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Spatial modeling in sustainable peat land management based on Peat Hydrological Units (KHG)

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Abstract. *Utilization of peatlands becoming more massive from time to time. On the other hand, efforts are needed to ensure the sustainability of peatland functions for the environment. To support the sustainability of peatland functions, spatial modeling with the basis of KHG is needed to facilitate its management. This study aims to provide input on optimizing peatlands based on KHG to be used for the community while maintaining its sustainability. The method used is spatial analysis that covered data KHG, Land Unit, Soil, Ground water level (GWL), Rainfall data. The study results show that KHG helps more focus on determining the AOI (Area of interest) to be researched. The inputs needed for research based on KHG, are:- KHG analysis of: 1. land unit; 2. Rainfall data; 3. GWL data; 4. Soil data. That can identify KHG areas that need attention to be managed properly the tidal peatland, and the peat dome for conservation efforts. Analysis of KHG with rainfall and GWL can obtain the months (February and November), which function as controls on the success of management through the GWL value.*

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INTRODUCTION

Tropical peatlands play an important role in environmental, social, and economic aspects. Peatlands in Indonesia are the largest tropical peatlands in the world (± 14.9 million ha) distributed in Sumatra, Kalimantan, and Papua (Ritung and Sukarman, 2016). About 30% of it has the potential for agricultural land, and 43% is found in Sumatra (Wahyunto and Daira, 2014). Peatlands, although including marginal land, but in their development, it is under pressure to change. The conversion of land originally in the form of forests has shifted land for plantations, agriculture, settlements, and physical infrastructure. Land that has been heavily degraded and becomes critical land covers an area of approx. 48.3 million ha or 25.1% of the total area of Indonesia. For peatlands of about 14.9 million ha of peatlands in Indonesia, ± 3.74 million ha or 25.1% of the total area of peat has been degraded and overgrown with shrubs (Junedi *et al*., 2017).

To maintain peatland sustainability, the government has designated peat areas in Indonesia with the Peat Hydrological Unit (KHG). Spatially KHG is defined as a peat ecosystem between 2 (two) rivers, between a river and the sea and/or in a swamp. KHG, as a hydrological unit on peatlands, is used as an instrument to preserve peatlands. Peatlands will remain sustainable if they are always in a water-saturated condition, either permanently or temporarily (Harun *et al*., 2020). This study aims to determine input on optimizing peatlands

based on KHG to be used for the community while maintaining its sustainability. Determination of inputs is done by using KHG as the basis for land use.

METHOD

Study Area and Data

The study area is the Kepulauan Meranti Regency, which is dominated by peatland (Mulyani and Agus, 2017). Meranti Islands Regency is one of the regencies in Riau province that consists of 3 (three) large islands: Padang Island, Tebingtinggi Island, and Rangsang Island. The total area is 3 714.19 km^2 or 4.26% of the area of Riau Province (BPS, 2020). Geographically Meranti Islands Regency is located at coordinates between 0°42'30"-1°28'0" N and 102°12'0"-103°10'0" E and is located on the east coast of Sumatra Island, with its boundaries as follows. In the north it is bordered by the Malacca Strait and Bengkalis Regency; in the south, it is bordered by Siak Regency and Pelalawan Regency; in the west bordering Bengkalis Regency; to the east, it is bordered by Karimun Regency and Riau Islands Province (see Figure 1).

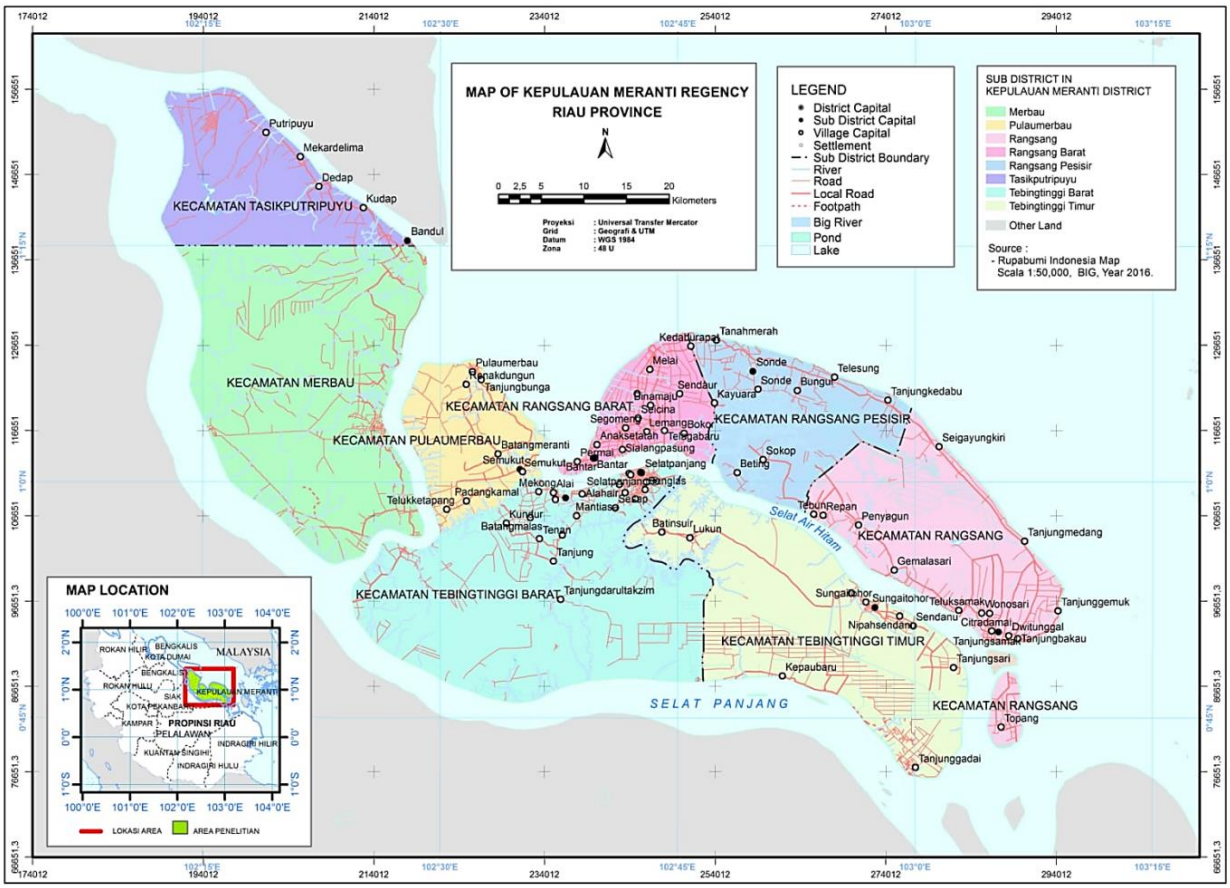


Figure 1 Kepulauan Meranti Regency, Riau Province

Method of Data Collection

In this study, the data used include: land unit, soil map, ground water level (GWL), topographical map (RBI) scale 1:50 000, and KHG map. The data collected is included in the category of secondary data. The types of data, their acquisition, and their uses are presented in Table 1. The entire data is used for spatial modeling in efforts to manage peatlands in a sustainable manner based on the KHG. In this spatial modeling using spatial analysis.

Table 1 Data type, data source and data obtained

Data Type	Data Source	Data Obtained	Description
Land Unit	BBSDLP	Land unit	Distribution of land unit
Soil Map	BBSDLP	Soil type	Distribution of soil type
GWL	BRGM	GWL	Indication of peatland
RBI	BIG	Base map	
KHG	KLHK	Area of KHG	For unit analysis
Rainfall	LAPAN	TRMM Rainfall	Rainfall Data

Note: BBSDLP: center for agricultural land resources, ministry of agriculture; BRGM: peat and mangrove restoration agency; BIG: geospatial information agency; KLHK: ministry of environment and forestry

Method of Data Analysis

The study begins with the coverage of the KHG which is grouped into several land units that are typical of peat areas. To get the variety of land units contained in the KHG area, a spatial analysis is carried out first by means of overlaying (see Figure 2). With this step, the distribution of land units in the KHG area is obtained. Land unit is a land where one or more of its components have special characteristics and the land unit is an environmental unit with various sizes that can stand alone (Buurman *et al*., 1988).

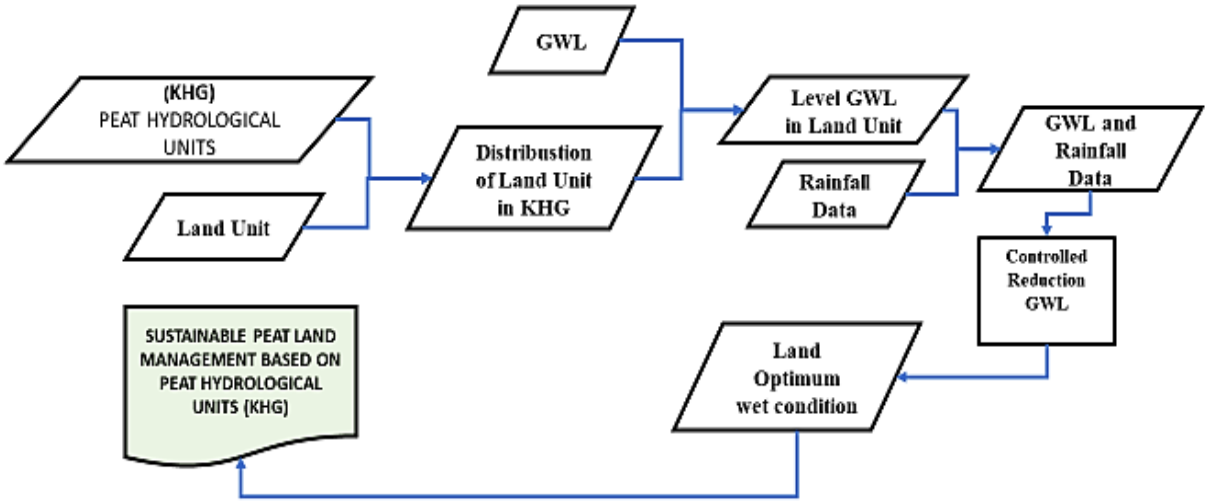


Figure 2 Flow chart of study

In peatland management, an important parameter that determines its sustainability is the condition of GWL. The deeper the GWL, will be drier the peatlands. With dry peat conditions, peatlands have great potential to be easily burned or easily burned (Putra *et al*., 2016). Efforts are needed to control GWL, so that it remains in the optimum depth range. The optimum condition of peatland based on GWL is the depth of it that can still be used for cultivation, on the one hand the wetness of the peatland is still maintained. Considering the government regulation PP No. 57 year 2017 concerning procedures for measuring groundwater, the allowable GWL for land use on peatlands is ≤40 cm. Thus, in peatland management, the GWL condition needs to be controlled so that it does not reach more than minus 40 cm.

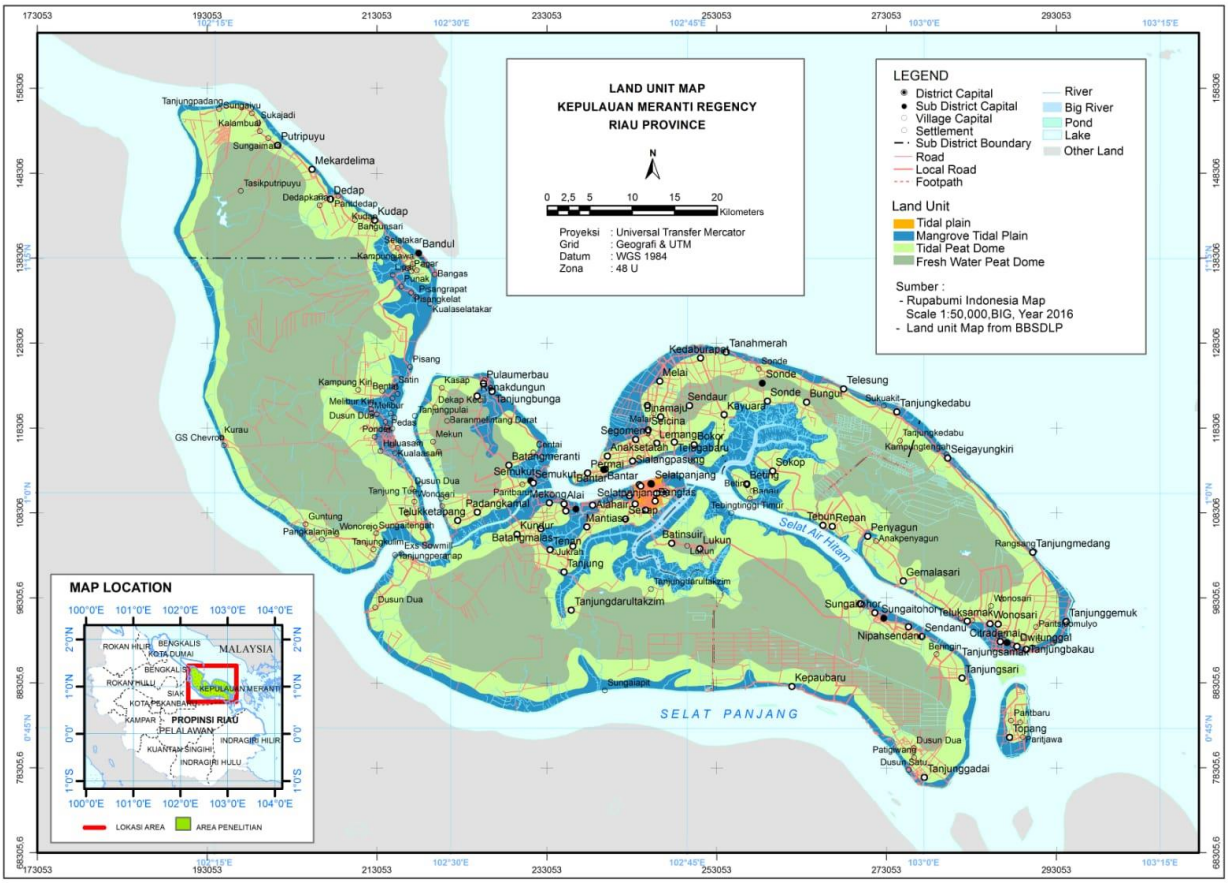
In this case, the KHG acts as an area unit that is used as a direction for peatland management areas. In one KHG there is a hydrological system, where in the wet session peatlands are able to absorb water up to 13 times its volume (Wildayana *et al*., 2019). In the dry session, peatlands can release water, so peatlands can still be wet. This role is utilized for sustainable peatland management based on peat hydrological Unit (KHG).

Peat Hydrological Unit (KHG)

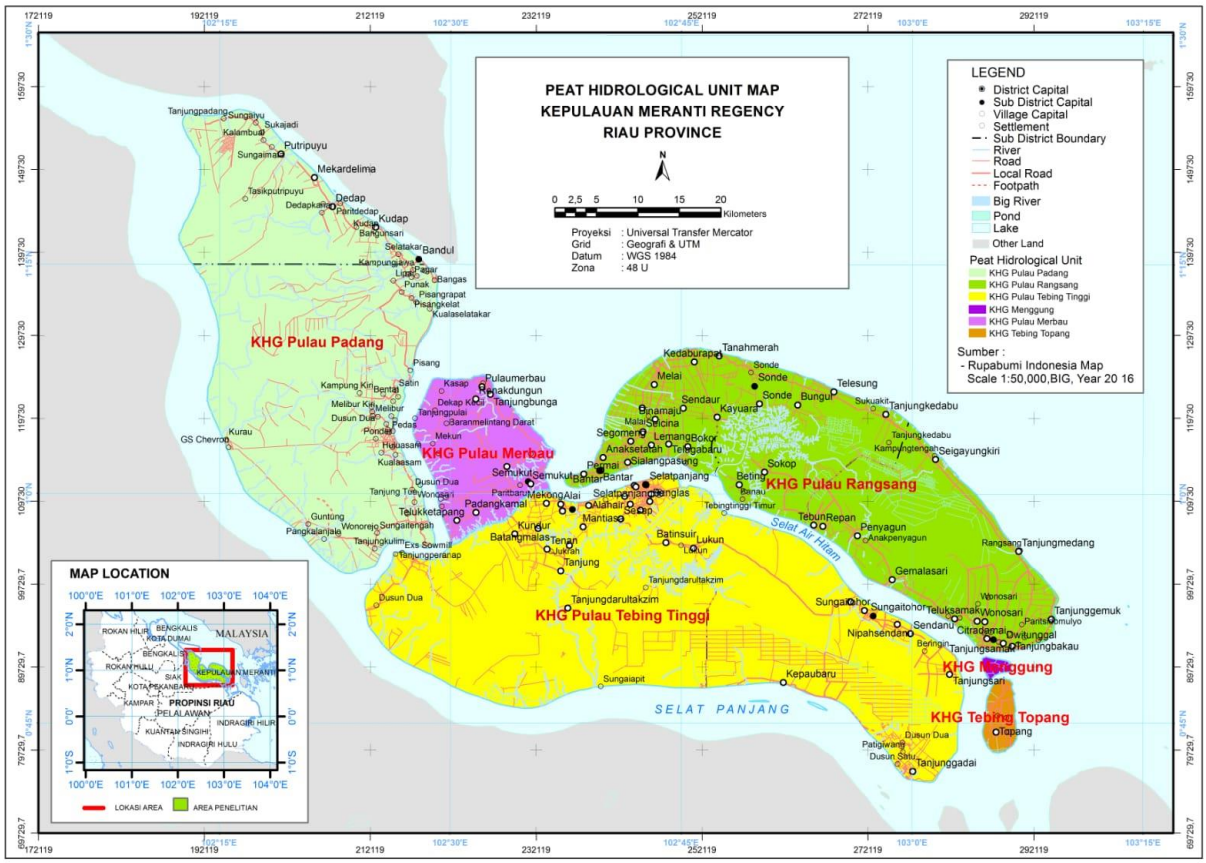
The peat hydrological unit (KHG) according to Government Regulation PP. No. 57 year 2016 is a Peat Ecosystem which is located between 2 (two) rivers, between the river and sea, and/or in swamps. Meanwhile, the peat ecosystem is an arrangement of peat elements which are a unit that influence each other in forming balance, stability, and productivity. In accordance with the Decree of the Minister of Environment and Forestry of the Republic of Indonesia Number SK.129/MENLHK/SETJEN/PKL.0/2/2017 concerning the Establishment of a National Peat Hydrological Unit Map, Indonesia has 865 Peat Hydrological Units (KHG) with a total area of 24 667.804 ha which is evenly distributed on Sumatra Island, with 207 KHG covering 9 604 529 ha, Kalimantan Island with 190 KHG covering 8 404 818 ha, Sulawesi Island with 3 KHG covering 63 290 ha, and Papua Island with 465 KHG covering 6 595.167 ha.

Based on the zoning of the KHG, the Meranti Islands Regency has 6 (six) KHGs: 1. KHG Merbau; 2. KHG Rangsang; 3. KHG Pulau Padang; 4. KHG Tebingtinggi; 5. KHG Pulau Menggung; 6. KHG Pulau Tebing Topang with their distribution as shown in Figure 3b. The area of each KHG based on the sub-district administration area is shown in Table 2. Overall the total area of KHG in Meranti Islands is 363 476.20 ha, with the largest percentage of KHG area being in Tebing Tinggi District (42.20%). Merbau District (36.56%), Rangsang District (14.17%), and Rangsang Barat District (7.07%).

The Tebing Tinggi Island KHG, has a conservation function of 884 ha or 66.3% of the total area of the KHG in Kepulauan Meranti Regency (Kepmen LHK, 2017b), and the cultivation function of 45 627 ha or 33.7% of the total KHG area in the Meranti Islands Regency.



(a)



(b)

Figure 3 (a) Land unit in Kepulauan Regency and (b) KHG in Kepulauan Meranti Regency

Table 2 KHG area per sub district

No	KHG Name	Sub District	Area (ha)
1	Pulau Padang	Merbau	111 286.27
		Rangsang	51 486.88
2	Pulau Rangsang	Rangsang Barat	25 705.69
		Tebingtinggi	11 767.21
3	Pulau Merbau	Merbau	21 601.20
4	Pulau Tebingtinggi	Tebingtinggi	138 060.60
5	Pulau Menggung	Tebingtinggi	654.34
6	Pulau Tebing Topang	Tebingtinggi	2 914.02
	Total		363 476.20

Ground Water Level (GWL)

GWL is the depth of the water table from the ground surface. GWL measurement can be done manually or automatically. For this study GWL data obtained automatically in real time from SIPALAGA (Peatland Water Monitoring System). A SIPALAGA station is used as a representation of GWL data in this study area, namely in Kedabu Rapat, Rangsang Pesisir Sub District, and in Semukut Merbau Island Sub District. GWL has a correlation with rainfall. The correlation between the amount of rainfall and GWL is carried out to obtain the periodization of rainfall and the range of GWL. GWL data obtained from August 2019 to August 2021. Based on the average of monthly rainfall from 1998 to 2019, it appears that the maximum rainfall (wet season) occurs in November, and the minimum monthly average rainfall (dry season) occurs in February.

RESULT AND DISCUSSION

Land Unit and KHG

In the Meranti Islands Regency, there are three land units which are land: Tidal peatland, tidal plain mix vegetation, and peat dome fresh water (See figure 3a). All of the land unit has a flat relief or flat topography (see Table 3). These conditions have an impact on the slow flow of water in peatlands, so that unspoiled peatlands will be inundated with water either permanently or periodically. The land units that are developing are Tidal peatland, Peat Dome Fresh water, Tidal Plain Mix Vegetation, and the lithology is dominated by organic material.

The KHGs in the Meranti Islands Regency, there are 2 (two) land units located throughout the region: Tidal peatland (>3 m), and Tidal plain Mix Vegetation. With the results of the spatial analysis, it shows that in all KHGs, a good understanding of the characteristics of peatlands is needed in their use, because in all KHGs in the study area there is Tidal peatland whose peat depth is >3 m. Peat with a depth of >3 m was categorized as very deep peat and it designated for conservation land. While the soil type were Typic Haplosaprist, which based on the level of maturity was categorized in mature maturity. While the area whose soil is included in the Typic Sulfihemist, based on the level of maturity is included in the medium maturity.

There is one land unit: Peat Dome Fresh Water (>3 m). This land unit is very important in peatland management, because its needed maintained to serve it's sustainability. Peat dome is a land unit that is topographically higher and also has a peat thickness and that is higher than the surrounding land (Salsabila, 2021). Thus, the KHG in which there is a peat dome has a strategic role in water storage, because the peat dome has a thicker peat, so the volume of water stored is also greater.

Table 3 Distribution of land unit in KHG area

No	Land Unit	Lithology	Relief/ Morphology	Soil	KHG
1	Tidal peatland (>3 m)	Organic Material	Flat	Typic Haplosaprist Typic Sulfihemist	1,2,3,4,5,6
2	Tidal plain Mix Vegetation	Clay Deposit	Flat	Typic Sulfaquent Sulfic Endoaquent Typic Hydraquents	1,2,3,4,5,6
3	Peat Dome Fresh Water (>3 m)	Organic Material	Flat	Typic Haplosaprist Typic Haplohemist	1,2,3,4

Note: KHG: Pulau Padang (1); Pulau Rangsang (2); Pulau Merbau (3); Pulau Tebingtinggi (4); Pulau Menggung (5); Pulau Tebing Topang (6)

GWL, Season, and Land Unit

GWL in peatlands is strongly influenced by the wet season, and dry season. In the wet season, peatlands get their supply from rainwater, causing the groundwater level increase. In the dry season, peat releases water, causing groundwater decrease. In the wet season the GWL becomes shallow, and in the dry season the GWL gets deeper (Runtunuwu *et al*., 2011). Based on the average of monthly rainfall from 1998 to 2019, it appears that the average maximum rainfall (wet season) occurs in November, and the average minimum monthly average rainfall (dry seson) occurs in February. By referring to the 22 years of rainfall data (year 1989 up to 2019) which shows the same pattern between the average maximum rainfall (wet season) occurring in November, and the average minimum monthly average rainfall (dry season) occurring in February, it is synthesized with GWL conditions, February and November. GWL in February (dry season) ranges from 0.596 m in 2020 up to 0.835 m in 2021. GWL in November (wet season) ranges from 0.42 in 2019 to 0.451 m in

2020. The condition of GWL at the maximum average rainfall and the minimum average rainfall are presented in Table 4.

Table 4 The condition of GWL at the maximum average rainfall and the minimum average rainfall

Year	GWL (m) Average Rainfall		Description
	Maximum	Minimum	
2019	-0.42		No data at Feb 2019
2020	-0.451	-0.596	
2021		-0.835	No data at Nov 2021

From these results, it shows that implementation of peatland management, what is considered is the control of the ground water level (GWL). GWL is the key to peatland sustainability and maintained on GWL value still ≤0.40 m. In this case, KHG plays a role in emphasizing which areas in Peatland must be managed and utilized properly to ensure its sustainability (Imanudin *et al*., 2019).

CONCLUSION

From the findings in this study, it shows that the KHG is needed as a unit of analysis and mapping in peatland studies in an effort to maintain its sustainability. KHG also helps to focus more on determining the AOI (Area of interest) to be researched. The inputs needed for research based on KHG, are: KHG analysis of 1) land unit; 2) Rainfall data; 3) GWL data; 4) Soil data because it can identify KHG areas that need attention to be managed properly. In this study are the tidal peatland, and the peat dome for conservation efforts. Through the analysis of KHG with rainfall and GWL, it also can be obtained the months (February and November) which function as controls on the success of management through the GWL value.

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