A Review on the Tropical Peatland Characteristics Towards Sustainability of Peatland in Malaysia

Kajian Semula Ciri-ciri Tanah Gambut Tropika ke Arah Kemampanan Tanah Gambut di Malaysia

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ABSTRACT *The natural ecosystem is a dynamic relationship between living organisms and their environment. There are two types of ecosystems: natural and artificial ecosystems. Peatland is classified as a natural ecosystem. This review covers the trace and major elements, and the character of their accumulation in peat, with a particular emphasis on peat properties, conservation and restoration. Peatland is a valuable but vulnerable resource in the world, representing a valuable carbon pool and energy as a functional system while playing a main function in hydrological and biochemical cycles. Research in the characterization and data inventory of tropical peatlands is very important to determine the peatland's status and identify the key knowledge gaps that need to be addressed. The results are important for the conservation, restoration and sustainability science of peatland areas through the characterization of the physical soil, nutrient content and carbon pool emission for the classification of peatland conservation status before development because the disturbance impact in peatland can be irreversible. The best use of peatland considers the trade-off between development and conservation. The increasing Malaysian population has increased land demand; large peatland areas in Malaysia have been slotted for other land uses. The expansion to other land uses will cause biodiversity to decline and carbon emissions to escape into the atmosphere during the process of either land-use change or a process that involves human and natural causes. The peatland environmental problems related to peatland drainage include water table imbalance and peat fires. However, a precise understanding of the ecological, hydrological, and biodiversity processes and interactions is fundamental to adequately restoring degraded peatlands, preserving the remaining areas, and understanding the management action, whether on a small or large scale. Therefore, this paper provides an overview of the Peatland status area in Malaysia with recommendations for conservation and restoration to avoid or reduce potential ecological and biodiversity impacts for sustainability science.*

Keywords: *Characteristic, conservation, restoration, tropical peatlands, sustainability, conservation and restoration*

1. Introduction

Peatland is an important terrestrial ecosystem of a particular conservation value because of its high biodiversity and importance in global chemical cycles as a carbon pool. The peatland area is a complex ecosystem composed of organisms living in a given habitat plants and animals are the biotic components of the ecosystem, while the subsoil, water, air, light,

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temperature, climate and rain are part of the abiotic component. The characterized peatland by a substantial accumulation of organic matter in the soil (peat), resulting from long-term excess of net primary production at the surface compared to decomposition throughout the peat column. Globally, peatland covers an estimated area of 400 million hectares, equivalent to 3% of the land surface, and contains around one-third of the carbon stored in the terrestrial biosphere (Jaenicke et al., 2008; Veloo et al., 2015). Peatland areas have been reported in more than 130 countries around the world and Malaysia has 2.6 Mha or 8% of the total areas, of which about 70% (1.6 Mha) is located in Sarawak (Miettinen et al., 2016). Peatland areas in Malaysia have been declining since the independence in 1957 (over 60 years) due to the introduced policies such as "agriculture is business," leading to most peatlands in Malaysia being explored for agricultural and commercial uses. However, the exploration activities were especially logging, for land clearing in agriculture and urban human settlement. In recent years, more than half of the high-value peatlands (plant species, soil carbon store, biodiversity) have been developed either in the forests or the Permanent Forest Reserves (PRFs), but the PRFs are targeted for selective logging and other uses. For example, they support a large diversity of flora and fauna species, some of which are endemic or endangered (Page et al., 1997).

2. Literature Review

The land-use changes in the Malaysian peatland over the past few decades have induced multifarious environmental consequences, especially on peatland ecology, hydrology and biodiversity (Miettinen et al., 2015). Recently, issues in peatland area have received high priority, focusing on ecology (Zak, et al., 2018; Ratcliffe, et al., 2017; Brown et al., 2015; Hájek, 2014; Page, et al., 2009; Lamentowicz, et al., 2005), eco-hydrology (Young, et al., 2017; Morris, et al., 2011; Van, et al., 2011; Larsen, et al., 2007; Waddington, et al., 2005; Trepel and Kluge, 2002), sustainability (Rawlins and Morris, et al., 2010; Tolvanen, et al., 2013; Limin, et al., 2008), and biodiversity indicators (Woziwoda and Kopeć, 2014; Rumchander, et al., 2012; Koh, et al., 2011; Schindler, et al., 2010).

The specific biophysical characteristic of peatlands depends on the soil characteristics and properties, the mixture of fragmented organic materials formed under appropriate climate (precipitation) and topography condition (location of peatlands) (Dhowian and Edil, 1980; Hashim and Islam, 2008). Almost all regions in the world where peatland areas occur are either those with high precipitation excess, or temperate and boreal zones or lowland areas where shallow gradient and topography maintain the impermeable substrate saturation (Holden et al., 2004). Von (1992) has classified a peatland system based on several factors, such as botanical composition, degree of humification, and the watercolor in peat after squeezing. The scale is based on the degree of fibrousness, starting from H1 (highly fibrous) to H10 (very low fibrous). The degree of decomposition is based on the Von Post scale number (Silc and Stanek., 1977; Chapman and Warner., 1992; Chapman et al., 2002; Huat, 2004; Grover and Baldock., 2013; Bourgault et al., 2018). Other researchers use an

American Society for Testing and Materials (ASTM) for the standard procedure in peatland classification with the dry mass of unrubbed fibre being 0–32% (Sapric), 33–67% (Hemic) and >67% (Fabric), respectively (Bridgham et al., 2000; Idi and Kamarudin, 2012; Özcan et al., 2018). The general classification by Holden et al. (2004) is based on two fundamental factors, such as the source of nutrients (chemical properties) and water (water table balance). The source of nutrients and water from outside of a peatland is very important to determine the characteristics and formation process of the peatland. Besides that, organisms that decompose the plant materials are cultured and identified (Bunt, 2012).

The biodiversity of tropical peatland is rare due to its natural, yet fragile ecosystem with important biological and hydrological functions. As a natural ecosystem, a variety of unique flora and fauna species are found in peatland areas, providing economic resources to local people. Furthermore, the hydrological component attenuates or accentuates flooding for the water linkage movement as runoff and groundwater flow below the peat surface. The long-term capability of peatland is to store or absorb CO_2 or other gases, controlling global climate change (Ojanen et al., 2013). Hence, due to the land demand for human development, peatland areas are intensively and rapidly developed and degraded (Holden, 2005; Miettinen et al., 2012a). It is a sensitive area; a minor disturbance can negatively impact it, affecting the carbon dioxide (CO_2) emission and turning the peatland areas from carbon storage into a main source of worldwide climate change (Yule, 2010; McCarter and Price, 2013) while significantly contributing to the environmental and human socio-economic impacts, locally or globally. Land-use changes in peatland for commercial extractions like forest logging and agriculture have devastated large peatland areas, especially the ones located close to the development areas (Chapman et al., 2003; Nugent et al., 2003).

Figure 1 shows the distribution of peatlands in Malaysia and Table 1 shows the data of land cover distribution in the peatlands of Malaysia in 2015. The data were analyzed by Miettinen et al. (2016) using satellite data (land cover classification). From the summary of the data, Malaysia has the highest proportion of peatland area converted or changed to other types of land use (60–66%). That study started from 1990 to 2007 and 2015. This study has proven that the status of peatland areas in Malaysia decreased from 1990 to 2015. The rapidly decreasing forest cover in peatland areas as a natural and increasing area of the managed land cover type has drastically changed the main function of peatland, ecology and hydrology in this region. The argument of the data is why have the peatland areas become the main target of developers for other land uses. This can be explained through its relevance for other uses, such as those listed in Table 1, especially for plantations. The plantation is dominant because the peatland areas are fertile and available flat land for planting (Ojanen et al., 2013).

In Malaysia, the peatland forest area is typically converted to agriculture via logging and land clearing using heavy machinery or burning for plantation. The process involves the preparation of drainage for the seedbed, reducing the depth of the water table and eliminating the water storage (Wösten et al., 2001; Wicke et al., 2011; Koh et al., 2011; Miettinen et al., 2016). Once the water has been drained, the peatland is extremely flammable,

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with the most degraded (lowest water table) peatland areas at the highest risk. An easy way to save time and money to clear the land is for farmers to start fires for a week, a month or even years, resulting in a loss of control; it is extremely difficult to extinguish the fire as it spreads very rapidly unless the natural water table is restored to its original state (Page et al., 2009; Miettinen et al., 2012b; Osaki et al., 2016). In addition, the fertile soil is exposed to erosion in the process of removing the trees to plant Oil Palm or Sago Palm (Merten et al., 2016; Zulkifley et al., 2015).

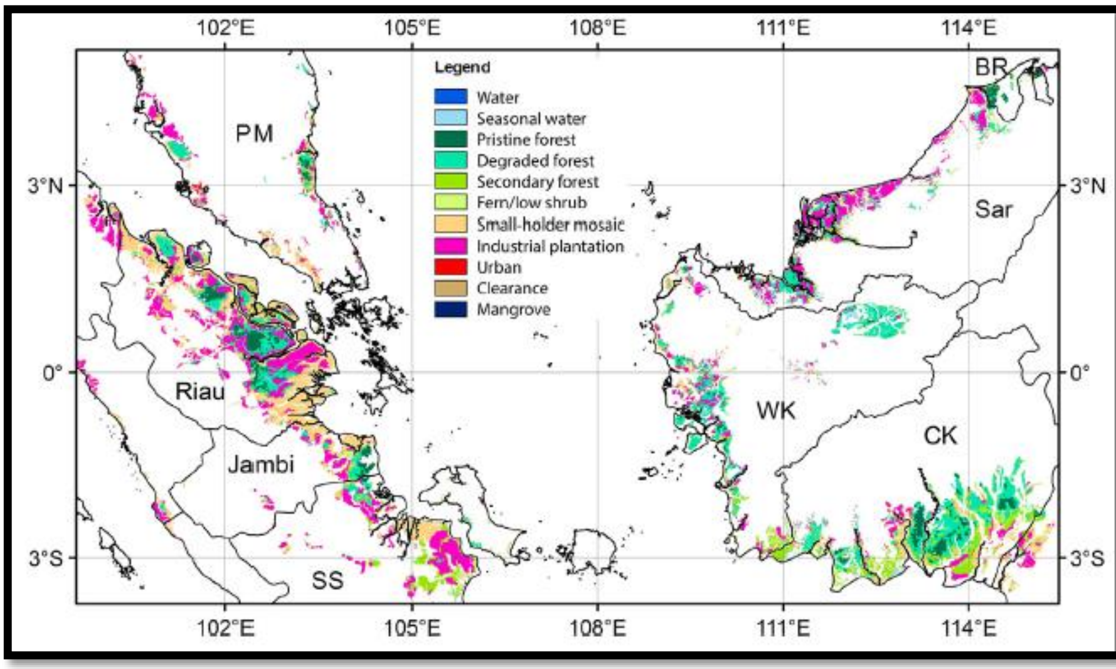

Figure 1. *Land cover 2015 in the major peat of the study area especially in Malaysia (research cover area).* Administrative areas referred to in the text are identified as PM = Peninsular Malaysia, Sar = Sarawak, BR = Brunei, SS = South Sumatra, WK = West Kalimantan, and CK = Central Kalimantan (Miettinen et al., 2016).

Table 1
The land cover distribution peatlands of Malaysia in 2015 (in 1000 ha)

	Water	Seasonal	Pristine	Degraded	Tall Shrub/	Ferns/Low	Small-holde	Industrial	Urban	Clearance	Man-grove	Total

		Wat er			Seconda ry Forest	Shru b	r Area	plant ation				
Peninsular Malaysia	9.84	3.06	41.1 5	152.17	48.91	34.0	267.1	279.3	24.6	30.0	1.4	891.7
Sarawak	1.73	1.31	7.60	383.44	152.27	12.7	141.0	725.1	10.3	8.6	5.2	1449.4
Sabah	0.96	0.97	3.40	43.25	21.20	22.3	25.74	66.2	2.0	2.3	2.5	190.8

Source: Miettinen et al., 2016

Maintaining the peatland area is impossible due to the high demand for agricultural land and development necessities. Due to the rapid changes in peatland areas in Malaysia over the past decades that have induced a variety of environmental impacts, some questions need to be investigated and answered before it can be decided if the exploitation of peatland related to commercial activities is sustainable over the long term. The first question is on the location of the peatland—urban, rural, permanent forest reserve, and production forest reserve. The second is on the size of the exploited area—delimitation, modelling, and predicted volume of peat. The third is on the commercial activities proposed for the peatland—recreation, agriculture, horticulture, settlement, industrial, and road. The fourth is on the effect of peat extraction on the main functions—carbon pool, flood control, global carbon cycle, water cycle, climate change, and valuable biodiversity. The fifth is the conflict of interests between the local people and animals like orangutans, monkeys, and others. The final one is on the time taken to restore the land to its original condition. Therefore, one of the important challenges for ecological science in this era is to thoughtfully consider the influence of peatland in ecology, hydrology, biodiversity, and its relationships with the socially dynamic perspective of identifying occurrence and status; improving assessment for conservation and preventing further degradation; targeting, restoring, and conserving the peatland; and sharing the experiences and expertise on successful sustainable peatland management.

This review paper provides information on the current status and land use change trends in peatland areas in Malaysia and recommendations for restoration and conservation. Besides that, the key knowledge gaps will be identified, and where they need to be addressed for future exploration of sustainable research. The main objectives of this review paper are to present: (1) The current research and status on the important attributes of tropical peatlands in Malaysia to provide improved knowledge; (2) The main function, contribution and land use changes effect of peatland in Malaysia, either in undisturbed or disturbed area; and (3) Recommendation for restoration and conservation to find the key gap for future sharing knowledge and for expanding the research horizon.

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3. Research Methodology

3.1 Formation and Biogeography of Peatland

The formation and biogeography of peatland are based on the environment and some of the factors stated earlier. The organic material collected along with the resulting sediment forms a peatland based on their intrinsic characteristics and unique interactions between the biosphere, lithosphere, and atmosphere. Some of the factors that influence peatland preservation are the humidity equilibrium (precipitation and evaporation), high-relative humidity, topographic (land use) and geological conditions responsible for water retention, and its low substrate pH and nutrient availability. The tropical peatland, especially in Malaysia, differs from other peatlands because the lowland peatland is almost exclusively ombrogenous—in which water and nutrient supplies to the surface are derived from the precipitation (Rainfall, dust and aerosol)—while the geogenous peatland, additionally fed by water that has been in contact with the mineral bedrock and soil, has more limited distribution as it is confined to the edges of coastal lagoons, the banks and the flood zones of rivers, and the margins of the upland lakes. The lowland ombrogenous peatland supports the peat swamp forest, while the freshwater swamp forests are associated with geogenous peatland (Page et al., 2006). According to Ingram (1983), the deposits in the peatland area are divided into two compositions or layers: acrotelm and catotelm. The upper layer is the acrotelm. It is the surface layer of peat soil, which is typically <50 cm thick, having varying oxidation states due to the moisture and water table fluctuations. The highest water conductivity recorded in this layer is 10^{-2} ms^{-1}. This area or zone transitions the water movement in stretched peatland columns. The second layer is the catotelm, which is below the acrotelm layer. The nutrient content in water and soil is different from the acrotelm layers. The hydraulic conductivity in a catotelm is lower than that in an acrotelm layer, which is between 10^{-5}–10^{-8} ms^{-1}. Normally, the peatland is divided into two basic landform types: bogs and fens. The bog areas' characteristics include low pH (<4.2), low calcium (<2.0 ppm) surface water and low flora species richness (typically dominated by sphagnum moss). The other type of peatland is fens. Unlike bogs, it is located along a concave or flat area (upland or river levee). The characteristics include higher pH (>4.2), high soluble nutrients like calcium (>2.0 ppm), and high flora biodiversity. Typically, for the flora bioindicator, bogs are distinguished by the low number of species and the dominance of moss that resulted from the water characteristics of its acrotelm (Reeve et al., 2000).

The peatland in Malaysia is in the lowland and is often flooded and swampy (fens). Much of the peat areas are marked as abandoned swamps. Almost all natural peatlands in Malaysia are peat swamp forests formed thousands of years ago, where the saturated soil or estuary was frequently flooded, preventing the organic materials from being fully decomposed. The Malaysia peatland has a saline influence if the location is near to the estuary (brackish water) (Alvin, 2010). Despite that, many of the peatlands that are now far inland, possibly around 100 km away from the coast, are especially in Sarawak (Alvin, 2010). However, over the years, land demand due to development has increasingly converted mineral soil areas; until now, the border of peat swamps stretched, especially in Peninsular Malaysia. In the East Malaysia, Sabah and Sarawak, there is low opportunity for the variety of land use because the states already have a considerable amount of land as peat. The peatland forest areas have decreased due to the systematic clearing, drainage and burning for agriculture, development and recreation. This process will negatively impact the flora and fauna, especially the rare and endangered species such as orangutan (*Pongo Pygmaeus*), which is mostly found in the states of Sabah and Sarawak. The most valuable plants in peatlands are timber species such as ramin (*Gonystylus bancanus*), including *Dactylocdus stenostachys*, *Dryobalanops Rappa* and Meranti group (*Shorea Platycarpa*, *S. Albida*, and *S. Uliginosa*), which are mainly harvested routinely for the economic sector, especially in the Sarawak State for production (Posa et al., 2011). According to Anderson (1961), the peatland forest was classified into six distinct phasic communities (PC), such as PC 1 (mixed forest), PC 2 (Alan Forest), PC 3 (Alan Bunga Forest), PC 4 (Padang Alan Forest), PC 5 (Center of highly developed peatland and very stunted vegetation), and PC 6 (Padang Paya Forest) based primarily on the topographic factor and successional stages (Phillips, 1998). Alan Forest refers to the Shorea albida tree with highly merchantable timber tree, while Paya refers to the wetland area.

3.2 Physical Properties of Peatland

The peatland in Malaysia has been recognized as one of the main groups (classification soil) of soil by the Department of Agriculture (DOA). In terms of engineering, the peatland is one of the softest and most troublesome soft soils and is subjected to variability, and enormous primary and long-standing consolidation settlements (Razali et al., 2013). Based on the physical properties, each peatland has its unique characteristics that are different from other areas. Different peatland locations result in different physical properties due to the local climate and environment. Table 2 shows the physical properties of a few peatlands located in Malaysia. The varying results are due to the location, climate, water table, time of ageing, and inlet of inorganic sediments deposited during the peatland formation. Therefore, these are the factors that cause the different features in peat soils throughout Malaysia. In geotechnical engineers, the natural content or water content (w) is defined as a mass ratio of the pore water phase to the solids phase, expressed as a percentage. In the natural condition of peatlands, peat usually has extremely high-water content and vice versa. The liquid (w_L) and the plastic limit (PL) have physical meanings for remoulade fine-grained mineral soils and they correlate with many fundamental peat soil parameters used in design and construction practice (O'Kelly, 2015). The plasticity Index (PI) which is the size of the range of water content where the soil exhibits plastic properties was calculated. This test indicated the limit where the soil starts to behave as plastics from solid behavior. Other physical properties such as specific gravity and organic content also important parameters to measurement.

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Table 2
Physical properties of selected peatlands in Malaysia

Properties	West Malaysia Peat Organic Soil	East Malaysia Peat Organic Soil	Johore Hemic Peat (MARDI-, Pontian)	Klang Valley,	Matang, Sarawak Peatland	Pontian Peat Soil
Natural Water, w (%)	200–700	200–2207	230–500	414–674	360–623	848.7
Liquid Limit, w_L (%)	190–360	210–550	220–250	202–220	69–95	-
Plastic Limit, PL (%)	100–200	125–297	-	-	-	-
Plasticity Index, PI (%)	90–160	85–297	-	-	-	-
Spec. Gravity, Gs (%)	1.38–1.70	1.07–1.63	1.48–1.8	0.95–1.34	1.35–1.82	1.46
Organic Content (%)	65–97	50–95	80–96	89–99	43–81	99.20
Unit Weight (kN/m^3)	8.3–11.5	8–12	7.5–10.2	-	-	9.8
Refs.	Huat (2004)	Huat (2004)	Zainorabidin & Bakar (2003)	Hashim & Islam (2008)	Kolay et al. (2011)	Razali et al. (2013)

The physical properties listed in Table 2 are only based on the conducted research in Malaysia. Other parameters such as texture, fiber content, ash content, bulk density, linear shrinkage, the level of decomposition, and pH can be used as the basis for peatland classification. Other classifications can be based on the source of peat and field situations during the deposition. To discuss peatland properties, all factors in the list must be considered. Observation and research in the peatland areas must involve collecting soil samples to determine the degree of peatland properties and the catchment characteristics of the peat sources. According to Stanek and Silc (1977), information about peatland types, the areal extent, volume, and topography are needed for decisions regarding peat utilization like horticulture, oil, manure, chemical, settlement, and commercial industries.

Generally, the moisture content depends on the precipitation (climate) and water supply from the runoff and stream, but the physical properties are important to determine the water content since the coarse organic particles can retain water like a sponge. The highest gravimetric moisture content in peatland is related to the low bulk density, and bearing capacity as a result of high organic coarse particles (high pore volume) and buoyancy (Huat et al., 2011). The gravimetric moisture content has been the major variable in peatland composition evolution in terms of the ecological process and system, for example, the carbon content, organic matter to biomass ratio, biological composition, and dependence on water and temperature (Rodriguez-Iturbe, 2000; Zalewski, 2000; Zalewski, 2013).

4. Study Findings

The research conducted by Hashim and Islam (2008) in a few peatlands in Malaysia, especially in the West and South of Peninsular Malaysia, found that the water storage capacity in peat soil is very high because of the composition and physical properties of the peatland. Besides that, the soil color depends on the soil properties, but in almost all peatlands, it is dark brown. Based on that research, they classified the soil as H4 based on the classification suggested by Von Post Scale in 1922. The Von Post Scale is a number system based on a few factors: the botanical composition, degree of humification, and color of peatland water after squeezing. Von Post has formed a guide starting from H1 to H10. H1 refers to peatlands with fiber content higher than H10. Thus, the degree of decomposition in peat increases from H1 to H10. The H3 and H4 peat soil categories are located near the surface, but H5 and H7 are classified based on the increasing depth of the peat soil. Table 3 (Appendix) shows the classification of the Von Post Scale and the few researchers who have researched on the peatlands in Malaysia using the classification.

The peatland properties include the presence or absence of peat maturity or texture of the wood (decomposed or undecomposed) (Valoo, 2015). The peatland areas in Malaysia are very important for their main function as carbon pools and natural flooding control areas (Yule, 2010). The existence of peatland areas since millions of years ago has maintained the ability to engage and store carbon dioxide from the air, and at the same time, to play a major role in moderating global climate. The emission of carbon dioxide gas from the peatland, either by natural or man-made fire for soil fertility, will impact the global climate. Besides that, the other function of peatland is that it can either attenuate or accentuate the floods occurring in the area. As mentioned earlier, the degree of decomposition and changing climate can alter the natural peatland’s physical properties. Imbalanced inlet and outlet in peatland areas will change the water table in peat, whether to classify it as peat swamp or peat soil. In peat swamp areas where the water table is stable or near the surface, the dead plants and mosses are not fully decayed because of the permanent water saturation and low oxygen concentration, resulting in the accumulation of peat. The spatial and temporal dynamics of soil properties in peatlands have often been investigated in connection to the interaction with several hydrologic, atmospheric and ecological processes. The water table controls the rate of rainfall infiltration, deep percolation and runoff generation (Porporato et al., 2002).

4.1 Function, contribution and land use changes affect of peatland

Function and contribution Peatlands are very important because the peatland areas in Malaysia have changed markedly from natural forests to agricultural areas for Oil Palm and Sago Palm. Nowadays, the land demand in Malaysia for agriculture and commercial use has

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resulted in land-use changes from natural peatland to other land uses (Miettinen and Liew, 2010; Wicke et. al., 2011; Padfield et al., 2015; Miettinen et. al., 2016; Osaki and Tsuji, 2016). When the land-use change occurs, managing the peatland becomes a serious task to maintain a sustainable ecosystem function. Thus, the protection of existing or undisturbed peatlands with scientific and biodiversity values is imperative, and the conservation with restoration is performed especially on degraded peatlands to maintain or restore it. According to Chapman et al. (2003), the limited management in peatland areas and repression or exploitation for human demand, either for agricultural or commercial use, will have a long-term effect on the ecosystem, hydrological, biodiversity, and climate.

The existing natural ecosystem refers to the reflected interaction or interdependence involving living organisms, including humans who are directly involved with their environment. This process started when humans decided to develop natural peatland, affecting the interdependence between living organisms, declining its biodiversity and changing the ecological processes (Sklar et al., 2005; Norowi et al., 2010). Ultimately, the peatland loses its main ecosystem function as a carbon pool and flood control (Wösten, & Ritzema, 2001; Osaki & Tsuji, 2016; Padfield et al., 2015). Additionally, the valuable biodiversity in peatland, especially the dipterocarp forest and wetland, holds important economic value. The Malaysian peatland provides many important natural ecosystem services, including water cycle regulation, flooding control, biodiverse habitat, and carbon storage (sequestration and emission). The carbon emission from peatland, fire and land-use change worsens climate change. The natural peatland, which is highly sensitive due to its location near the development areas, should be conserved and protected from further degradation. Losing the function of peatland as carbon storage can be returned. Thus, proper planning in developing peatlands for any use is vital to avoid the loss of ecosystem functions and to increase peatland productivity.

The peatland forest cover in Malaysia in the past decade has decreased and deforestation rates remained high (Miettinen and Liew, 2010; Miettinen et al., 2012). Deforestation and conversion to managed land cover types are expected to continue but current cover distribution in the peatlands of Malaysia is unknown. Meanwhile, peatland deforestation and conversion taking place in Malaysia, and particularly the role of Industrial plantation development in it (Oil Palm and Sago Palm) because of the intensification of agriculture due to the growing population, has become one of the most discussed topics (Jackson et al., 2009; Page et al., 2006). Malaysian peatlands play a critical role such as water supplies, regulating and reducing flood damage, providing fish, timber and resources for local communities, and regulating the release of greenhouse gases by storing a large amount of carbon (Wösten et al., 2006). The peatland alteration only involves the land-use changes that only affect the hydrology condition and carbon pool emission. Unlike other countries, some peatlands are extracted for fuel supply (Armstrong et al., 2010) and absorbent material (Wind-Mulder, 1996). All processes involve the removal of natural living vegetation, resulting in bare soil before continuing the conversion to plantation or development. Unstable peatland and installation of drainage linkage ditches result in low water content and table, affecting the soil nutrient content; the natural or clearance burning by farmers will persist for a long time. Besides that, the low water retention and water transmission characteristics are also affected (Shantz and Price, 2006). Peatland areas especially in tropical areas of Malaysia are very important forests in regional hydrological cycles. As we know, the tropical peatlands function mainly as a carbon pool and at the same time, for as a freshwater supply and control system. The distribution of peatland in Malaysia functions as an aquifer by absorbing and storing water during the monsoon season for flood control, releasing the water slowly when the rainfall is low or changing the monsoon pattern. They help balance the water table between periods of low and high rainfall.

4.2 Recommendation for Restoration and Conservation in Malaysia

Peatland conservation and restoration involve two phases. First is to re-establish the water content or water table, and second is to re-classify the peatland based on the recolonization, decomposition and natural species. Scientific and modeling approaches highlighted in the ecology ecosystem engineering and sustainable restoration concept must be applied to achieve the peatland equilibrium. Understanding the peatland's historical conditions is very important because the changes inflicted by anthropogenic activities in the past, present or future have altered the natural ecology, hydrology and biodiversity. The holistic understanding of all parties, either directly or indirectly is very important because the detailed record of the stratigraphic remains of plants and animals that can provide information on past civilizations and climates play an important role in the global carbon balance.

Restoration and conservation must become an integral component of peatland management in Malaysia and in the world, with good management and a clear strategy. Normally, since all ecosystems are dynamic, strategies for restoring and conserving cannot be based on fixed or static attributes. The best management practice is to set the best achievable goals based on the desired characteristics for the future system and to analyze the current data to gain insights for new research and solutions (Hobbs and Harris, 2001; Jandl et al., 2007). The recommendation on peatland restoration and conservation must have a stakeholder, land use planner, natural resource manager, ecological consideration, and cooperation with Non-Government Organizations (NGO) such as World Wide Fund Malaysia (WWF) (conservation and sustainable use of tropical peat swamp forest and associated wetland ecosystem, Project of the Government of Malaysia), Sahabat Alam Malaysia (SAM), and Wetlands International Malaysia Nature Society and ASEAN Peat Forest Project (APFP) for provide a platform and initiative activities to achieve sustainability (Nath et al., 2017). To achieve the objective, the government as a stakeholder must play a role in the designation of natural peatland to RAMSAR peatland areas, or natural peatlands as the permanent forest that offers sustainable ways to support the activities, including inviting researchers as programmers (Padfield et al., 2015).

It is known that in Malaysia, a large proportion area of the peatland has been developed (Tan et al., 2009; Miettinen and Liew, 2010). The developed program for

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monitoring the area needs to be established to monitor from the natural peatland, in the process and after establishment the land use changes. The governments enact such acts or policies to monitor and evaluate projects in practice or preserve the selected area for development while providing adequate buffer zones to ensure their protection area. For example, the new policy such as Association of South East Asian Nations (ASEAN) Peatland Management Strategy (ASEAN Secretariat 2007) and International Union for Conservation of Nature's (IUCN) Commission of Inquiry on Peatlands, UK, and country-wide policies such as the Scottish Soil Framework (Scottish Government 2009), national greenhouse gas (GHG) emission reduction plans for Indonesian peat (IIPC [International Indonesian Peatland Conversation], unpublished data 2013) and deforestation and forest degradation (REDD) illustrate the intent of policymakers to address past perceptions and inappropriate peatland management practices to reduce greenhouse gas emissions is done through avoiding deforestation (selective logged), updating the education awareness among the community, and maintaining the main function of peatlands (Paoli et al., 2010; Padfield et al., 2015). This program has the potential to reverse peatland degradation, increase the resilience of biodiversity and deliver important ecosystem service to the local community. Generally, the developer must have a feasibility project and Environmental Impact Assessment (EIA) before and after the peatland areas are developed. At the same time, the developer must have specific buffer zones to ensure their protection and the gazette area should be banned from development permanently. Therefore, to protect existing peatlands and restore the degraded peatlands to sustainability, the stakeholders cooperate with developers to create an urgency of policies for sustainable development in the county to protect these valuable ecosystems. Therefore, supporting the existing policies and initiatives by all agencies involved, the stakeholder, government or non-government, is another aspect for consideration. Additionally, cooperation and contribution from local communities are required to maintain the originality of existing peatland areas of all kinds of activities that could disturb the area's sustainability such as open burning, poaching, mining, and forest clearing. For further development until a peatland brief research for establishing, as well as a holistic, multi-sectoral, integrated environmental assessment and planning procedure are completed; a gazette of peatland forest parcels as protected areas; implementing a highly restricted multiple-use policy that allows development only in degraded areas and ensuring protection of the critical hydrological role of peatland in providing fresh water supply for human use as an overriding criterion in assessing any development scheme.

To maintain conservation and restoration for sustainability and measure the peatlands needed to enlarge and enforce the protected areas, either in disturbed or undisturbed areas, continuous research for brief database collection to maintain the sustainability in peatland areas and identification of key knowledge gaps need to be addressed. Restoration and conservation are not straightforward program that can easily lead to success. Cooperation of the stakeholder with the developer is needed for the development; and the community, including researchers, is to explore and follow the recommendation. Identifying the trends of development in peatland areas of where and how empirical evaluations are being conducted will help directly for future research in conducting a research area where these evaluations are needed, such that these aims are achievable. The conservation of peatland forests is very important because the forest provides good ecosystem services, including high biodiversity, pest control, water balance and storage, carbon sequestration, and carbon storage (Koh et al., 2011; Joosten et al., 2012). Therefore, researchers need to know the requirements for restoration and conservation of peatlands to maintain the function of peatlands to provide good services.

Thus, a new strategy is formulated via communication with education awareness to enhance the stakeholders, developers, academic researchers, and the public on the importance of the peatland area in either Malaysia or globally. In Malaysia, a Tropical Peat Research Institute (TROPI) to develop scientific, and technical knowledge and understanding of the tropical peatlands. The main objective of the TROPI is to undertake cutting-edge research and research development on tropical peatland, to promote high-caliber local and international collaborations with global leading research institutes, act as a centre of excellence and reference with an integrated research databank, and generate or disseminate scientific knowledge and provide advisory support on the management and wise use of peatland. As a research centre, TROPI is a good institute that has the role of an advisor to the government, developer, academic researcher, and public in reframing specified issues or complex problems to break through communication barriers and generate a new way of thinking (Padfield et al., 2015)

The existing networking was built among the Malaysia peatlands expertise community. Based on the literature review, many researchers have done extensive research on peatlands in Malaysia. A few researches require a combination of different skills and disciplines, international and local scientists, engineers, geographers, biologists, sociologists, and planners to fulfil the key knowledge gap. As a result, the research conducted can be used as a knowledge hub for improving the restoration and conservation strategy. Multidiscipline research design needs to improve with a holistic understanding in the form of sustainability in the management of conservation and restoration. In addition, a platform (annual forum or seminar) should be established for the peatlands community to discuss and present the results of research conducted either locally or globally. Ideally, from their research result, the stakeholders and government will take action to allow for greater policy or update the existing policies.

Peatlands in Malaysia need to be given thorough attention for conservation and restoration or rehabilitation for the next generation to fulfil its their functions as carbon pools and flooding control. At the same time, carrying capacity and valuable biodiversity will be maintained or improved with the resulting resistance to stress. To reach that target, constructive evaluation monitoring and comprehensive principles are required during the planning process (Lucchese et al., 2010). Without a real understanding of the peatland areas for conservation and restoration programs to succeed, cooperation from the government, developers and community is vital to develop ideas for sustainability purposes. The millions

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of Ringgits spent is useless if no serious action towards sustainability is performed or if they are spent on projects that cannot be adequately evaluated.

5. Conclusion

Peatland has unique characteristics, depending on the location and climate. Nowadays, the natural peatland is increasingly exploited since the demand for land forces the surrounding community to switch to commercial activities. To maintain the integrity of the peatland ecosystem, restoration and conservation are the only ways to explore and find the research gap for the next researchers to provide solutions for land use changes affecting to environment or humans. Perhaps, more than any other forest ecosystems, peatland forest is susceptible to the synergistic effects of multiple human disturbances because of the balance that exists among vegetation, peat and hydrology. The impacts of peatland activities on floods, drought, haze, and climate change have been a great concern to societies in the last decade. The positive feedback loops among deforestation, drainage and fire mean that peatland is easily degraded once the balance of the system is upset. The changes occurring in Malaysian peatlands seriously impacted the local and regional health and livelihoods, significantly contributing to climate change and increasing peatland fires (Yule, 2010). However, a critical challenge remains to create an initiative suitable for practical applicability in local farmers. Thus, consider revising further research to investigate all aspects of peatland areas to find important opportunities, given the enormous global importance of peatland as carbon storage. In the development of peatlands in Malaysia for economic purposes, serious impacts have resulted from a lack of understanding of the holistic ecology of the peatland ecosystem and the environmental impacts of the global balance of carbon.

Peatlands restoration and conservation has the potential to reverse land degradation, increase the resilience of biodiversity flora and fauna, hydrology cycle, carbon storage, and deliver the important ecosystem services from local to global level (Dohong et al., 2017; Charters et al., 2019). However, especially in Malaysia, because of land demand for development purposes, the peatland area was sacrificed for agriculture (oil palm or sago palm), urban area (Sibu Town in Sarawak, Putrajaya, in Selangor, KLIA airport and Sepang Circuit), and recreation area (Tasik Bera). The development in peatland areas is still ongoing because the continuous demand will, without a doubt, impact the environment. Therefore, the government or stakeholders in Malaysia need to plan for either the short term or long term in maintaining the sustainability in peatland areas. Effective restoration and conservation programs in Malaysia need more research and recommendation practices to be widely incorporated into natural resource strategies from the local tropical peatland to the global level.

Empirical evidence attributed to ecological knowledge in supporting the restoration and conservation of peatland areas, either in natural or development resource management for long-term research, is being conducted and further research for the recovery of ecological functions is required. There are still gaps in the research area based on different locations and climates, main contributions of peatland either locally or globally, the characteristic interrelationship between hydrology and land cover, and paleo hydrology in the determination of the age of the peatland. In the future, we need to focus on filling these gaps and understanding the benefits or impact of restoration and conservation for better management.

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Appendix

Table 3

Peatland classification according to Von Post Scale

Degree of Humification	Description	Location in Malaysia	Reference
H_1	Completely undecomposed peat, which releases almost clear water. Plant remains easily identifiable. No amorphous material present.		
H_2	Almost completely undecomposed peat, which releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.		
H_3	Very slightly decomposed peat, which releases muddy brown water but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present (Sapric).	Pontian	Razali et al., 2013
H_4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.	Klang, West Johor, Matang Sarawak & Pontian	Hashim and islam, 2008; Gofar and Sutejo 2007; Kolay et al., 2011; Yulindasari, 2006
H_5	Moderately decomposed peat, which, when squeezed, releases very "muddy" water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty.	Tasik Bera	Wüst et. al., 2003
H_6	Moderately decomposed peat, which forms a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The structure is more distinct after the squeeze. (Hemid).	Parit Niah	Adon et al., 2013
H_7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.		

H_8	Very highly decomposed peat with large quantity of amorphous material with very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibers that resist decomposition.		
H_9	Practically fully decomposed peat, in which there is hardly any recognizable plant structure. When squeezed it is fairly uniform paste. (Fibrous).		
H_{10}	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.		

Source: Von Post, (1922) and edited from Abon et al., 2012.