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RESEARCH ARTICLE

Peat Restoration through the Geography Subject for Community Life and Environmental Sustainability

Ahmad Nubli Gadeng[1], Dede Rohmat[2], Ruliani[3], Mirza Desfandi[4]

[1,3,4] Department of Geography Education, Faculty of Teacher Training and Education, Universitas Syiah Kuala, Banda Aceh, Indonesia
[2] Department of Geography Education, Faculty of Social Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
Corresponding author : ahmadnubli@usk.ac.id

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ABSTRACT

This study aims to examine how peat restoration can be promoted through the geography subject for community life and environmental sustainability. The method employed is qualitative library research (a literature study), in which data were gathered from books, scientific journals, official reports, and government regulations, and then analysed through content analysis and thematic synthesis. The findings show that peat restoration for community life and environmental sustainability can be pursued through several complementary strategies: (1) hydrological restoration (rewetting), comprising canal blocking, canal backfilling, drilled wells, and retention ponds; (2) revegetation; (3) livelihood revitalisation; and (4) learning embedded in the geography subject at senior high school (SMA/MA), which demands an additional role from teachers in delivering the best possible knowledge to students during classroom learning. Integrating peat conservation into formal education is considered a powerful step because knowledge of peat conservation is introduced to students from an early age; with such awareness, students can wisely protect the peatlands within their communities. The outcomes of this educational process will be seen not in the present but in the future. It is therefore hoped that the devastating forest and land fires on peatlands that occurred in Indonesia at the end of 2015 will not recur.

Keywords: peat restoration; geography subject; community life; environmental sustainability.

1. INTRODUCTION

Large-scale peat restoration in Indonesia began after the forest and land fire disaster at the end of 2015. That year was the worst in the history of forest and land fires in Indonesia over the preceding eighteen years, and several neighbouring countries such as Malaysia and Singapore were affected by its impacts (BRG, 2016a). The fires did not occur in only a few provinces but were spread across several large islands, principally Sumatra and Kalimantan, since these two islands contain the majority of Indonesia's peatlands (BRG, 2016b). In Sumatra the fires were concentrated in Riau, Jambi, and South Sumatra, while in Kalimantan they were concentrated in West, Central, and South Kalimantan.

Most forest fires in Indonesia occur on peatlands. According to BRG (2016b), around 33 per cent of the total burned area was peatland, and the resulting haze became extremely hazardous—not only for the people who inhaled it but also for the wider environment. The fires were largely caused by inappropriate patterns of peatland management: in order to accelerate and simplify land conversion, or to replace old vegetation with new crops, communities took the shortcut of burning the vegetation on the peat. Fires occurred especially on peatlands that had already been converted into large-scale plantations holding land-clearing permits issued by previous administrations (BRG, 2016b). In a similar vein, Yuliani (2017) noted that peat fires occur as a consequence of the irresponsible use of peat swamps; the canals built by companies cause peatlands to become damaged, dry, and highly flammable.

Forest and land fires are, in essence, an inherited problem from past peatland management. For at least eighteen years, fires have recurred in Indonesia during prolonged dry seasons intensified by the super El Niño phenomenon, and their impacts have become increasingly damaging to the population (BRG, 2016b; Erlina, 2017). This situation reflects a lack of community knowledge about the correct and effective management of peatlands. Yuliani (2017) further argued that the absence of cheap, easy, and rapid land-clearing technology encourages communities to burn when preparing land for agriculture or plantations. Such imprudent land clearing is driven by socio-economic conditions and by the belief that the ash from burning can serve as fertiliser. In addition, industrial timber-plantation (HTI) and plantation companies that covertly use communities to clear land by burning—so as to reduce clearing costs—have also triggered land and plantation fires.

A lack of knowledge about environmentally friendly farming and plantation systems means that haze disasters still occur every year in several Indonesian provinces. Haze from forest and peatland fires can spread and disrupt air-transport systems, economic activity, and public health, causing acute respiratory infections (ARI), diarrhoea, and skin irritation (Sumantri, 2003; Aiken, 2004; Hergoualc'h & Verchot, 2013; Darmawan, 2016).

Rather than yielding benefits, these erroneous behavioural patterns have triggered major disasters, namely forest fires in several regions of Indonesia. Fires on peatlands are in fact more dangerous than fires on non-peat land, as Yuliani (2017) and Erlina (2017) explain:

Fires on peatland are more dangerous than fires on dry (mineral) soils. In addition to producing crown and surface fires, peat fires can also produce underground fires within the peat that generate thick smoke and inflict harm on many parties. Beyond the burning of surface vegetation, the peat layer itself burns and smoulders for a long time, producing thick smoke as a result of incomplete combustion.

The government recorded that 2.6 million hectares of forest and land burned between June and November 2015, generating dense haze that became a national problem (BRG, 2016b). This prompted the Government of the Republic of Indonesia to act quickly to address the fire disaster and to rehabilitate the peatlands that had been damaged.

To this end, the government established an agency known as BRG (the Peatland Restoration Agency / Badan Restorasi Gambut) on 6 January 2016. Its principal task is to accelerate the recovery process and restore the hydrological function of peat damaged mainly by the fires and drought of late 2015. The agency was mandated to work over a five-year period with a peat-restoration target of approximately two million hectares (BRG, 2016b).

The establishment of BRG reflects the seriousness of the Indonesian government in resolving the problem of forest and land fires and demonstrates its concern for the damaged peatlands scattered across several regions. It is hoped that, once restored to their pre-fire condition, these peatlands can again be used by communities for daily needs and for revitalising the livelihoods of the populations living around them. Peat recovery must also improve the welfare of surrounding communities (BRG, 2016b). Beyond livelihood revitalisation, another goal of peat restoration is long-term environmental sustainability, because degraded peatlands left neglected would disrupt the ecosystems of the many living things they support and could ultimately have fatal consequences for human life.

Alongside restoration, other measures can help prevent a recurrence of the 2015 fires. BRG has recognised that rehabilitating burned peatland requires enormous effort and cost, so the best strategy is in fact fire prevention (BRG, 2016b). Prevention has been pursued through community socialisation, but formal socialisation has not yet been undertaken. One avenue for such formal education is the geography subject taught at senior high schools (Sekolah Menengah Atas, SMA) and Islamic senior high schools (Madrasah Aliyah, MA). Geography contains several relevant learning topics—for example, in Grade X, "the dynamics of the lithosphere and its impact on life", and in Grade XI, "the management of Indonesia's natural resources", "food, industry, and energy security", and "natural-disaster mitigation".

While teaching these topics, teachers can incorporate material on the importance of protecting peatlands for human life and environmental sustainability. Students should be taught from an early age how to manage and protect the peatlands in their communities, so that in the future they do not repeat the same mistakes, such as burning forests. Accordingly, the present study aims to examine how the restoration of peatlands—important for community life and environmental sustainability—can be promoted through the geography subject at SMA/MA.

2. LITERATURE REVIEW

2.1 Peatland: Definition and Characteristics

Peat is organic material that forms and accumulates naturally from plant remains that are incompletely decomposed under excessively wet (waterlogged) conditions; it is non-compact, undergoes slow weathering, has a thickness of 50 centimetres or more, and accumulates in swamps (Pedoman Pelaksanaan, 2016; Noor, 2001). Peat is often grouped as organic soil, although this does not mean that all organic soils are peat (Noor, 2001). Several regions of Indonesia have distinctive names for peat soil, for example tanah hitam (Java), sepuk (West Kalimantan), and tanah rawang or tanah payo (Riau and Jambi) (Noor, 2001). Peat also has many English equivalents, including peat, bog, moor, mire, and fen, while peat swamps (peatswamps, marsh) are understood as wetlands (Erlina, 2017).

2.2 Peat Formation

Peat forms from the accumulation of plant remains, whether already decayed or not. The accumulation thickens because decomposition is inhibited by oxygen-poor conditions and other environmental factors that suppress decomposer organisms. Consequently, peatlands are commonly found in back-swamp areas or in poorly drained depressions (BRG, 2016b). The formation of peat soil is a geogenic process—soil formation driven by deposition and transport—differing from mineral-soil formation, which is generally a pedogenic process (Hardjowigeno, 1986). Peat ecosystems generally form and lie between two rivers, or between a river and the sea or swamp; over the long term the accumulation of peat layers fills the swamp or lake and eventually forms peat domes (peat domes) (Dohong et al., 2017).

The formation of a peat layer typically occurs because its rate of decomposition is slower than its rate of accumulation. This slowing of decomposition is caused by several physical and biological environmental factors, such as water saturation, nutrient poverty, oxygen deficiency (anaerobic conditions), and high acidity (low pH). Peat formation in Indonesia is estimated to have begun in the Holocene (about 5,000–10,000 years ago) (Noor, 2001; Agus & Subiksa, 2008). Some studies estimate that peat worldwide formed between 10,000 and 5,000 years ago (during the Holocene), while peat in Indonesia formed between 6,800 and 4,200 years ago (Andriesse, 1994). Based on radio-isotope dating (carbon dating), peat in Central Kalimantan is older still—formed about 6,230 years ago at a depth of 100 cm and up to 8,260 years ago at a depth of 5 m (Siefermann et al., 1987, in BRG, 2016b). Peat grows at a rate of between 0 and 3 mm per year (Page et al., 2002).

2.3 Distribution of Peatlands

Peatlands in Indonesia occur in both lowlands and highlands. Lowland peat swamps are generally located in tidal and valley swamp areas, lying between two large rivers on landforms such as river back-swamps (backswamp), coastal back-swamps (swale), closed basins, and coastal plains. Highland peat swamps are generally found in closed basins, such as those at Rawa Pening (Central Java), Padang Sidempuan (North Sumatra), and Lake Sentarum, Kapuas Hulu (West Kalimantan). Most peat swamps occur in the lowlands and only a small proportion in the highlands (BRG, 2016b). The largest peat deposits are distributed across Sumatra, Kalimantan, and Papua (BRG, 2016b).

Globally, Indonesia's peatlands rank fourth in extent after Canada, Russia, and the United States. Indonesia has around 20 million hectares of peatland, Canada 170 million, Russia 150 million, and the United States 40 million (Agus & Subiksa, 2008). Southeast Asia is the region with the largest tropical peatlands in the world, holding 56 per cent of the world's tropical peat; Indonesia alone accounts for 47 per cent of the world's tropical peat, making it the largest peat-owning country in Southeast Asia (BRG, 2016b). Table 1 summarises the comparison of the world's largest peatlands.

Table 1. Comparison of the world's largest peatland areas

Rank	Country	Peatland area (million ha)
1	Canada	170
2	Russia	150
3	United States	40
4	Indonesia	20

Source: Agus & Subiksa (2008).

2.4 Peat Ecosystem: Types, Functions, and Biodiversity

A peat ecosystem is an integrated whole of peat components that interact to form balance, stability, and productivity (Pedoman Pelaksanaan, 2016). In essence, it is the interaction among three principal forming elements—peat soil, vegetation, and water (hydrology)—which together constitute a peat hydrological unit (Dohong et al., 2017). Peat can be classified from several perspectives, as summarised in Table 2.

Table 2. Classification of peat based on various criteria

Criterion	Classes
Maturity level	Sapric (mature), hemic (semi-mature), fibric (raw)
Depth	Peaty soil (<50 cm); shallow (50–100 cm); moderate (100–200 cm); deep (200–300 cm); very deep (>300 cm)
Fertility / position of formation	Eutrophic, mesotrophic, oligotrophic peat
Formation environment	Ombrogenous and topogenous peat
Location	Inland, transitional, and coastal peat

Source: Dohong et al. (2017).

The functions of peat ecosystems are divided into protection functions and cultivation functions. Regulations mandate that within a single Peat Hydrological Unit (Kesatuan Hidrologis Gambut, KHG), at least 30 per cent must be designated as a protection function, covering the peat dome and its surroundings. Peat protection areas also include peat more than three metres thick, peat that provides habitat for endemic or protected species, and peat located within protected areas (Dohong et al., 2017; Pedoman Pelaksanaan, 2016).

Indonesian peatlands are generally characterised by large, forested peat domes (woody peat) covering extensive peat swamp and forest in low-lying landscapes, located mainly between large rivers. Peat swamp forest is a unique and fragile ecosystem, both in terms of its peat habitat—rich in organic matter, with thicknesses ranging from less than 0.5 metres to more than 20 metres—and its high ecological value. Of the roughly 258,650 species of tall trees recorded worldwide, about 13–15 per cent (some 35,000–40,000 species) are found in Indonesia's peat ecosystems (Osaki & Tsuji, 2016). There are no fewer than 30–122 tree species with a diameter of 10 centimetres in every hectare of peat swamp in

Indonesia (Posa et al., 2011). Peatlands are also home to 35 species of mammals, 150 species of birds, and 34 species of fish; several of these are endemic and protected under the IUCN Red List, including the false gharial, langur, orangutan, Sumatran tiger, and sun bear (WWF, 2009). The world's tropical peatlands cover about 42 million hectares and are estimated to store approximately 148 gigatonnes of carbon (Osaki & Tsuji, 2016).

Peatlands play an important role in maintaining environmental balance, both as water reservoirs and as carbon storage. Peat also hosts endemic and distinctive biodiversity, shaped by the characteristics of the peat ecosystem: acidic pH, nutrient poverty, and a thick, permanently waterlogged organic layer. These conditions support only certain flora and fauna capable of adapting to the peat environment, with the highest centre of peat-ecosystem biodiversity located in Kalimantan (Myers et al., 2000). The role of tropical peat as an emission sink and water store is therefore vital, yet it also poses a serious threat to the world if it is not managed well (BRG, 2016b).

2.5 The Concept of Peat Restoration

Restoration refers to the various efforts undertaken to recover land that has been damaged by natural or anthropogenic factors. According to Pedoman Pelaksanaan (2016), peat restoration is an effort to recover degraded peat ecosystems so that the hydrological condition, structure, and function of the peat ecosystem return to a restored state. The ecological degradation of Indonesian peatlands has generally been caused by two main activities: open drainage and land fires. Altering the natural properties of peatland creates substantial ecological losses; uses that ignore the natural properties of peat render it dry and highly flammable. Damage to peat ecosystems can affect both the local environment (in situ) and the surrounding environment (ex situ) within a single hydrological unit. Downstream flooding in a watershed is one impact of peat-ecosystem degradation. Deforestation and the use of peat for agricultural systems requiring deep drainage (>30 cm), together with burning, cause very high CO_2 emissions (BRG, 2016b).

2.6 Geography Education for Environmental Awareness

Education is a strategic instrument for cultivating environmental awareness from an early age. After studying geography at SMA/MA, students gain numerous benefits, including improved (1) spatial intelligence, (2) ecological intelligence, (3) disaster preparedness, and (4) a spirit of defending the nation and love of the homeland (Gadeng et al., 2016; Gadeng et al., 2020; Furqan et al., 2020; Gadeng et al., 2022). These competencies position geography as a suitable vehicle for internalising values of peatland conservation. The precondition, however, is that teachers are able to teach all geography learning materials well, employing appropriate learning approaches, methods, models, and media—preferably those drawn from the students' immediate environment—so that the surrounding peatland itself can serve as a learning resource.

3. METHOD

This study employed a qualitative approach using the library-research method (a literature study). Library research is a series of activities concerned with methods of collecting library data, reading and recording, and processing research material, without requiring fieldwork (Zed, 2014). It is a data-collection technique in which the data are drawn from literature—such as books, printed and online media, articles, and reports of previous research—to review theories relevant to the research problem, to fill gaps in prior research, and to answer the research questions (Hasan, 2002; Sarwono, 2010; Darmadi, 2014; Creswell, 2010). A literature review conducted systematically and transparently is a legitimate research methodology in its own right and is particularly appropriate for synthesising evidence and mapping the state of knowledge on a given topic (Snyder, 2019).

The data sources in this study were secondary, comprising: (1) primary references in the form of official documents and reports of the Peatland Restoration Agency (BRG), guidelines for peat-restoration implementation, and related government regulations; and (2) supporting references in the form of national and international scientific journal articles, books, and proceedings addressing peat, peat restoration, and geography education. Sources were selected purposively based on their relevance to the themes of peat restoration, community life, environmental sustainability, and the geography subject at the senior-high-school level.

Data were collected through documentation, namely by tracing, reading, recording, and organising written material relevant to the research focus. The collected data were then analysed using content analysis and thematic synthesis, carried out through the interlinked stages of data reduction (organising and selecting relevant information), data display (grouping the information into themes), and drawing conclusions (interpreting the relationships among themes) (Miles & Huberman, 1994). To maintain the credibility of the findings, source triangulation was applied by comparing and cross-checking information obtained from several references before conclusions were drawn (Bungin, 2011). Through these procedures, the study organises the existing body of knowledge on peat restoration and formulates how it can be integrated into geography learning at SMA/MA.

4. RESULTS AND DISCUSSION

Following the fire disaster of 2015, efforts to restore peatlands comprise three main components—rewetting, replanting, and improving the welfare of local communities—known as the 3R (or 3P) principle (BRG, 2016b). The discussion below explains the implementation strategy of these three approaches, followed by their integration into the geography subject at SMA/MA.

4.1 Peat Restoration Strategies

4.1.1 Hydrological Restoration (Rewetting)

Hydrological restoration is carried out by rewetting peatlands that have become damaged and dry. Rewetting can be achieved by building canal blocks, backfilling channels, and constructing drilled wells (BRG, 2017b). The proper target of peat rewetting is not to raise the water table as high as possible (creating inundation), but to raise it sufficiently to increase peat moisture, especially in the dry season, so that the peat is less prone to oxidation and burning. Table 3 summarises the main rewetting techniques and their functions.

Table 3. Hydrological restoration (rewetting) techniques and their functions

Technique	Description and function
Canal blocking	Building blocks within human-made canals, ditches, or channels to hold water, reduce surface run-off, and raise the water-storage capacity of the canal body and its surroundings; also serves as a water source for firefighting and, in coastal areas, restrains saltwater intrusion.
Canal backfilling	Filling in sections of a channel upstream of a canal block—or filling it entirely—to reduce downstream flow, lower water pressure on the block, extend the block's service life, and stimulate natural vegetation growth.
Drilled wells	A simple, cheap, and efficient technique for pumping abundant groundwater from the aquifer beneath the peat surface, used to wet the peat and to supply water for extinguishing fires; pumps are fitted with a 150 m hose to reach hotspots flexibly.
Retention ponds (embung)	Water-storage basins that hold reserve water within the peat ecosystem, serving mainly as a water source for extinguishing fires during water scarcity in the dry season.

Source: adapted from BRG (2017b) and Dohong et al. (2017).

Canal blocking aims to hold water within human-made ditches or channels by constructing blocks, thereby reducing the draining of water from the peat aquifer, slowing surface outflow, and raising water storage in the canal and its surroundings (BRG, 2017b). Yuliani (2017) explains its rationale:

> The purpose of building canal blocks is to restore wet and moist peat conditions and to reorganise peatlands that have already been excavated. The canal blocks hold back the swift flow of water from the peat dome and redirect it sideways. With the blocks, water seeks its way sideways rather than in a single direction, producing a wetting effect and reducing drainage at the water-source dome. Because peat is porous like a sponge—shrinking when there is no water and swelling again when water is present—canal blocks keep the peat from shrinking. Most importantly for current concerns about fire and haze prevention, canal blocks are an effort to prevent the recurrence of peat fires and haze; they also provide a water source for extinguishing fires. In coastal areas, canal blocks restrain the rate of saltwater intrusion, helping sago to grow well.

Thus, surface- and ground-water levels can be raised or at least maintained at an optimal level, particularly in the dry season, so that peat water is not lost to rivers or nearby locations and the wetness and moisture of the peat are preserved, minimising the chance of fire (BRG, 2017b). One means of addressing peat-ecosystem degradation is the construction of canal blocks or water-regulating structures that keep the water table at least 0.4 metres below the peat surface in cultivation zones (Dohong et al., 2017).

Canal backfilling is an effort to prevent water from escaping through the channel by filling in certain sections (BRG, 2017b). Backfilling is carried out along the channel upstream of the canal block using material from around the ditch, or by filling the ditch entirely so that it no longer conveys water. Care must be taken so that extracting this material does not create new problems, such as new ditches formed by the excavation. The aims of backfilling are to: (1) reduce downstream flow and gradually fill the section of ditch immediately upstream of the canal block; (2) reduce water pressure on the block and improve its durability; and (3) stimulate the natural growth of vegetation.

Drilled-well technology is a simple, cheap, and efficient technique for drawing on the abundant water available in the aquifer beneath the sub-surface and surface layers of peat, providing a water source both for firefighting equipment and for wetting the peat (BRG, 2017b). Not all locations are suitable, but drilled wells have proved effective in preventing the spread of peat fires in remote areas. They are expected to strengthen the capacity of community groups to extinguish land fires quickly and serve as a short-term means of wetting and firefighting; beneath the peat lies a large groundwater source that can be used when canals are dry because blocking is not yet optimal. Drilled-well pumps are equipped with a 150-metre hose so that they can flexibly reach emerging hotspots, and they can be used both to extinguish fires and to wet the peat when the weather is too dry and fire-prone (BRG, 2016b).

Retention ponds (embung) are water reservoirs that store reserve water within the peat ecosystem (BRG, 2017b). Their main purpose is to serve as a pool of water for extinguishing fires, particularly during water scarcity in the dry season. The implementation of peat rewetting depends on three factors: (1) priority zoning, (2) variation in the slope of the channel bed, and (3) channel dimensions. Priority zoning determines the type of rewetting technique required; the variation in bed slope determines the target rise in canal-water and ground-water levels and the appropriate block density; and the variation in channel dimensions, together with priority zoning, determines the type of intervention needed—for example, whether backfilling or canal blocking is required.

For cultivation-function areas, the aim of rewetting infrastructure is water-level management, so the structures built are canal blocks or water-retaining structures fitted with an overflow/spillway to release excess water; the crest elevation of the overflow must not be deeper than 0.4 metres below the peat surface, in accordance with Government Regulation No. 57 of 2016 (Dohong et al., 2017). For conservation areas, the aim is water conservation, so the infrastructure may take the form of canal blocks or water-retaining structures and canal backfilling, which do not require an overflow; the crest elevation of the structure is recommended not to exceed the peat surface in order to avoid lateral scouring and leakage. Such structures should be peat-friendly, and permanent materials such as concrete—which cannot integrate with peat over time—are therefore not recommended (Dohong et al., 2017).

In general, the objective of rewetting peat that has been degraded and excessively dried by drainage-canal networks is to restore peat hydrological function, reflected in the stabilisation of the water table and increased wetness and moisture. Rewetting is expected to deliver short-, medium-, and long-term benefits, including: (1) reduced risk of land and forest fires; (2) reduced rate of peat subsidence; (3) reduced greenhouse-gas emissions; (4) restored peat hydrological function; and (5) accelerated peat restoration (Dohong et al., 2017).

4.1.2 Revegetation

The approach applied in revegetation is adjusted to land-cover conditions, hydrological conditions, management status, the presence of communities, social conditions, BRG restoration-map zoning, and other related factors (BRG, 2017b). For locations within a company's concession, concession revegetation is applied, with the planting system adjusted to the function of the area within the concession and to BRG's peat-management zoning; this has implications for the choice of plant species and planting techniques. In concession revegetation, the concession holder is both responsible for and the implementer of field activities and bears the financing, while the government—assisted by other parties such as universities and non-governmental organisations—performs monitoring and supervision.

For areas close to communities, or where community activity exists or is under way, participatory revegetation is applied. This approach offers at least two planting-system options: adaptive agroforestry (agroforestry) and paludiculture. As the name suggests, participatory revegetation is carried out by communities, ideally facilitated by non-governmental organisations or universities, and financed from the state budget (APBN) or donors; here too the government monitors and supervises field activities. For non-concession areas outside community-activity zones, intensive revegetation is applied, commonly through reforestation and enrichment planting, with the government as implementer and responsible party and financing from the state budget or donors. To protect and safeguard revegetation sites from fire, the planting of firebreaks can be combined with all three revegetation approaches (BRG, 2017b).

4.1.3 Livelihood Revitalisation

Within and around the peat areas of the seven priority restoration provinces, there are 2,495 villages/urban wards, of which approximately 1,205 fall within the peat-restoration target areas (BRG, 2017b). BRG has determined that community-based peat restoration is carried out on a village/ward or customary-community basis. This aligns with the mandate of Law No. 6 of 2014 on Villages, under which villages hold origin rights and traditional rights to manage the interests of local communities. For communities living within and around peat ecosystems, villages should be given a strategic role in protecting and managing the peat ecosystem and in actively restoring damaged peat areas, with the community as the principal beneficiary. Livelihood revitalisation through the optimisation of profitable alternative commodities within the peat ecosystem is essential for improving welfare (BRG, 2017b).

The benefits of peat restoration are considerable given the extensive environmental damage to peat ecosystems, which are both unique and vulnerable (BRG, 2017a). Peat areas can store water, provide habitat for numerous species, and help control climate change. Although peatlands cover only 3 per cent of the earth's land surface, they can store 550 gigatonnes of carbon—equivalent to 75 per cent of atmospheric carbon, or twice the amount of carbon contained in all non-peat forests. The benefits of peat ecosystems include forestry, flood control and water supply, tourism potential, local livelihoods (fisheries, agriculture, plantations), climate stabilisation, biodiversity, and education and research (Yuliani, 2017).

The Peat Care Village (Desa Peduli Gambut) programme promotes haze-disaster mitigation in fire-prone peat villages, while also encouraging the recovery of burned farmland; economic improvement through peat management based on local wisdom; the revitalisation of social institutions; the resolution of tenurial conflict; and the recognition and legalisation of community rights and access through social-forestry, customary-forest, or agrarian-reform schemes (BRG, 2017b). The substance of area development can take various options depending on the village's economic potential, with the key requirement that the potential developed must contribute to peat restoration—for example: (1) burn-free, paludiculture-based agriculture; (2) freshwater fisheries; (3) livestock; and (4) ecotourism (BRG, 2017b).

Peatlands in Indonesia offer many benefits, providing timber and non-timber forest products, storing and supplying water, storing carbon, and serving as habitat for biodiversity, including rare flora and fauna found only in this ecosystem (Yuliani, 2017; Erlina, 2017). As population growth increases and land availability for agriculture, plantations, industrial timber, settlements, and infrastructure becomes limited, choices are increasingly directed towards peatlands. In Sungai Tohor, sago palms thrive in wet, peat-rich forests, and their growth depends on the wetness of the soil and peat; these trees provide the Sungai Tohor community with a stable livelihood (Yuliani, 2017). Alongside sago cultivation, the community has also built canals fitted with blocks to prevent the spread of fires and to avoid soil erosion that would render the canals dysfunctional. With canal blocking keeping the peat wet and less flammable, the peat function that suits sago—one of the community's plantation commodities—is preserved. Conserving the environment as a form of local wisdom in turn boosts the community's economy from the agricultural and plantation sectors, because soil fertility is maintained and yields increase (Erlina, 2017).

Studies by BRG have also identified local practices of environmentally friendly peat farming. Farmers in Tanjung Jabung Barat, Jambi, for example, have successfully cultivated liberica coffee on 2,500 hectares of peatland; in Sungai Tohor, Riau, communities have successfully cultivated and produced sago; and in Gohong Village, Pulang Pisau, Central Kalimantan, communities have successfully grown dragon fruit on peatland (BRG, 2016b). These local practices reveal a great opportunity to integrate conservation and peat recovery with improved community welfare. A number of crops are known to be viable on peatland, ranging from pineapple, coffee, and dragon fruit to rice. Some communities also make use of purun (Eleocharis dulcis, a grass-like plant that thrives in wet peat), bamboo, or thorny pandanus as weaving material for mats, fish containers, and other household goods—for example in Ulakkemang and Menang Raya villages in Ogan Komering Ilir (OKI), South Sumatra. In Muara Jambi, resam ferns (Dicranopteris linearis) are transformed into fashion accessories such as vests, hats, bracelets, rings, and even car-seat covers, serving fashion, style, and health purposes.

4.2 Peat Restoration through the Geography Subject at SMA/MA

One of BRG's functions is the socialisation and education of peat restoration; accordingly, restoration plans and activities need to be socialised and coordinated among rights-holders and stakeholders (BRG, 2017a). Such socialisation involves government, communities, academics, customary institutions, civil-society groups, and companies, with participants including relevant government officials, academics, non-governmental and community organisations, sub-district heads, village heads and representatives, and company/permit-holder representatives, particularly in the peat-restoration target villages. The education undertaken by BRG so far has been intended only for communities; the present study extends this to educating SMA/MA students about the importance of correct and effective peatland management. Because students are the nation's future generation, if they acquire knowledge about peat while still in senior high school, they will be able to take the right actions to protect peatlands once they enter society—for the sequence begins with knowing, continues with caring, and ends with protecting the peatlands within the community.

One means of introducing peat to SMA/MA students is through the geography subject, which contains several relevant learning topics. In Grade X, the topic "the dynamics of the lithosphere and its impact on life" allows peatland knowledge to be embedded in the sub-topics of soil formation and the distribution of soil types, as well as soil use and conservation. In Grade XI, peat-restoration knowledge can be embedded in "the management of Indonesia's natural resources"—specifically in the sub-topics of the potential and distribution of forestry, mining, marine, and tourism resources; environmental impact assessment (AMDAL) in development; and the use of natural resources based on the principles of sustainable development. Finally, knowledge of peatland-fire mitigation can be embedded in the "natural-disaster mitigation" topic—specifically in the sub-topics of the types and characteristics of natural disasters, the disaster-management cycle, the distribution of disaster-prone areas in Indonesia, and community participation in disaster mitigation. Table 4 maps this integration.

Table 4. Integration of peat-restoration topics into the SMA/MA geography curriculum

Grade	Learning topic	Sub-topic for embedding peat material
X	The dynamics of the lithosphere and its impact on life	Soil formation and distribution of soil types; soil use and conservation
XI	The management of Indonesia's natural resources	Potential and distribution of forestry, mining, marine, and tourism resources; environmental impact assessment (AMDAL); sustainable use of natural resources
XI	Food, industry, and energy security	Sustainable use of peatlands for food and energy
XI	Natural-disaster mitigation	Types and characteristics of disasters; the disaster-management cycle; distribution of disaster-prone areas; community participation in mitigation

Source: processed by the authors (2023).

By understanding the importance of protecting the peatlands in their communities, students are expected to develop an inner awareness that motivates them to protect peatlands from destruction by burning, so that peat fires such as those of 2015 do not recur. This is part of disaster-mitigation education for the fire hazard. Geography teachers are further expected to understand thoroughly the natural conditions around their place of teaching; where they recognise that their school is located in a peatland area, they can embed material on the importance of protecting and conserving peat during classroom learning. Teachers should deliver such material as effectively as possible, using learning approaches, methods, models, and media drawn from the students' surroundings, thereby making the peatland itself a learning resource. To do so, teachers must be able to teach all geography material well, as expected above. In practice, to enhance students' knowledge and understanding of peatland, teachers should give examples of peatland located around the students' place of residence so that students can observe it directly; distant examples should be avoided, as these may confuse students and impede their understanding of the material explained in class.

5. CONCLUSION

Peat restoration for community life and environmental sustainability can be pursued through several complementary strategies: hydrological restoration (rewetting) via canal blocking, canal backfilling, drilled wells, and retention ponds; revegetation; livelihood revitalisation; and, importantly, learning embedded in the geography subject at SMA/MA. Integrating peat conservation into formal education is a powerful step because knowledge of peat conservation is introduced to students from an early age; with such awareness, students can wisely protect the peatlands within their communities. The results of this educational process will be seen not in the present but in the future, so that the devastating forest and land fires on peatlands, such as those that occurred at the end of 2015, are not repeated.

It is recommended that the government incorporate curriculum content on the importance of peatlands into schools located within peat regions, so that knowledge of peatlands is provided to students from an early age even though students will also encounter peatland material in the geography subject in Grades X and XI. Ultimately, it is hoped that both formal and non-formal socialisation of the importance of protecting peatlands will succeed within the everyday life of communities living in peatland areas.

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