers' preference to rice is that they can harvest twice per year, ensuring a more frequent source of income (especially for farmers who have shallow peat). The same applies for rubber trees in terms of harvest frequency.

Van Beukering et al. (2008) further explained that two factors influenced land use strategies among Central Kalimantan farmers:

(a) **Type of peatlands**. Deep peatland tends to be used less intensively for rubber because of difficulty with drainage and low productivity. Shallow peat (less than 1 m) tends to be used more intensively for rice, vegetables, and fruits.
(b) **Plot size**. People with just one hectare of land, use their entire plot for food crops, especially rice, whereas owners of larger plots tend to have more diverse land uses.

Intensive Usage

The importance of peatland for agriculture has increased not only for local people but also for large-scale plantations. In recent years, large areas of tropical peatlands have been cleared and drained, especially for cash crops such as oil palm and timber plantations. Increasingly, to some extent, vegetable crops have undergone intense cultivation, especially in the vicinity of urban areas (Agus et al. 2012). Present conversion rates mean that approximately 51% of the total peatland area of 14.9 Mha remain as natural (primary and secondary) forests. 18% of peatlands have been used for various kinds of agriculture and forest plantations and 3% have been utilized for various uses such as building and mining.

The main areas with rapid development of oil palm plantation on peatland are Riau (the Indonesian province with the largest area of peatland), Jambi, Central Kalimantan, West Kalimantan, and East Kalimantan. Since 2016, the Indonesian government has enacted a policy to restore degraded peatland in seven priority provinces; one of them is West Kalimantan, with a total protected area of 28,136 ha, the permitted cultivation area is 64,078 ha, and nonpermitted area is 27,239 ha (See Fig. 6.1). In Riau province, the total targeted area for restoration is 815,180 ha, protected area is 43,810 ha, permitted cultivation area is 707,836 ha, and nonpermitted cultivated area is 43,810 ha (Fig. 6.2). Areas for timber (Acacia) plantations are mainly in Riau and Jambi Provinces (Gunarso et al. 2013). Under smallholders, intensive uses are for vegetable crops, fruit trees, and oil palm plantation. Areas of vegetables and fruits are relatively small because of high capital and labor requirements. The intensification of peatland use involves the development of drainage canals and use of chemical fertilizers and more often than not, land preparation involves fire. Most of the intensification is characterized by monoculture systems, which ultimately cause the loss of some of the peatland's primary ecosystem functions.

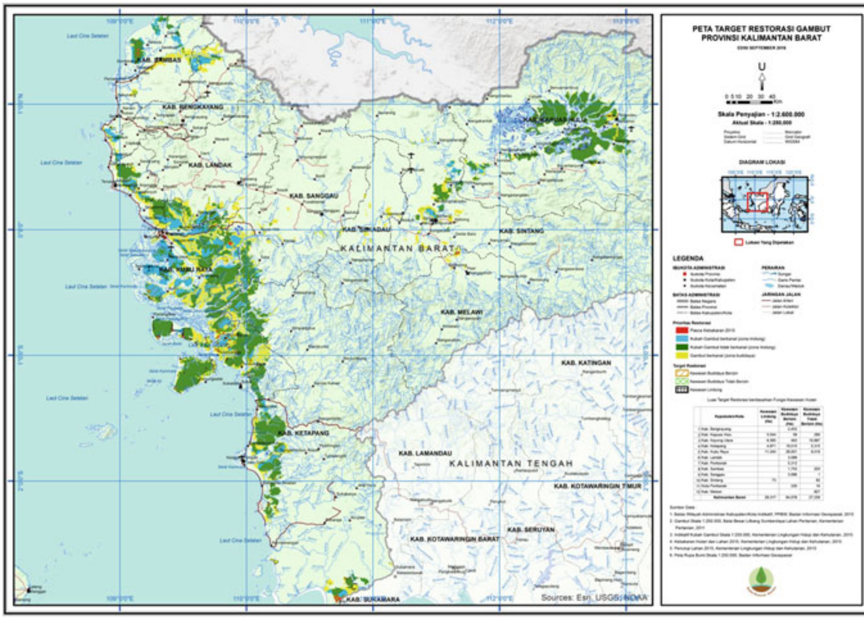

Fig. 6.1 Peatland restoration target area by peatland restoration Agency in West Kalimantan Province. *Source* Peatland restoration agency, Republic of Indonesia, 2017

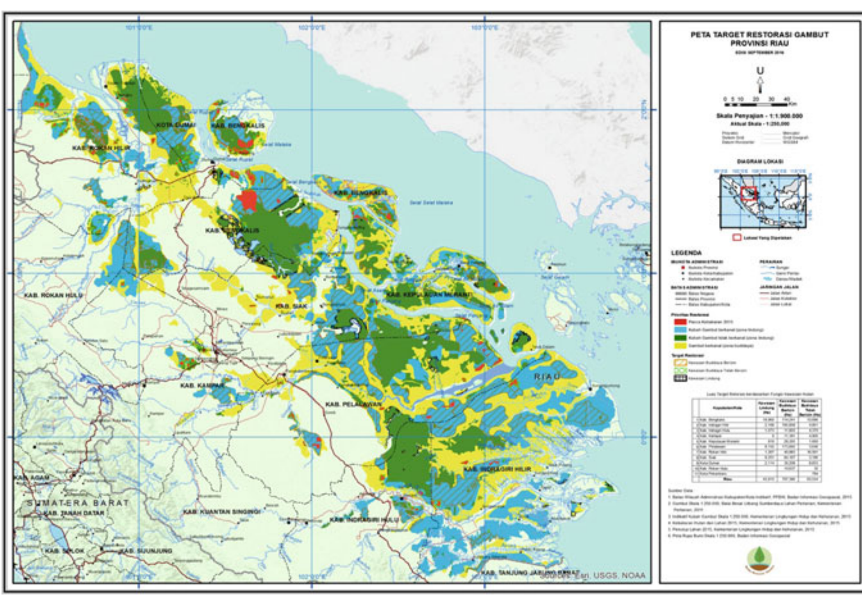

Fig. 6.2 Peatland restoration target area by peatland restoration agency in Riau Province. *Source* Peatland restoration agency, Republic of Indonesia, 2017

Multifunctionality of Peatland

The various tangible and intangible functions of peatlands are generally poorly understood or incompletely recognized and it is often the case that different stakeholders consider peatland from their own perspectives. This is one of the fundamental root causes of uncoordinated use, degradation of peatland, and repeated conflicts among stakeholders. In general, in its original form, peatland provides various ecosystem services, some of which are intangible to the public because their values are not marketable. Intangible services include (1) water retardation and thus regulation for landscape hydrology function, (2) carbon sink and thus carbon storage, and (3) a diverse ecological niche for various flora and fauna and thus biodiversity function (Agus and Subiksa 2008). With an increase in the population and higher demands on land, the role of peatland has become more important for employment, food security, and income generation.

Peatland Ecosystem Functions

Ecosystem functions are the free services that ecosystems provide to humanity (WRI 2005) and their services include the goods provided by the ecosystems and the different functions they perform, both of which directly or indirectly benefit human well-being and that of other species, flora and fauna. Peat swamp forests play an integral role in maintaining a wider regional ecosystem balance and critically support social and economic systems through the functions they provide. Table 6.1 presents an overview of the main peatland ecosystem functions, categorized into direct uses, indirect uses, and nonuse values. These three types of values form the total economic value of peatlands and constitute the beneficial outcome of the hydrological, chemical, and biological processes within the ecosystem. In particular, hydrological functions are especially important on a local scale. Peat is hydrophilic, absorbs water during the rainy season, and releases it slowly during dry periods. Intact peatlands possess a great potential to mitigate the loss of life and damage to infrastructure by reducing flooding downstream of peatlands. Intact peatlands can also help to maintain minimum flows in rivers during the dry season and can minimize drought stress in peat areas surrounding peat domes. In addition, the wetland ecosystem of peatlands helps to prevent saline water intrusion from the sea into inland areas.

Table 6.1 Ecosystem services provided by peat swamps ecosystem

Peatland values	
Direct use *(production functions)*	•Storage of water •Ecotourism
Direct extractive use of biodiversity	•Food (e.g. Fish) •Medicinal plants •Ornamental plants •Aquarium fish •Timber •Non-timber forest produce, such as rattan and other plants for construction purposes, •Fuel and handicrafts
Indirect use *(regulation functions)*	•Storage and sequestration of carbon •Reduction of downstream flood by its high (up to 13 times its dry mass) water absorbing capacity •Reduction of drought impact by maintenance of base (minimum) flows in rivers by releasing water slowly during dry periods •Prevention of saline water intrusion
Non use	•Spiritual, historical, and cultural values
	•Aesthetic values
Biodiversity attributes	•e.g., species richness and endemism

Source ASEAN (2006)

Integrated Functions of Peatlands

Land use change is often accompanied by changes to people's livelihood settings and the environmental functions of peat. Deterioration of peatlands is usually associated with extensive clearing and draining that, in turn, results in significant socioeconomic changes and the loss of environmental quality. These losses can sometimes lead to tensions between key stakeholders at local, regional and international levels. The Mega Rice Project (MRP) in Central Kalimantan, launched by the former President Soeharto on December 26, 1995, through Presidential Decree No. 82/1995, with the objective of developing approximately one million hectares of peatland for food crop production (especially rice), is an example of mass peatland development that ended in mass deterioration. The MRP, covering an area of 1,457,100 ha, left many problems that included;

1. Socioeconomic: Nonpayment of land compensation fees and loss of means of daily subsistence by the local inhabitants as a result of damage to their traditional fishponds (locally called *beje*) and other forest products such as rattan, latex, food, and medicines (Jaya 2004).
2. Biophysical: A decrease in water quality from increased acidity and the lowering of the water table leading to a decrease in water regulation functions of the land and loss of vegetation cover.

The MRP implementation was reevaluated in May 1998 and this revealed that from the outset, the project had been misguided in terms of its rationale, strategy, planning, implementation, monitoring, and budget allocation. Research has subsequently shown that the mass transformation on the peatlands has led to a rise in frequent fires related to droughts (Putra et al. 2008). A review of the MRP also concluded that from the 40-50% of the total project area that consisted of peatlands, only 400,000 ha of the peatland were actually suitable for agriculture, and the rest should have been conserved as an environmental safeguard.

Another example of negative socioeconomic impacts is the expansion of palm oil plantations on forest-dependent communities. Many people who live in rural areas depend on forests for a wide range of goods and services. The conversion of forests has impacted considerably on the livelihoods and culture of indigenous populations and the environmental problems associated with intensive agricultural development of peatland have included artificial drainage inducing subsidence of the ground surface; hydrological changes that may eventually lead to the loss of the peat swamp environment along with its ecological functions (e.g., biodiversity, water storage, hydrological regulation, and carbon storage). Furthermore, fertilizers and pesticides led to long-term water pollution and the burning of peat and vegetation during land clearance resulting in intensive air pollution (Rieley and Page 2005; Parish et al. 2012).

Due to the fragility of peat swamp ecosystems and the high environmental services they provide, it is essential to use them in a wise and sustainable way. Joosten and Clarke note that "the wise use of mires and peatlands as those uses of mires and peatlands for which reasonable people now and in the future will attribute no blame. The word 'use' is employed in its widest meaning, including conservation and nonuse" (Joosten and Clarke 2002: p. 19). Building upon this definition, Rieley and Page (2005) have stated that the wise use of peatlands can maintain their functions and values to support environmentally compatible development for sustainable agriculture. They thus suggest a multiple wise use of tropical peatlands that optimizes their economic, social, and ecological values. This is done by harvesting renewable resources in a sustainable way while conserving nonrenewable resources and maintaining the attributes and functions of the land.

This approach implies that limited areas of peatland can be converted to support small-scale agriculture. In such cases the following guidelines should be considered: the selection of the areas should ensure minimal impact on the ecosystem's functions; the suitability of the crop for peatland cultivation should be determined carefully; and finally, drainage networks should be carefully constructed and be kept shallow for agricultural use.

The Economics of Peatlands: Development Versus Conservation Uses

Peatlands produce marketable and nonmarketable products. Marketable products are those related to agricultural production such as palm oil, latex, corn, rice, fruits, and vegetables. In some, but rare instances, the peat itself is harvested and used as fuel or growth media in nurseries and thus it is marketable. On the other hand, peatland under natural forest conditions provides several ecosystem services (Agus and Subiksa 2008; Parish et al. 2012) which can be valued in economic terms, but under the current economic system, the market seems not yet consider them as something valuable (Goda et al. 2006). These services may include those listed in Table 6.1.

Market Values of Peatlands

Herman et al. (2009) conducted an economic analysis of oil palm plantations on peat and mineral lands and concluded that oil palm plantation development was as economically feasible on peatlands as on mineral lands. Their study assumed a range of crude palm oil (CPO) prices of IDR 6000 (US\$0.45) to 10,000 (US\$ 0.75) kg^{-1} and palm kernel prices of IDR 4500 (US\$0.35) to 6500 (US\$0.50) kg^{-1}. Under those assumptions oil palm plantations on mineral land generated a net present value (NPV) of IDR 0.90 million (US\$67.5) to 3.01 million (US\$225) ha^{-1} yr^{-1} under the nucleus estate scheme and IDR 0.70 million (US\$52.5) to 2.53 million (US\$189.8) ha^{-1} yr^{-1} under large plantation scheme. On peatland, the NPV was IDR 0.74 million (US\$57.8) to 2.85 million (US\$213.8) ha^{-1} yr^{-1} under the nucleus estate scheme and IDR 0.55 million (US\$41.3) to 2.39 million (US\$179.3) ha^{-1} yr^{-1} under large plantation scheme. Other indicators of financial analysis, the benefit/cost (B/C) ratio and the internal rate of return (IRR) also support the argument of economic feasibility. With the assumption of CPO price of IDR 10,000 kg^{-1} (US\$0.75) and palm kernel prices of IDR 6500 kg^{-1} (US\$0.50), under the nucleus estate scheme, the IRR ranged from 33 to 34% (which are well above the discount factor of 15%) and the B/C ratio ranged from 1.4 to 2.3 on mineral land. On peatland, they ranged from 31 to 33% and 1.3 to 2.2, respectively.

In addition to palm oil, Herman et al. (2009) have conducted research on various other crops including vegetables, pineapple, maize, and rubber: adaptable and competitive on peatland. The results of their financial analysis in West Kalimantan, based on different scenarios of prices in 2009, are presented in Table 6.3. Oil palm was shown to be superior to rubber and comparable to intensive cultivation pineapple system in terms of the NPV. However, in many cases, smallholder farmers have shown a preference for rubber over oil palm and tradition pineapple over the more intensive system. In the case of rubber, low input and continued harvest are important considerations and in the case of traditional pineapple, low input is the main factor because many farmers cannot afford the high input system. For annual crops, vegetable crops provide the highest profits, but capital and labor involved in vegetable crops were also high. Maize required lower capital for supplies and labor with much lower profits compared to vegetables. Vegetables and pineapple were also subject to high price fluctuations. What is important to note is that capital for oil palm and rubber could be an impediment factor. Smallholder farmers tended to gradually develop their farms to avoid high and abrupt investment at the beginning of farm development. Despite very high net profits from vegetable farming on peatland (Table 6.2), it did not change rapidly. Instead, *sawah* (paddy field in rotation with secondary crops of either maize or vegetable crops) was the form that developed most rapidly. Oil palm on peatland commenced in the study districts in West Kalimantan and its expansion is expected to be steady (shown in Fig. 6.3) or possibly show an acceleration in cultivation. Areas of traditional rubber plantation were decreasing and this seemed to be related to the higher incentives of other commodity developments.

Table 6.2 Analysis of capital, net profits (for annual crops) and the net present values, NPV (for perennial crops)

Crop	Capital (IDR ha^{-1})	Net profit (IDR ha^{-1} yr^{-1})	Annualized NPV at 15% discount factor (IDR ha^{-1} yr^{-1})		
			Scenario 1 (S1)	Scenario 2 (S2)	Scenario 3 (S3)
Oil palm	30,437,000	–	822,248	1,769,473	2,716,698
Rubber	15,230,000	–	400,080	1,108,869	1,817,658
Pineapple, traditional	3,827,500	–	242,421	529,330	816,240
Pineapple, intensive	9,947,500	–	1,184,833	1,864,897	2,544,960
Vegetables	2,500,000	10,009,000	–	–	–
Maize	1,250,000	2,226,102	–	–	–

Remarks: Crude palm oil price for Scenario 1 (S1) in IDR kg^{-1} = 6000; S2 = 8000; S3 = 10000. Palm Kernel price for S1 = 4000; S2 = 4500; S3 = 5000. Crumb rubber prices in IDR kg^{-1} for S1 = 7000; S2 = 11,000; S3 = 15,000. Pineapple fruit for S1 = 400; S2 = 500; S3 = 600.
Source Herman et al. (2009)

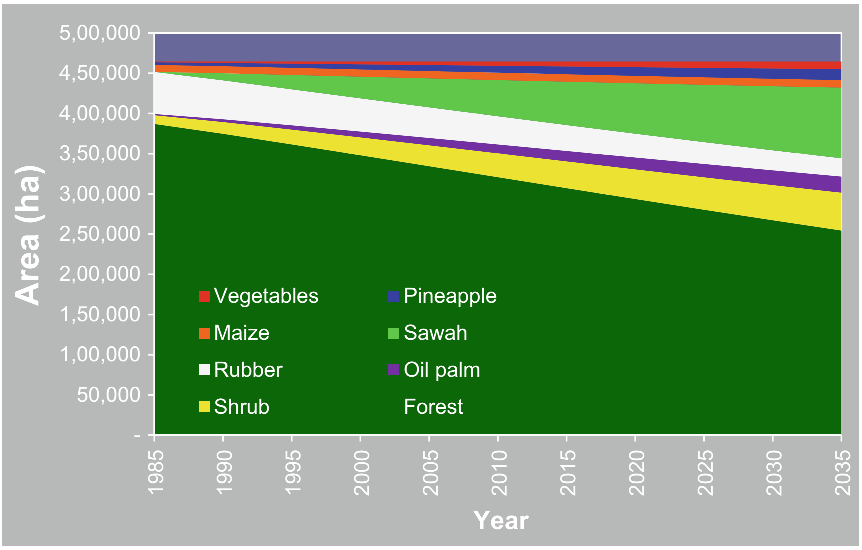

Fig. 6.3 Historical (1985–2009) and linear projection until 2035 of land use change in Kubu Raya and Pontianak Districts, West Kalimantan Province. *Source* Agus et al. 2012

NonMarket Values of Ecosystem Functions

Economic valuation is an attempt to assign quantitative values to the goods and services provided by environmental resources, whether or not the goods are marketable. Many efforts by economists and others have been made in the last few decades to "internalize the externalities" by modifying market valuation and by placing more emphasis on ecosystems functions (Starrett 2000).

There exist a series of methods to calculate the economic valuation of peatlands according to the Ministry of the Environment Regulation No. 14/2012; (1) Total economic value of Natural Resources and Environment, and (2) Degraded Environment Economic Values. Using these methods, natural peat swamp forest ecosystems in Zamrud Nature Reserve in Siak district (Riau province, Sumatra island, 31,480 ha), and Sebangau National Park in Katingan regency (Central Kalimantan province, Borneo island, 568,700 ha) were valued at around IDR 2.95 trillion (US$221,338,500) and IDR 2.3 billion (US$172,569), respectively. The loss of environmental resources is an economic problem because the natural assets are lost or degraded, some perhaps irreversibly.

Any options for environmental resource management, either to leave it in its natural state, allow it to degrade, or convert it to another use, has implications in terms of the gains or losses of these valuable assets. The decision of what use to pursue for a given environmental resource, and ultimately whether the current rates of resource loss are "excessive," can only be made if these gains and losses are properly analyzed and evaluated. For example, preserving an area in its natural state involves the direct costs of preservation and this may include paying guards and rangers to protect and maintain the area and perhaps also the cost of establishing a "buffer zone" for the surrounding local communities. Development options are sacrificed if preservation is chosen, which implies foregone development benefits (opportunity costs).

The economic values of peatlands' functions of flood mitigation and water supply are substantial. Whiteman and Fraser (1997) estimated the value of these functions of about US$91.60 ($ha^{-1}$ yr^{-1}) or IDR 925,253 (ha^{-1} yr^{-1}). Furthermore, drained peatlands are very susceptible to destructive fires during dry periods. The 1997 fires that burned 2–3% of the land area of Indonesia had an economic impact of at least US$9 billion or equivalent to IDR 90,909 billion (Van Eijk and Leenman 2004). These fires lead to adverse economic impacts through the destruction of commercial timber, plantations, and farmland; a reduction in tourism; the temporary shutdown of commerce, industry, and travel; and an increase in health care costs (Sastry 2002). In addition to the fires' destruction, smoke, and haze impair photosynthesis, thus lowering agricultural and forestry production in unburned areas. Fires also eliminate seeds and seedlings, further degrade hydrologic functions, and cause soil erosion (Schrier-Uijl et al. 2013; Tacconi 2003). Repeated fire events lead to soil subsidence and the risk of flooding, which destroys crops and increases carbon emissions. A cost-based study by Tacconi (2003) estimated that the fires of 1997 cost around US$4.5 billion through losses in various sectors such as timber, tourism, transportation, and agriculture, in addition to the actual costs of fighting the fires. Furthermore, in 2014 the fires that occurred in the Riau peatlands caused economic losses of around IDR 15 trillion (US$1,125,450,000) (BNPB 2014). It is important to note that early calculations of the total economic costs of the fires in 2015 in Indonesia alone exceeded US $16 billion. This is more than double the damage and losses from the 2004 tsunami (which affected provinces in Indonesia and other countries), and equal to about 1.8% of Indonesia's GDP[1].

One approach to maintaining the environmental functions of peat forest is through implementing a sustainable harvesting system. Although shifting to a sustainable harvesting system reduces the net benefits of timber harvesting, one case study has suggested that this was more than offset by the increased nonmarket benefits, primarily hydrological, and carbon storage values (Wetlands International 2007). When the carbon price was relatively high, some experts have suggested to concentrate on the value of carbon captured and stored by peat swamp ecosystems. Preserving forests and peat swamps, which would otherwise be converted, and collecting the resulting recurrent revenues provided by the carbon offset market may be more lucrative for landholders in some areas than conversion to oil palm (Butler 2007) provided that such markets are in place.

[1]See Indonesia's fire and haze crisis. http://www.worldbank.org/en/news/feature/2015/12/01/indonesias-fire-and-haze-crisis Accessed 14 January, 2017.

Many economic valuation studies try to compare various scenarios and usually come to the conclusion that the sustainable use of natural resources creates much more value than their unsustainable use. Such results are often dependent on the inclusion of nonmarket ecological services because in the long term, the benefits of those are often higher than the marketed benefits. Yet in reality, forest conversion continues because of a lack of awareness of the wider (nonmarket) economic, social, ecological, and environmental benefits (Joosten and Clarke 2002) and because of the absence of incentives provided to landholders. Therefore, considering the value of carbon storage and other benefits provided by peatlands, policies need to be developed for compensation of the opportunity cost to landholders for providing public goods. This means that payments for environmental services in various forms must be realized.

Tradeoffs Between the Environmental and Development Objectives

Several indirect substitutions cost methods have been used to evaluate the economic values of ecosystem functions. These include the Hedonic Price Method (HPM), Contingent Valuation Method (CVM), Willing to Pay Method (WTP), and Replacement Cost Method (RCM) (Goda et al. 2006). HPM may not be suitable for peatland because it is about dealing with the amenities of land for housing environment that are reflected in land prices and wages. The CVM has been increasingly used for valuation of multifunctionality of agriculture. In this method, questionnaires are sent to the general public who benefit from the environmental functions and ask them how much they are willing to pay (WTP) for maintenance of such functions (Agus 2006). For example, if peat forest is important for water storage and water redistribution, the respondents (the local beneficiaries) are asked how much they are willing to pay for the forest conservation. RCM evaluates the cost incurred by individuals for restoring certain environmental quality. For example, for reducing heat among the people who live near, where peat forest used to be, they have to use electric fans or air conditioners to restore cooler conditions provided by the forest. The costs for purchasing and operating those appliances are called RCM.

For CO_2 emissions reduction, the approach of opportunity cost has been used widely (e.g., Gregersen et al. 2010; Herman et al. 2009; White and Minang 2011). In this case, opportunity cost can be defined as the ratio of change in profits (net present value, NPV) divided by the change in carbon stock. In other words, opportunity cost is NPV divided by the unit weight of GHG emissions as illustrated in Fig. 6.4. In Fig. 6.4, the change of a hectare of forest with the carbon stock of 250 t C ha^{-1} to a hectare of agricultural land with the carbon stock of 5 t C ha^{-1} causes the net change of 245 t C ha^{-1}. The estimated profits from agriculture are US \$400 ha^{-1}, while forest profits are US \$50 ha^{-1} and both are expressed in the NPV terms. So the difference in NPV is US \$350 ha^{-1}. The opportunity cost of

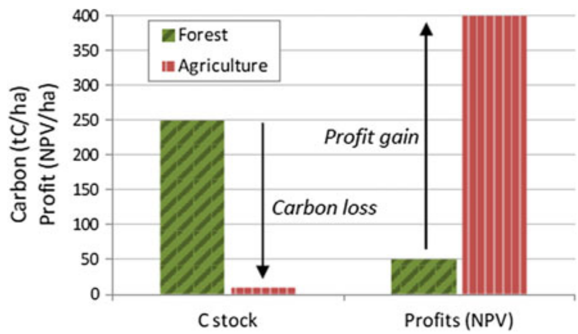

Fig. 6.4 Illustration of carbon loss and profit gain from converting forest to agriculture *Source* White and Minang 2011

Table 6.3 Opportunity costs of conserving peat forest from conversion to oil palm plantation under the nucleus estate and large plantation schemes with the assumption that mean greenhouse gas annual emission under oil palm plantation is 64 t CO_2 (ha. yr)$^{-1}$ and under forest is zero (adapted from Herman et al. 2009)

Plantation model/ Stakeholder	Net present value (at 15% df)		Opportunity cost	
	IDR (ha yr)$^{-1}$	USD (ha yr)$^{-1}$	IDR/t CO_2e	USD/t CO_2e
Nucleus estate (NE)	2,845,000	310	44,520	4.84
Plasma farmer	*2,180,000*	*237*	34,034	*3.70*
Nucleus	*4,856,000*	*528*	75,886	*8.25*
Large plantation	2,387,000	260	37,253	4.05

Opportunity cost = NPV/64 t CO_2 (ha yr)$^{-1}$
Assumptions: Crude palm oil price was IDR 10,000 kg^{-1}; palm kernel price was IDR 6500 kg^{-1}

conserving or not changing forest to agriculture equals US $350 ha^{-1} divided by the 245 t C ha^{-1} not emitting C or equals US $1.43/t C. However, carbon emission compensation is based on carbon dioxide equivalents (CO_2e). A conversion factor of 3.67 is needed to translate t C to t CO_2e. So, the potential emissions of land use change is 245 t C ha^{-1} * 3.67 t CO2e/t C = 899 t CO_2e ha^{-1}. Therefore, the equivalent opportunity cost of avoided emissions is US $0.39/t CO_2e. From the perspective of the beneficiaries the expression in terms of per ton CO_2e is more popular, but for landholders, the more relevant expression is per ha. Thus, the opportunity costs of not converting the forest to agriculture, from the landholders' perspective is US $350 (ha yr)$^{-1}$.

Table 6.3 gives an example of the opportunity cost calculation of conserving Indonesian peat forests. The main driver of forest conversion in this example is oil palm plantation and so the NPV of peat forest versus oil palm plantation and annual average CO_2 emissions (from a 25-year cycle) of peatland under oil palm plantation were the main input data. The assumption of the mean annual CO_2 emissions under oil palm plantation of 64 t CO_2 (ha yr)$^{-1}$ include emissions from biomass loss from deforestation and peat decomposition.

This calculation shows that the opportunity cost range is from US $3.7 to 8.25/t CO_2e or equivalent to the NPV of US $237 to $528 (ha yr)$^{-1}$. Landholders expect a compensation is equivalent with the NPV. For carbon buyers, the opportunity cost of US $3.7 to 8.25/t CO_2e indicates how much money they have to spend on compensation to reduce certain amount of emissions.

Scoping Activities in Peatland Restoration for Local Communities

Thousands of villages' peatlands are currently scheduled for restoration between 2016–2020 and communities will play a strong role in restoration activities. Three primary methods will be employed in restoring degraded peatland: rewetting, revegetation, and the revitalization of livelihoods (3R Integrated Method). Scoping activities in peatland restoration for local communities includes the following three areas:

1. Revitalization of Integrated Water Management to Speed up the Restoration of Peatland Ecosystems

During the dry season, large-scale companies tend to stem peat water in order to flood canals to prevent fires so that peatland become dry, plants die, and easily catch fire. In this case, there is an urgent need to research the hydrology of peat swamps in order to prevent disruption by fire. This may include activities including the trial creation of partition canals, water ropes, ponds, and the optimal normalization of canals so that they can simultaneously support the recovery process of ecosystem peatlands that burnt in the areas occupied by peat swamp communities. Partnership opportunities between large-scale companies and local communities in the improvement of water flow are needed to accelerate the recovery process of the peat swamp ecosystem. Studies should suggest water sharing interventions. The aim of restoration work is to improve hydrological regimes thus groundwater levels should be maintained at 0.4 m from the peatland surface. There is a need to develop groundwater level monitoring in real time to provide up to date information on the hydrological conditions. Peatland should be managed as a total hydrological unit at a landscape level.

2. Revegetation of Local Species for Building Productive Plantation Forests, and Facilitating Access to Timber and NTFPs Market in Order to Improve Community Welfare

Revegetation of degraded peat forests, in general, are well-known, but the development of agroforestry on peatlands by selecting the type of plant that is adaptive, without drying peat, and mixing with other types of plants (commercial timber, fruit trees, root crops, medicinal plant, and firebreaks plant) still requires further research. This is needed to develop productive plantation forests that can provide daily, short-, medium-, and long-term income for farmers, as well as prevent disruption by fire. Identifying types of products that can become a leverage for community development can open up opportunities for policy intervention in order to improve local communities' welfare. There are a number of potential crops such as sago palm *(Metroxylon sago)*, coffee trees, coconut *(Cocos nucifera)*, jungle rubber *(Hevea sp)*, pineapple (*Ananas* sp) and many others forest tree species proven to grow in degraded peatland such as bintangur *(Callophylum sumtaranum)*, jelutung *(Dyera lowii)* and meranti rawa (*Shorea uliginosa*). These can develop into integrated farming systems, silvofishery, and agroforestry, locally known as kebun kayu campuran (mixed trees gardens).

3. Social Transformation to Strengthen Community Perspectives in Relation to Functions and Economic, Social and Environmental Benefits of Peatland
Communities living in peat swamp ecosystems can be categorized as both indigenous and immigrant communities. Indigenous communities are groups of people that used to live in harmony with their natural surroundings, but these have changed due to external influences. Immigrant communities, on the other hand, tend to be extractive. Fires have resulted in a loss of community livelihood for those who depend on peat swamps such as farming, livestock breeding, hunting, fishing, and peat swamp timber production. To support the improvement of peat swamp conditions, it is crucial to research those important values in society that need to be strengthened, especially those related to the alignment of economic, social, and environmental functions and benefits so that social transformation can occur effectively. There are a number of local communities that are enthusiastic to be involved in restoration activities, as illustrated by those in the village areas of Tebing Tinggi Timur and Bukit Batu (sub district in Riau Province). However, to guarantee the continuity of restoration activities, it is important to understand their basic necessities. Any meaningful restoration must provide benefits as a means for improvement of livelihood and strengthening the capacities for organization at a village level to weather change and move beyond current economic practices.

Conclusion

This chapter has discussed the socioeconomic and environmental values of peatland and included examples of financial analysis and economic valuation and discussion of fieldwork data in Riau and West Kalimantan, Indonesia. Despite the number of challenges and problems, especially with the responsible management of peatland, it does offer various kinds of socioeconomic functions that can potentially benefit local communities. Beyond the market and nonmarket values of peatland, there are also tradeoffs between environmental and development objectives. In the current global market's need for cheaper resources, there is a strong push for conversion to oil palm plantation in many parts of Indonesia, especially in peatland areas. The opportunity cost of CO_2 emissions reduction by conserving peat swamp forest from conversion to oil palm plantation ranged from US \$3.7 to 8.25/t CO_2e. This is far higher than the current registered emission reduction compensation price. The opportunity cost is higher than the carbon market price, and a carbon market is not available currently, especially for peat forest conservation. Therefore, this chapter can offer lessons to policy makers in the government's ministries to consider the issue of socioeconomic functions of peatland, establish compensation alternatives to peatland-holders beyond the carbon market, and balance the needs between environmental protection and local community's development. This chapter suggests that peatland restoration requires intervention through three integrated methods: rewetting, revegetation, and the revitalization of livelihood. Local communities play a fundamental role in the success of peatland restoration achievement, as they have direct interaction with peatland areas. Therefore, transformation must involve the community in any peatland restoration activities and empower them in responsible management activities for improving the basis of their livelihood and ensuring the protection of swamp peatlands. Peat conservation measures imply high opportunity costs, however indigenous and adaptive plants show economic promise to further develop markets, paludiculture techniques, and change management options to rewet peatlands. Restoration measures by rewetting, revegetation, and revitalisation of livelihood can offer strong benefits to local communities and be potentially more sustainable than current drainage-base agriculture, but only if the environmental effects are made more explicit.

References

Agus, F. (Ed.). (2006). *Final Report: Country case studies on multifunctionality of agriculture in ASEAN Countries*. Jakarta: The ASEAN Secretariat, Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF).

Agus, F., & Subiksa, I. G. M. (2008). *Lahan gambut: Potensi untuk pertanian dan aspek lingkungan.*[Peatland: farming potentials and environmental aspects]. Booklet. Bogor: Balai Penelitian Tanah dan World Agroforestry Centre (ICRAF) SE Asia. (in Indonesian).

Agus, F., Dariah, A., & Jamil, A. (2013b). *Kontroversi pengembangan perkebunan kelapa sawit di lahan gambut* [Controversies on conversion of peatland for palm oil plantation]. In H. Soeparno, E. Pasandaran, M. Syarwani, A. Dariah, S. M. Pasaribu and N. S. Saad (Eds.) *Politik Pembangunan Pertanian Menghadapi Perubahan Iklim* [Development politics of agriculture in the face of climate change], (pp. 452–473) (in Indonesian). Jakarta: IAARD Press.

Agus, F., Gunarso, P., & Wahyunto. (2014b). *Dinamika penggunaan lahan gambut* [The dynamics of peatland use]. In F. Agus, M. Anda, A. Jamil, & Masganti (Eds.), *Lahan Gambut Indonesia*: *pembentukan, degradasi dan potensi mendukung ketahanan pangan dan kualitas lingkungan* [Indonesian peatland: Formation, degradation, and potentials to support food security and environmental qualities] (pp. 85–100). Jakarta: IAARD Press. (in Indonesian).

Agus, F., Henson, I. E., Sahardjo, B. H., Harris, N., van Noordwijk, M., & dan Killeen., T. J. (2013a). *Review of emission factors for assessment of CO_2 emissions from land use change to oil palm in Southeast Asia*. Kuala Lumpur: Roundtable on Sustainable Palm Oil.

Agus, F., Santosa, I., Dewi, S., Setyanto, P., Thamrin, S., Wulan, Y. C., & Suryaningrum, F. (Eds.). (2014a). *Pedoman Teknis Penghitungan Baseline Emisi dan Serapan Gas Rumah Kaca Sektor Berbasis Lahan: Buku I - Landasan Ilmiah* [Technical guidelines of land-based emission and sequestration calculation: Book I - The Scientific Background]. Jakarta: Badan

Perencanaan Pembangunan Nasional, Republik Indonesia (Indonesian National Development Planning Agency, BAPPENAS). (in Indonesian).

Agus, F., Wahyunto, A., Dariah, E., Runtunuwu, E. S., & Supriatna, W. (2012). Emission reduction options for peatlands in the Kubu Raya and Pontianak Districts, West Kalimantan, Indonesia. *Journal of Oil Palm Research, 24,* 1378–1387.

Anderson, P. (2013). Free, Prior, and informed consent? Indigenous peoples and the palm oil boom in Indonesia. In O. Pye & J. Bhattacharya (Eds.), *The palm oil controversy in Southeast Asia: A transnational perspective*. (pp. 244–258) Singapore: ISEAS.

Andriesse, J. P. (1988). *Nature and management of tropical peat soils (Soils Bulletin 59)*. Rome: FAO- Food and Agriculture Organization of the United Nations.

ASEAN (Association of Southeast Asian Nations). (2006). *Rehabilitation and sustainable use of peatlands in South East Asia. Full project brief for international fund for agricultural development and global environment facility*. Jakarta: ASEAN Secretariat.

Baccini, A., Goetz, S. J., Walker, W. S., Laporte, N. T., Sun, M., Sulla-Menashe, D., Hackler, J., Beck, P. S. A., Dubayah, R., Friedl, M. A., Samanta, S., & Houghton, R. A. (2012). Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nature Climate Change 2*, 182–185. doi:https://doi.org/10.1038/nclimate1354, ISSN: 1758-678X.

Beukering, P. van., Schaafsma, M., Davies, O., & Oskolokaite, I. (2008). *The economic value of peatland resources within the central Kalimantan peatland Project in Indonesia: Perceptions of local communities. Central Kalimantan Peatlands Project*. (Report E-08/05, June 28, 2008).

BNPB (Badan Nasional Penanggulangan Bencana). (2014). *Upaya Penanggulangan Bencana di Indonesia. Bahan Presentasi Kuliah Umum* [Efforts of disaster prevention in Indonesia. Presentation material for general lecture]. Riau Bebas Asap. Presentation for public lecture. Pekanbaru, 28 April 2014 (in Indonesian).

Butler, R. (2007). The Impact of Oil Palm Borneo. Retrieved July 10, 2016, from http://data.mongabay.com/borneo/borneo_oil_palm.html.

Collier, W. L. (1982). *Lima puluh tahun transmigrasi spontan dan transmigrasi pemerintah di tanah rawa Kalimantan* [Fifty years of spontaneous migration and government-sponsored migration in Kalimantan peatland]. In J. Hardjono (Ed.), *Transmigrasi: Dari Kolonisasi Sampai Swakarsa* [Transmigrasi*: From colonial times to self-reliance*]. Jakarta: Gramedia (in indonesian).

Eijk, P. van., & Leenman, P. (2004). *Regeneration of fire degraded peatswamp forest in Berbak national park and implementation in replanting programmes. Water for food and ecosystem project on: "Promoting the river basin and ecosystem approach for sustainable management of SE Asian lowland peatswamp forests." Case study Air Hitam Laut river basin Jambi province, Indonesia.* The Netherlands: Alterra & Green World Research, Wageningen.

Furukawa, H. (1994). *Coastal wetlands of Indonesia: Environment, subsistence and exploitation*. Kyoto: Kyoto University Press. Retrieved July 15, 2016.

Goda, M., Kada, R., & Yabe, M. (2006). Synthesis and conclusions. In F. Agus (Ed.), *Final report country case studies on multifunctionality of agriculture in ASEAN countries* (pp. 415–431). Jakarta: The ASEAN Secretariat & Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF).

Gregersen, H., El Lakany, H., Karsenty, A., & White, A. (2010). *Does the opportunity cost approach indicates the real cost of REDD + ? Rights and realities of paying for REDD+*. Washington, D.C: CIRAD & Rights and Resources Initiative.

Gunarso, P., Hartoyo, M. E., Agus dan, F., & Killeen, T. J. (2013). *Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea*. Kuala Lumpur: Roundtable on Sustainable Palm Oil.

Haris, A. (2001). *Manajemen Lahan Orang Banjar* [The land management of the Banjarese]. Fakultas Pertanian Universitas Lambung Mangkurat, Banjarbaru (Unpublised manuscript; in Indonesian).

Herman, Agus, F., & Las, I. (2009). *Analisis finansial dan keuntungan yang hilang dari pengurangan emisi karbon dioksida pada perkebunan kelapa sawit.* [Financial analysis and opportunity cost of carbon dioxide emission reduction in oil palm plantation]. *Jurnal Litbang Pertanian, 28*(4): 127–133 (in Indonesian).

Jaya, A. (2004). Ecological planning of tropical peatlands for carbon and water conservation. Ph. D. Thesis. University of Nottingham, UK (Unpublished).

Joosten, H., & Clarke, D. (2002). *Wise use of mires and peatlands – background and principles including a framework for decision-making*. Saarijärvi: International Mire Conservation Group & International Peat Society.

Kobayashi, N. (2008). *Sustainable peatland management: Socio-economic and environmental aspect*. Paper presented at international symposium "Sentinel earth: Detection of Environmental Change," at Hokkaido University, Sapporo, July 5–7.

MacKinnon, K., Hatta, M. G., Halim, H., & Mangalik, A. (2000). *Ekologi Kalimantan* [The Ecology of Kalimantan]. Jakarta: Prenhallindo.

Momose, K. (2002). Environments and people of Sumatran peat swamp forests II: Distribution of villages and interactions between people and forests. *Southeast Asian Studies, 40*(1), 87–108.

Noor, M. (2001). *Pertanian Lahan Gambut: Potensi dan Kendala* [Peat farming, the potential and limitations]. Yogyakarta: Kanisius (in Indonesian).

Noorginayuwati, A. Rafiq, R. Yanti, M. A., & Jumberi, A. (2006). *Penggalian Kearifan Lokal Petani untuk Pengembangan Lahan Gambut* [Exploring the farmers' local wisdom for peatland development]. Banjarbaru: Balai Penelitian Pertanian Lahan Rawa (in Indonesian).

Page, S., Morrison, E. R., Malins, C., Hooijer, A., Rieley, J. O., & Jauhiainen, J. (2011). *Review of peat surface greenhouse gas emissions from oil palm plantations in Southeast Asia*. Washington, DC: International Council on Clean Transportation.

Parish, F., Lim, S. S., Perumal, B., & Giesen, W. (Eds.). (2012). *RSPO Manual on Best Management Practices (BMPs) for management and rehabilitation of natural vegetation associated with oil palm cultivation on peat*. Kuala Lumpur: RSPO.

Putra, E. I., Hayasaka, H., Takahashi, H., & Usup, A. (2008). Recent peat fire activity in the mega rice project area, central Kalimantan, Indonesia. *Journal of Disaster Research, 3*(5), 1–8.

Rieley, J. O., & Page, S. E. (Eds.). (2005). Wise use of tropical peatlands: Focus on Southeast Asia. The Netherlands: Alterra. online at www.restorpeat.alterra.wur.nl.

Rina, Y., & Noorginayuwati. (2012). *Sosial dan ekonomi petani di lahan gambut* [Social and economic farmers on peatland]. In M. Noor, M. Alwi, D. Mukhlis, D. Nursyamsi, & M. Thamrin (Eds.), *Lahan Gambut: Pemanfaatan dan pengembangannya untuk pertanian* [Peatland: Its functions and development for farming] (pp. 217–247) (in Indonesian). Yogyakarta: Kanisius.

Ritung, S., Wahyunto, N. K., Sukarman, H., Suparto, C. T. (2011). *Peta Lahan Gambut Indonesia Skala* 1:250.000 (Map of Peatland in Indonesia, scale: 1:250,000, p. 11). Jakarta: Ministry of Agriculture, Republic of Indonesia (in Indonesian).

Saman, T., & Limin, S. (1999). Socio-economic values of wetlands for dayak community in Central Kalimantan. In T. Iwakuma et al. (Eds.) *Proceedings of the International Symposium on Tropical Peatlands, Bogor, Indonesia* (pp. 22–23). Sapporo: Graduate School of Environmental Earth Science, Hokkaido University.

Sastry, N. (2002). Forest Fires, air pollution, and mortality in Southeast Asia. *Demography, 39*(1), 1–23.

Schrier-Uijl, A. P., Silvius, M., Parish, F., Lim, K. H., Rosediana, S., & Anshari, G. (2013). *Environmental and social impacts of oil palm cultivation on tropical peat: A scientific review. Final report*. Kuala Lumpur: Roundtable on Sustainable Palm Oil.

Sheil, D., Casson, A., Meijpaard, E., Noordwijk, M. van., Gaskell, J., Sunderland-Groves, J., Wertz, K., & Kanninen, M. (2009). *The impacts and opportunities of oil palm in Southeast Asia: what do we know and what do we need to know?* (Occasional paper no. 51). Bogor: Center for International Forestry Research (CIFOR).

Starrett, D. A. (2000). Shadow pricing in economics. *Ecosystems, 3,* 16–20.

Tacconi, L. (2003). *Fires in Indonesia: Causes, costs and policy implications*. CIFOR (Occasional Paper No. 38).

Umar, S., Noor, M., & Noorginayuwati, A. (2014). Kearifan lokal untuk peningkatan dan keberlanjutan produksi pertanian di lahan gambut [in Indonesian; *The local wisdom for agricultural sustainability on peatland*]. Jakarta: IAARD.

Wetlands International. (2007). Assessment on peatlands, biodiversity and climate change. Kuala Lumpur: Global Environment Centre & Wageningen.

White, D., & Minang, P. (Eds.). (2011). *Estimating the opportunity costs of REDD +: A training manual*. Washington: The World Bank.

Whiteman, A., & Fraser, A. (1997). *The value of forestry in Indonesia*. Jakarta: Indonesia-UK Tropical Forest Management Programme.

WRI (World Resources Institute). (2005). *Ecosystems and human well-being: Synthesis*. Washington: Island Press.