Sustainable peatland management: a case study of peatland development for oil palm plantation in East Kotawaringin Regency, Indonesia

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Abstract. This study aims to examine the status of a sustainable peatland management for oil palm plantations in East Kotawaringin Regency. The assessment was conducted on the dimensions of sustainable peatland management, namely: dimensions of the Criteria of Peatland, dimensions of the Use of Peatland, and dimensions of Guidance and Supervision of Peatland. Data collection was conducted by using questionnaires submitted to experts as many as 15 (fifteen) people who are competent according to the field of study. Determination of the index and status of the sustainable peatland management was carried out using the method of Multi Dimensional Scaling (MDS) the RapKOTIM-Peat Converted (RAPFISH Modified) approach. The results cocerning the measurement of the sustainable peatland management status in the dimension view of Criteria of Peatland using MDS RapKOTIM-PeatConverted approach indicate that the status of natural peat forests is less sustainable, the status of sustainable peatland management for oil palm plantations for planting age less than 4 years, planting age between 4-10 years, and planting age above 10 years are fairly sustainable. The leverage analysis of the Criteria of Peatland dimension states the sensitive attributes of organic C- content, acid sulphate soil layer, peat maturity level, peat thickness <3 m, and land ownership conflict. The sustainablility status of the peatland management in the view on the use of Peatland dimensions and the dimensions of Guidance and Supervision of Peatland either in natural peat forests and oil palm plantations with planting age less than 4 years, planting age between 4-10 years, and planting age above 10 years showing less sustainable status. The dimension of the Use of Peatland has the sensitive attributes of tree density (ha), drainage, peripheral drainage, land clearing without burning, compaction of plant pathways, as well as maintenance and conservation. The sensitive attributes of Guidance and Supervision of Peatland dimensions are supervision of the authorities, supervision of environmental function recovery, supervision of damage prevention, technical guidance, revocation of Cultivation Rights/HGU, and community empowerment. The status of peatlands management sustainability for oil palm plantations in a multidimensional manner at the four research locations shows a less sustainable status.
Key Words: sustainability, Criteria of Peatland, use of peatland, guidance and supervision of peatland, Multi Dimensional Scaling.

Introduction. Peatland ecosystem is a buffer of hydrology and carbon supply which is very important for the environment. Peatland ecosystems must be protected so that the value of the functions and benefits of these peatlands will remain beneficial in the present but also for generations to come. The conversion of the natural forest of peat land into oil palm plantations is suspected to have had a negative impact with the presence of land clearing activities which are carried out by removing vegetation. Peat is a marginal and fragile ecosystem that is easily damaged. Such conditions require the awareness of all parties to be wise and must see peat from various perspectives. Awareness of the importance of balance between various functions of peat, will further ensure the sustainability of the fulfillment of social, economic and environmental sustainability functions (Fernandes et al 2018; Murphy 2012; Lead et al 2010; Joosten & Clarke 2002).

The use of peat land for agriculture faces a dilemma (Liu et al 2018; Bader et al 2018; Bader et al 2018; Kennedy et at 2018), on one side peatland is required to meet the needs and food security, bioenergy development, and economic growth especially the development of export commodities (Arai & Matsuda 2018; Siregar et al 2018; Papilo et al 2018; Buchspies & Kaltschmitt 2018; Spring 2019; Lorenz & Lal 2018; Rival 2018; Kurniawan & Managi 2018; Lopez & Suryomenggolo 2018). On the other hand, Indonesia is committed to reduce greenhouse gas (GHG) emissions in accordance with the Presidential Regulation 61/2011.

The conversion of peat swamp forest into agricultural land has caused land damage. These agricultural activities include agriculture land-clearing, in the form of deforestation, bush slashing and burning of vegetation remnants. The making of drainage channels and compaction of land for preparing the agricultural land and the making of mounds (Radjagukguk 2000; Rieley & Page 2008; Page et al 2009; Hooijer et al 2010). Therefore, the development of peat land for agriculture must refer to the conception of sustainable agriculture.

The paradigm of sustainable agriculture leads to economic feasibility by providing efficient inputs while maintaining environmental sustainability and social benefits (Adnan et al 2018; Knickel et al 2018; Barrios et al 2018; Withers et al 2018; Liao & Brown 2018; Nagothu et al 208; Syahyuti 2006). Sustainable agriculture must be technically feasible, economically sound, socially acceptable and environmentally sound or feasible (Praneetvatakul et al 2001) with productive, competitive and efficient conditions and at the same time should maintain and improve the environment and socio-economic conditions of the local community (Dumelin et al 2002). More specifically, the use of peat land for oil palm cultivation can be done by taking into account the characteristics of peat so it does not cause damage to its environmental functions. Thus the effort of oil palm cultivation on peat land does not cause damage to environmental functions (Regulation of the Ministry of Agriculture No. 14/2009).

East Kotawaringin Regency has the peatland area of 3,618.35 km^2 from the total area of 16,796 km^2. This certainly has the potential for the development of agricultural commodities such as oil palm plantations as an effort to improve community welfare. Efforts of peatland development in the form of oil palm plantations are certainly carried out by taking into account the characteristics of peatlands so that not cause damage to environmental functions. Peatland as a specific ecosystem with specific characteristics of its peat, can only stand firmly with the linkages between its constituent components. Peatland ecosystem balance as a whole unit will be disturbed if one of its constituent components is disturbed. The occurrence of deterioration in the function of peat forests as a result of the conversion of land to oil palm plantations is one of the sources of the threat of peatland damage.

Regulation of the Ministry of Agriculture No. 14/Permentan/PL.110/2/2009 confirms that peatland has an important role for environmental sustainability which can be utilized for the oil palm cultivation. This regulation describes three dimensions in the use of peat land for oil palm cultivation, namely: (1) The Criteria of Peatland dimension which consists of ten attributes; (2) The Dimension of the Use of Peatland which consists of twelve attributes; and (3) The Dimensions of Guidance and Supervision of Peatland which consists of twelve attributes. On this basis, the purpose of the study is to examine the status of sustainable peatland management for oil palm plantations in East Kotawaringin Regency.

Material and Method

Location and time of the research. The research was carried out in East Kotawaringin Regency, Central Kalimantan Province, respectively, namely: (1) Natural peat forest in Kota Besi Subdistrict, and (2) Peatlands of oil palm plantations with planting age less than 4 years in Parenggean Subdistrict; (3) Peatlands of oil palm plantations with planting age 4-10 years in Cempaga Subdistrict; and (4) Peatlands of oil palm plantations with planting age above 10 years in Mentawa Baru Subdistrict, Ketapang. The research was conducted between the month of May 2017 and March 2018.

Method of data collection. The management sustainability of peatlands for oil palm plantations in Kotawaringin Timur Regency is measured based on three dimensions, namely: (1) Criteria of Peatland, which consists of ten attributes; (2) Use of Peatland, which consists of twelve attributes; and (3) Guidance and Supervision of Peatland, which consists of twelve attributes. Data collection was conducted using questionnaires submitted to fifteen experts/specialist by considering the expert judgment, in the form of: (1) competent according to the field of study; (2) reputation, status/position corresponding to the field of study; (3) credible and get objective recognition by the academic/community environment; (4) be at the location of the study; and (5) willing to be involved in research.

Statistical analysis. The analysis method concerning the sustainability of the peatland management for oil palm plantations in Kotawaringin Timur Regency was carried out using the method of Multi Dimensional Scaling (MDS) the RapKOTIM-PeatConverted (RAPFISH Modified) approach. RAPFISH (Rapid Appraisal for Fisheries) is developed by the University of British Colombia, Canada to assess sustainability. The MDS RAPFISH approach reflects the sustainability level of the dimensions studied based on constituent attributes and adjusted to the availability of information (Kavanagh & Pitcher 2004). The method of MDS the RapKOTIM-Peat Converted (RAPFISH Modified) approach to measure the status of sustainable peatland management is carried out with the following steps:

1) Evaluation and determination of the attributes (review attributes). Attributes are dimensional parameters that represent the condition of a sustainable peatland management in East Kotawaringin Regency. Evaluation and determination of attributes are carried out by the scientific judgment approach based on either the results of empirical studies as well as other literature sources by considering the availability of attributes data.
2) Giving an assessment to each attribute of each dimension. Giving an ordinal score in the range 0-2 or 0-3 or according to the attribute character that describes the assessment strata from the lowest (0) to the highest (3). A score of 0 is bad and a score of 3 is good.
3) Calculation of the index values and sustainability status assessment. The assumption of the performance of sustainable peatland management lies between 0 and 100%, the index and status category of each dimension of peatland management sustainability for oil palm plantations in Kotawaringin Timur Regency are presented in Table 1.

Table 1

Index and status of sustainable peatland management in East Kotawaringin Regency

No.	*Index value*	*Category*	*Information*
1	0.00 – 24.99	Bad	Unsustainable
2	25.00 – 49.99	Insufficient	Less sustainable
3	50.00 – 74.99	Fair	Fairly sustainable
4	75.00 – 100.00	Good	Highly sustainable

Source: Modification of Kavanagh & Pitcher (2004).

4) Monte Carlo analysis. Monte Carlo analysis is useful for studying (1) the effect of errors in the score attribute caused by the understanding of resource conditions; (2) the effect of variations in scoring due to differences in opinion or assessment by different studies; (3) and also see the quality of the stability of the method reference points that are carried out; (3) data entry errors or missing data; (4) The high value of stress of analysis results. Comparison of the Monte Carlo (MC) analysis and MDS analysis results at the 95% confidence level, if the difference value between the two analyzes is >5%, the results of the MDS analysis is inadequate/insufficient and if the difference between the two analyzes is <5%, the results of the MDS analysis is sufficient to estimate the sustainability index value (Kavanagh 2001).
5) Assessment of accuracy (goodness of fit). Goodness of fit is determined by the value of Stress (S), a good model is indicated by a stress value smaller than 0.25 (S<25%)

and if the stress value is higher than 0.25 (S>25%) then the MDS results has low accuracy (Kavanagh 2001).

6) Determine the leverage factor. Leverage analysis or sensitivity analysis shows sensitive attributes or leverage factors that are calculated based on standard error differences between scores with attributes and scores obtained without attributes. The leverage factor is seen from the results of RAPFISH at the highest (maximum) Root Means Square (RMS) value up to a value of half which is greater than the median value (RMS>Me) from each dimension attributes of the management sustainability (Kavanagh & Pitcher 2004). RapKOTIM-PeatConverted will produce sensitive attributes or leverage factors that contribute to the index and status of sustainable peatland management for oil palm plantations in East Kotawaringin Regency.

Results. Peatlands for oil palm cultivation must meet criteria that ensure the sustainability of peatland functions, namely: (a) only cultivated on community land and cultivation areas, (b) the thickness of the peat layer is less than 3 m, (c) mineral soil substrate under peat is not quartz sand and not acid sulphate soil; (d) sapric (mature) or hemic (half-mature) peat maturity level; and (e) eutrophic peat soil fertility rate (Regulation of the Ministry of Agriculture No. 14/2009) (Figure 1 a,b).

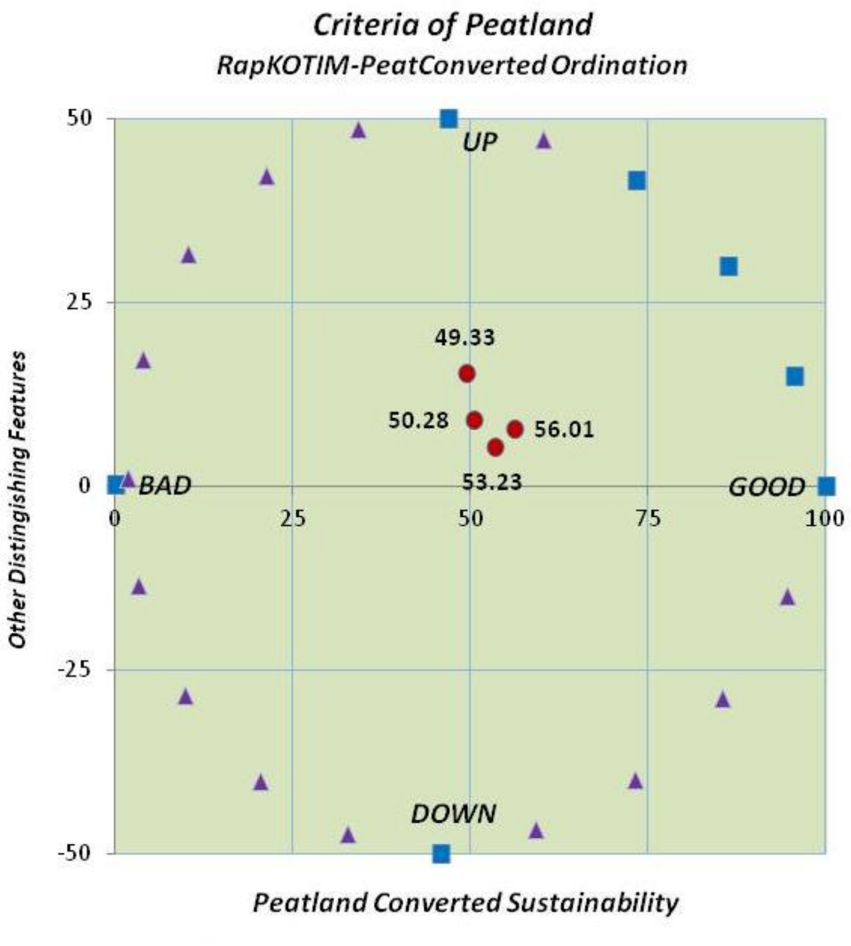

Figure 1a. MDS ordination of the dimension of Criteria of Peatland.

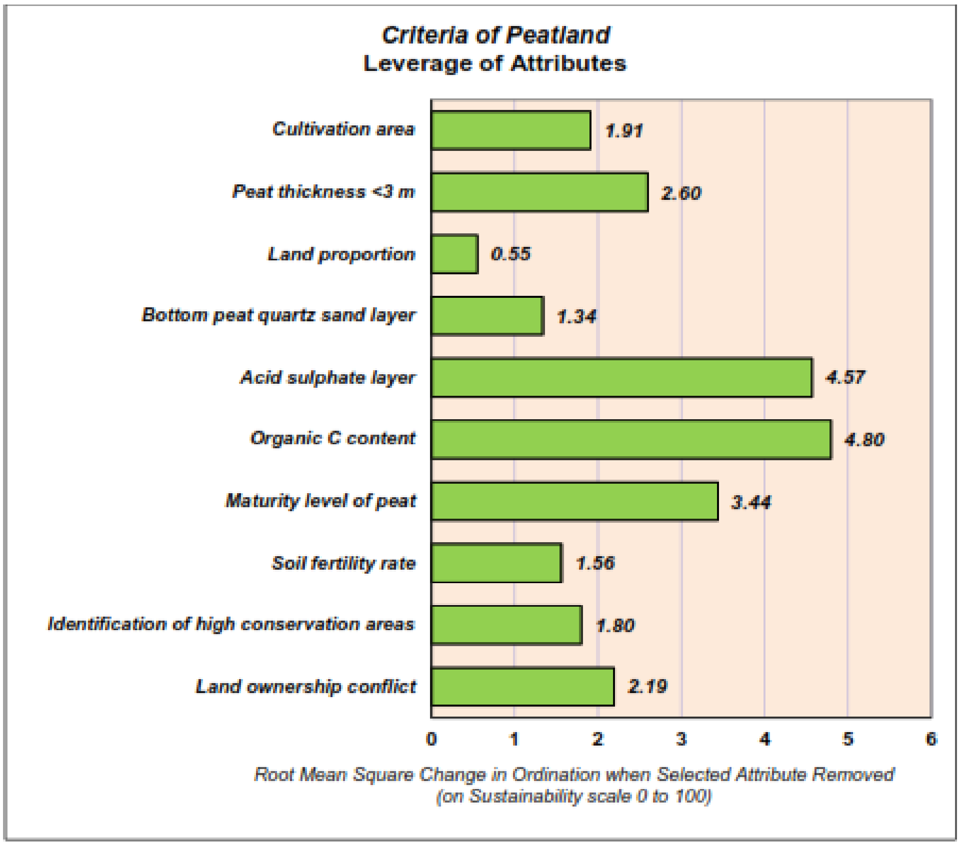

Figure 1b. RMS value of the dimension of Criteria of Peatland.

Processed result of RapKOTIM-PeatConverted concerning the dimension of Criteria of Peatland shows that the sustainability management of peatlands for oil palm plantations in natural peat forests has an index of 49.33 (less sustainable). Sustainability management of peatlands for oil palm plantations with the planting age less than 4 years has an index of 53.23 (fairly sustainable), oil palm plantation with the planting age between 4-10 years has an index of 56.01 (fairly sustainable), and oil palm plantation with the planting age above 10 years has an index of 50.28 (fairly sustainable).

The difference between the MDS index and the Monte Carlo index (α = 95%) is less than 5%, Stress (S) statistical parameter shows the goodness of fit (22.47% < 25%) with a coefficient of determination approaching value 1 or good condition (R^2 = 94.05%). RapKOTIM-PeatConverted is sufficient and also has a high accuracy as a status predictor of sustainability peatlands management for oil palm plantations the dimensions of Criteria of Peatland.

Sensitive attributes that are the leverage factors for the sustainable peatland management of the dimensions of Criteria of Peatland as the results of the respective leverage analysis are the followings:

1) Organic C content

Organic C is an indicator in determining the quality of organic matter which is strongly related to the rate of decomposition. The average organic C-content of the secondary natural peat swamp forest is 43.19%. Meanwhile, the average organic C-content of oil palm plantation land with the planting age less than 4 years is 35.48%, in planting age between 4-10 years is 35.95%, and in planting age above 10 years has an average of 35.36%. The overall organic C content is in the very high category with natural peat swamp forests having the highest organic C content.

High maturity levels indicate that the level of decomposition is ideal and the carbon stock/supply is lower. The decomposition process results in a decrease in the volume of peat so that the total volume of peat decreases and causes the carbon stock/supply decreasing (Tarnocai 2018; Zhong et al 2018; Tajuddin et al 2018; Daté et al 2018; Sihi et al 2018; MacDonald et al 2018; Estop-Aragonés et al 2018;

Girkin et al 2018; Agus et al 2011). Peat forest conversion can change the soil C deposit, and these changes lower the soil organic C stock/supply of about 20-50% (Naresh et al 2018; Agus et al 2010; Amacher $ Perry 2010; Powers & Veldkamp 2005; Lal 2005; Rhoades et al 2000). Soil organic C showed levels of organic matter contained in the soil. Peat soils usually have higher levels of organic C than mineral soils. The organic C level identifies the maturity level of peat. In the case of the fibric type peat, the level of organic C content will be higher compared to sapric and hemis (Soewandita 2008).

2) Acid sulphate soil layer

Peatland management for oil palm plantations in East Kotawaringin Regency is mostly carried out on quartz sand layers under the peat and consists of pure sand and the other part is acid sulphate soil layers with layers of pyrite or sulfidicides at a depth less than 50 cm below the peat soil surface. This shows that these peatlands are not suitable for oil palm cultivation. The Regulation of the Ministry of Agriculture No. 14/2009 states that the acid sulphate soil layer is tidal land, where the soil has a layer of pyrite or sulfidic which are greater than 2% at the surface of the peat soil.

3) The maturity level of peat

The maturity level of the peat at the depth of >3 m in the management of peatlands for palm oil plantations in East Kotawaringin Regency can be classified as it is shown in Table 2.

Table 2

The average maturity of peat in the management of peatlands for oil palm plantations in East Kotawaringin Regency

Peatlands	*Depth (cm)*	*Maturity*		*Color*
		Fiber content (%)	Decomposition	
Natural peat forest	1.14	82.86%	Fibric	Brown
Oil palm plantation with planting age <4 years	0.42	28.56%	Hemic	Dark brown
Oil palm plantation with planting age between 4-10 years	1.06	31.41%	Hemic	Blackish brown
Oil palm plantation with planting age >10 years	0.98	37.48%	Sapric	Black

The fibric type peat has brown color, the hemic type has dark brown color, and the sapric type has black color, in a wet state, the color of peat is usually darker (Najiyati et al 2005). In half-matured peat (hemic), namely half weathered peat, some of the original material can still be recognized, brown colored, and when it is squeezed its fiber material is 15 to 75%. Raw peat (fibric) namely peat that has not decayed, the original material can still be recognized, brown colored, and squeezed more than 75% of the fiber is still left. The raw peat is prohibited for the development of oil palm cultivation (Regulation of the Ministry of Agriculture No. 14/2009).

4) Peat thickness <3 m

Peat thickness in the peatlands managed for oil palm plantations in East Kotawaringin Regency varies with the proportion of land more than 70% in peat thickness less than 3 m. Regulation of the Ministry of Agriculture No. 14/2009 states that peat land that can be used for oil palm cultivation in the form of an overlays that has peat thickness less than 3 m and the proportion of land with peat thickness less than 3 m is at least 70% from the cultivated area.

5) Land ownership conflict

Land ownership conflict is a conflict that often occurs between large private companies/perusahaan besar swasta (PBS) of oil palm plantations and other parties, either the government (Forestry) and community groups. These conflicts include the existence of covert land-clearing activities by large private companies/PBS of oil palm plantation such as those located in the area of Rubung Buyung Village and its surroundings, Cempaga Subdistrict, Kotawaringin Timur Regency. Prolonged land conflicts also occurred between residents of Pantap Village, Kuala Kuayan Subdistrict, East Kotawaringin Regency and Private Large Companies of oil palm plantations in the area. The conflict also occurred between community groups belonging to the Marga Rahayu Village Unit Cooperative (Koperasi Unit Desa - KUD) and the large private companies in Antang Kalang Subdistrict, East Kotawaringin Regency. The company is accused of embezzling plasma land of around 300 ha by only distributing an area of 700 ha to KUD members from a total land area of around 1,000 ha belonging to members of the Marga Rahayu Village Unit Cooperative.

Improvements to the attributes of organic C content, acid sulphate soil layer, peat maturity level, peat thickness <3 m, and land ownership conflict will be able to leverage the status of sustainable peatland management for oil palm plantations of the dimension of the Criteria of Peatland.

Status of the Sustainable Peatland Management - Use of Peatland Dimension. The use of peat land for oil palm plantations includes planning, land clearing, planting, maintenance and conservation. Planning is carried out through the activities of inventory and identification (land mapping), garden/plantation design, and preparation of annual work plans. Land clearing is done without burning and applying good water governance (hydrology) rules. Planting is conducted by taking into account the carrying capacity of peatlands. Maintenance and conservation is carried out to maintain the groundwater level at certain depths so that it can support plant growth and the sustainability of the function of peatlands (Regulation of the Ministry of Agriculture No. 14/2009), presented in Figure 2 a,b.

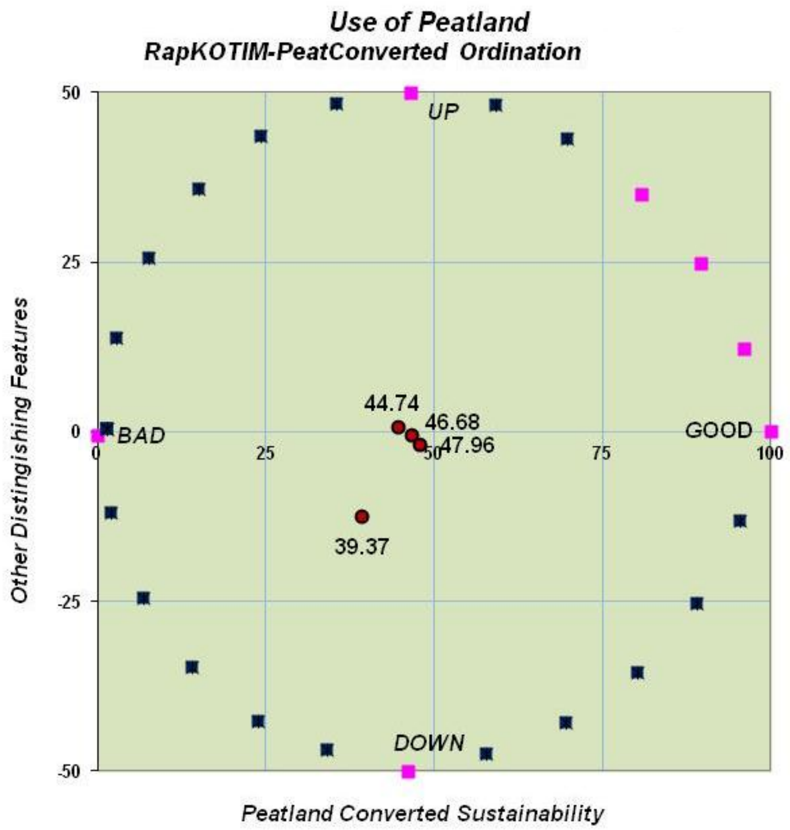

Figure 2a. MDS ordination of the dimension of Use of Peatland.

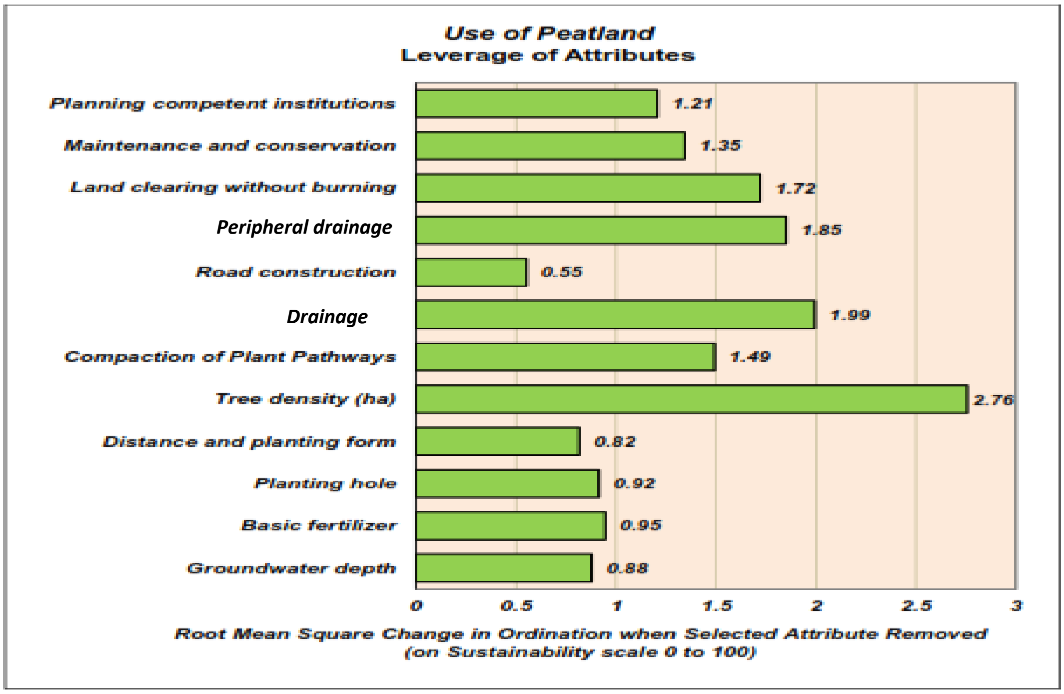

Figure 2b. RMS value of the dimension of Use of Peatland.

Processed result of *RapKOTIM-PeatConverted* of the dimension of Use of Peatland shows that natural peat forest has sustainability index of 39.37 (less sustainable). The management of peatlands for oil palm plantations with a planting age less than 4 years has an index of 46.68 (less sustainable), oil palm plantations with planting age between 4-10 years has an index of 47.96 (less sustainable), and oil palm plantations with planting age above 10 years has an index of 44.74 (less sustainable). The difference value in MDS index and Monte Carlo index (α = 95%) is less than 5% for all study locations, stress (S) statistical parameter show goodness of fit (23.24% <25%) with a coefficient of determination approaching value 1 or good condition (R^2 = 94.15%). *RapKOTIM-PeatConverted* is sufficient and has high accuracy as an estimator of the status of sustainable peatland management for oil palm plantations of the dimension of Use of Peatland.

Sensitive attributes which are the leverage factors of the sustainable peatland management of the Use of Peatland dimension resulting from leverage analysis output are the followings:

1) Oil palm plant density (ha)

Peatlands of oil palm plantations with planting age less than 4 years use the triangle method with a side length of 9 m and 7.5 m with planting density or Stand per Hectare (SPH) 163 trees, planting age between 4-10 years also uses the triangle method with a side length of 9 m and 8.5 m with planting density or Stand per Hectare (SPH) 148 trees. Planting age above 10 years with a long equilateral triangle method of 8.5 m each, use planting density or Stand per Hectare (SPH) of 160 trees.

Planting is carried out by taking into account the carrying capacity of peatlands. If the arrangement of the water system is carried out properly, planting activities can follow the requirements of the density of oil palm trees as many as 143 (one hundred and forty three) trees per hectare (9 meter planting space of equilateral triangle) or at other density levels according to the character of the canopy length of the oil palm varieties used (Regulation of the Ministry of Agriculture No. 14/2009).

2) Drainage

The main principle of water governance arrangement on cultivated peatlands for agricultural crops must be able to suppress the decline in environmental functions of peat land due to the process of drainage/groundwater level decline, but still be able to fulfill the requirements for growing cultivated plants (Blowers 2013; Wösten et al

2008; Schröder et al 2004; Joosten & Clarke 2002). Details concerning drainage in all peatland locations are shown in Table 3.

Table 3
Suitability of drainage in the management of sustainable peatlands in East Kotawaringin Regency

Peatlands	*Channel type*	*Width (m)*		*Depth (m)*	*Information*
		Up	*Down*		
Natural peat forest	Primary	2.43	0.98	1.12	*Less appropriate*
	Secondary	1.07	0.63	0.78	*Less appropriate*
	Tertiary	-	-	-	*Less appropriate*
Oil palm plantation with planting age <4 years	Primary	3.82	1.64	2.35	*Less appropriate*
	Secondary	1.41	0.56	1.62	*Less appropriate*
	Tertiary	0.86	0.42	0.75	*Less appropriate*
Oil palm plantation with planting age between 4-10 years	Primary	3.04	1.64	1.38	*Less appropriate*
	Secondary	1.65	0.75	1.44	*Less appropriate*
	Tertiary	0.74	0.68	0.65	*Less appropriate*
Oil palm plantation with planting age >10 years	Primary	3.25	1.10	1.50	*Less appropriate*
	Secondary	1.55	0.58	1.10	*Less appropriate*
	Tertiary	0.82	0.45	0.80	*Less appropriate*

The channel dimensions, namely the primary, secondary and tertiary channels, must be adjusted to the regional area and commodity developed (Agus & Subiksa 2008). Drainage consists of primary, secondary and tertiary channels. The primary channel functions to drain water directly to the final disposal area, among others, rivers and/or canals; or the primary can be a natural small stream which is cleaned or in the form of a new channel; and builds a fort and sluice gates in the tidal area. The secondary channel runs into the primary channel and serves to accommodate water from tertiary channels and also as a block boundary. The distance between secondary channels is 400 m to 500 m with length according to the channel conditions. Tertiary channels lead to secondary channels. Tertiary channels function to drain water to all secondary channels and accommodate water from the plant area. The tertiary channel interval depends on the drainage conditions in the field, a maximum of one channel for two rows of plants (Regulation of the Ministry of Agriculture No. 14/2009).

3) ***Peripheral drain***

The peripheral drain at each study location did not meet the requirements stipulated in the Regulation of the Ministry of Agriculture No. 14/2009. The existing peripheral drain is generally less able to limit the plantation area to the surrounding location because there are many peripheral drains that have been made untreated so that the dike not functioning properly. This of course will not be able to prevent the entry of water from outside the plantation area which results in the drying process unable to run smoothly. The boundary channel does not meet the channel size requirements, which are 4 m width and 4 m depth. Many embankments/dikes are not high enough so that during heavy rains and flood water from outside cannot be stopped. The existence of the embankment is also not in the form of a trapezium with only the size between 3-4.5 m. The condition of the dike and the peripheral drain which is not in accordance with this provision is certainly not able to show its role and function as a regulator of the groundwater level and prevents the entry of water into the garden/plantation from the surrounding area.

Construction of peripheral drain serves as boundary channel for the area, to regulate the groundwater level and also has main channel function. The channel has an upper width of ±4 m, bottom width ±3 m with a depth of 2 up to 3 m (Regulation of the Ministry of agriculture No. 14/2009).

4) **Land clearing without burning**

Kotawaringin Timur Regency is still in the red category in terms of forest fires with the potential for land fires still quite high due to low rainfall intensity. In August 2017 there were 18 forest fires with an area of burning of 134.8 hectares.

Land combustion as an accelerated form of oxidation can result in loss of peat soil organic matter, leaching of soil nutrients due to increased decomposition of peat, increased CO_2 emissions to the atmosphere (Radjagukguk 2000), and changes in soil physical, chemical and biological properties.

5) **Compaction of plant pathways**

Efforts to compact the plant paths have indeed been carried out, but in reality it is still unable to reduce the surface of the peat soil quickly and sufficiently (30-50 cm), so that in the process of further peat surface degradation, plant roots are less able to anchor deep in the soil so that many it tilts and then collapses.

Compaction of plant paths is needed so that the plant roots can anchor firmly in the soil, thereby reducing the tendency to grow tilted or fall. Each planting path is carried out compaction by mechanical method (Regulation of the Ministry of Agriculture No. 14/2009). If the plant path is compacted, oil palm is planted with the size of the planting hole of 60 x 60 x 60 cm. Meanwhile, if the path is not compacted, oil palm is planted with an outer hole size of 100 x 100 x 60 cm and inner hole size of 60 x 60 x 60 cm. Another alternative for compaction can be done by making a planting hole using a puncher *(*Regulation of the Ministry of Agriculture No. 14/2009).

6) **Maintenance and conservation**

East Kotawaringin has the widest high conservation value area of 27,502 ha among all plantations of the Regency, namely the area which has now granted oil palm plantation permits. However, East Kotawaringin only has 2.89% of the total area of Central Kalimantan with high conservation value with protected status, namely as a nature reserve and protected forest. This figure/number is the lowest compared to other regencies.

East Kotawaringin Regency has the most severe deforestation rate from all regencies based on an analysis of forest canopy/cover area from 1973 to 2012. East Kotawaringin also has the highest installed production capacity and concentration of palm oil mills (all 27 plants with installed capacity for processing are 1,585 ton Fresh Fruit Bunches/hour) and kernel plant (all 4 factories with a production capacity of 39.5 tons of kernel/hour). Nearly 48.839 hectares of high conservation value areas identified in East Kotawaringin are at risk of being affected by oil palm expansion. This area is under the status of convertible production forest/ convertible production forest (HPK) which allows for other uses, such as issuing permits for oil palm plantations. HPK will be important, especially to create scenarios for assessing land use as forests compared to oil palm plantations. There are significant regency-level opportunities for expansion of low-emission oil palm plantations on an area of 365.407 hectares and 48.839 hectares for the protection of important high conservation value areas as part of the land management corridor.

Improvements to the attributes of oil palm density (ha), drainage, peripheral drainage, land clearing without burning, compaction of plant pathways, and maintenance and conservation will be able to leverage the increasing status of sustainable peatland management for oil palm plantations of the dimensions of Use of Peatland.

Status of sustainable peatland management of the dimension of Guidance and Supervision of Peatland. Coaching is carried out, which includes education and training for the prevention and control of peatland damage, counseling of legislation relating to peatland exploitation; and/or technical guidance, to increase awareness and participation of plantation business actors in the context of sustainable peatland exploitation. Supervision includes exploitation/cultivation of peat land, to avoid damage to environmental functions and mitigate the impact and recovery of environmental functions that have been carried out in relation to damage to peatlands. The dimension of

Guidance and Supervision of Peatland in the management of peatlands in East Kotawaringin Regency consists of 12 attributes, presented in Figure 3 a,b.

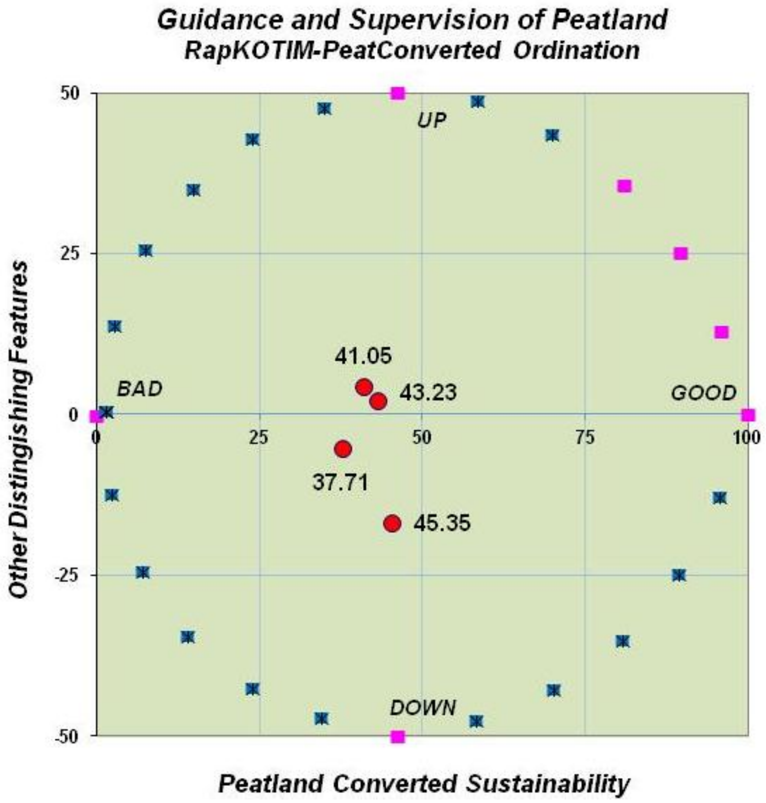

Figure 3a. MDS ordination of the dimension of Guidance and Supervision of Peatland.

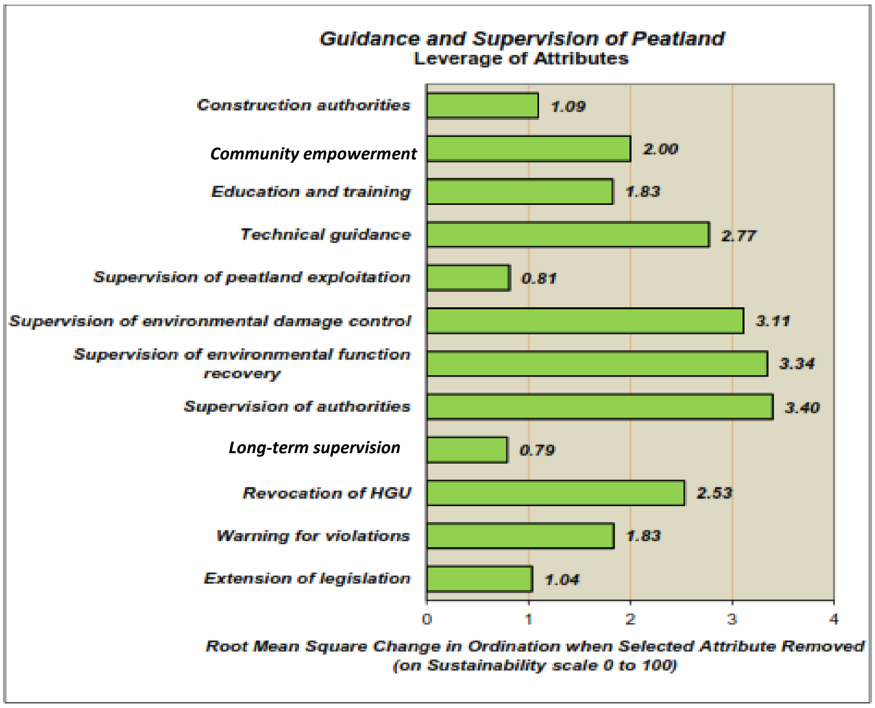

Figure 3b. RMS value of the dimension of Guidance and Supervision of Peatland.

The analysis result of *RapKOTIM-PeatConverted* of the Dimension of Guidance and Supervision of Peatland showed that natural peat swamp forest has a sustainability index of 45.35 (less sustainable). Peatlands on oil palm plantation with planting age less than 4 years has a sustainability index of 41.05 (less sustainable). Peatlands in oil palm plantation with planting age between 4-10 years has a sustainability index of 43.23 (less sustainable). Peatlands on oil palm plantation with planting age above 10 years has a sustainability index of 37.71 (less sustainable).

The difference value in MDS index and Monte Carlo index (α = 95%) is less than 5% for all study locations, *stress* (S) statistical parameter shows goodness of fit (22.67% <25%) with a coefficient of determination approaching value 1 or good condition (R^2 = 93.86%). *RapKOTIM-PeatConverted* is sufficient and has high accuracy as an estimator of the status of sustainable peatland management for oil palm plantations of the dimensions of Guidance and Supervision of Peatland.

Sensitive attributes which are the leverage factors for the status of sustainable peatland management of the dimension of Guidance and Supervision of Peatland as the result of leverage analysis are the followings:

1) Supervision from the authorities

Supervision of peatland management in oil palm plantations in East Kotawaringin Regency is still not optimal. This proved that there were still many violations that occurred in the management of peatlands, especially for oil palm plantation commodities. Supervision is of course supervision carried out by authorized parties such as Ministers, Governors and Regents/Mayors. Operational clarity from supervision is very important, because without learning from various implementations of existing regulations in Indonesia (especially those related to natural resources) of various supervisory activities cannot be carried out effectively.

Considering the peatland ecosystem does not recognize the limits of government administration then conservation efforts must be carried out through an approach in the form of protection of forests that grow over peatland areas and the establishment of a specific area to be managed as a representative of the conservation of peatland ecosystems. The rest is very necessary to carry out utilization actions by applying conservation principles in a planned and consistent manner, for example for ecotourism activities. Therefore more detailed arrangements are needed regarding the division of roles in supervision and also the operationalization of supervision. Although it does not need to contain step by step implementation of supervision, at least it can be explained more clearly the division of roles.

2) Monitoring the restoration of environmental functions

Damage to the functioning of peat ecosystems in Kotawaringin Timur Regency occurs as a result of wrong land management with the selection of business commodities which are not in accordance with the characteristics of peatlands. This is exacerbated by the drainage of peat water which results in dryness (dry irreversible) on the peat itself which is currently the trigger for fires. Facts in the field indicate that fires that occur almost every year with an ever increasing area is the fact that peat is no longer in its natural condition or has been damaged. Efforts to restore the function of peat ecosystems can be done through restoration of peat ecosystems, rehabilitation of peat ecosystems, and other ways that are in accordance with the development of science and technology.

3) Supervision of damage prevention/mitigation

The lack of supervision over the mitigation of peatland damage in East Kotawaringin Regency is partly due to the burning of peatlands in preparation for agricultural land, plantations, settlements, etc.; uncontrolled logging of peat forests for timber, construction of irrigation channels/ditches/canals for agricultural and transportation purposes. These activities not only cause physical damage to peatland/forest (such as land subsidence, burning and reduced peat area), but also cause loss of function of peat as a sink and carbon sequester, as a water catchment area which capable prevent flooding in surrounding areas in the rainy season and prevent saltwater intrusion in the dry season. Therefore supervision of the mitigation of peatland damage must begin early, especially in terms of preparing peatlands for oil palm plantations.

4) Technical guidance

Technical guidance is an effort to provide guidance to all stakeholders of peatlands directed at efforts to restore peatlands. For the implementation of restoration at regency level, needs to be established Implementation Team of Peat Restoration in East Kotawaringin Regency which is in charge of carrying out the restoration actions in accordance with the ratified restoration master plan. The fact shows that the implementation of technical guidance in East Kotawaringin Regency has not run well. The technical guidance should involve a unit of organization for the restoration executive level which institutionally strengthened regionally at the province level of Central Kalimantan to facilitate the planning, supervision and technical guidance on the implementation of the restoration of peat. The institutional includes several regional work units (SKPD), technical implementation unit (UPT) and related vertical agencies, and NGOs.

5) Revocation of cultivation rights (HGU)

The audit results from the company's audit team formed by the East Kotawaringin Regency Government at the end of 2016 found an illegal plantation of 537 ha. Dozens of oil palm companies in East Kotawaringin Regency are thought to have worked on land outside the cultivation rights (HGU) permit. Therefore the revocation of HGU is one of the efforts that must be made to provide a deterrent effect for oil palm plantation companies that have been proven to have committed misuse of permits the cultivation right.

6) Community empowerment

The orientation of peatland development as a government project must be replaced as an effort to empower with the activities and involvement of community groups to get involved in planning and management. The low community participation in East Kotawaringin Regency in preparing peatland planning and management makes sustainable peatland management unilateral and less sensitive to local culture. The appreciation and use of traditional wisdom that should be the basis for peatlands management at the local level is relatively low or even neglected.

Improvements to the attributes of supervision of the authorities, monitoring the restoration of environmental function, supervision of damage prevention/mitigation, technical guidance, revocation of Cultivation Rights (HGU), and community empowerment will be able to leverage the increasing status of sustainable peatland management for oil palm plantations of the dimension of Guidance and Supervision of Peatland.

Status of the Multidimensional Sustainable Peatland Management. The measurement of multidimensional sustainable oil palm plantation conversion peatland management status is a measurement of the merging of the attributes of dimensions of the Criteria of Peatland*,* dimensions of the Use of Peatland*,* and dimensions of Guidance and Supervision of Peatland which amounted to 34 attributes, presented in Figure 4.

The measurements results of *RapKOTIM-PeatConverted* show that natural peat forest has an index of 42.59 (less sustainable), peatland for oil palm plantation with planting age less than 4 years has an index of 47.69 (less sustainable), peatlands for oil palm plantation with planting age between 4-10 years has an index of 49.12 (less sustainable), and peatland for oil palm plantation with planting age above 10 years has an index of 44.10 (less sustainable)*.*

Statistical parameters state the goodness of fit (21.3% <25%) and the coefficient of determination is close to 1 or in good condition (R^2 = 95.3%). The difference value between the MDS and Monte Carlo indexes for the four study locations shows a difference less than 5%. *RapKOTIM-PeatConverted* quantitatively and quickly (rapid appraisal) is quite good used as an evaluation tool in determining the status of sustainable peatland management for multidimensional oil palm plantations.

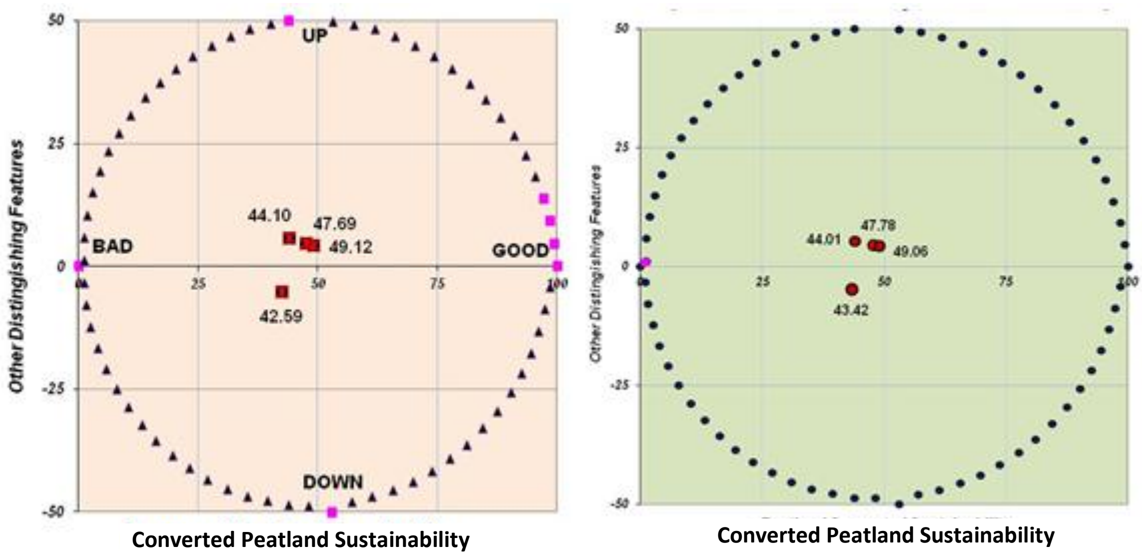

Figure 4. Multidimensional ordination of MDS and Monte Carlo analysis.

Conclusions. The status of the sustainable peatland management for oil palm plantations in the dimensions of the Criteria of Peatland shows that natural peat forest has the status of "less sustainable", peatland for oil palm plantations, each at the planting age less than 4 years, planting age between 4-10 years, and planting age above 10 years has "fairly sustainable" status. Concerning the sustainable peatland management for oil palm plantations for the Use of Peatland dimensions and dimensions of Guidance and Supervision of Peatland in all four research locations have a "less sustainable status". The status of sustainable peatlands management for oil palm plantations in a multidimensional manner at the four research sites is "less sustainable". Improvements should be made to sensitive attributes in each dimension so that it will be able to raise the status of sustainable peatland management for oil palm plantations. These attributes are organic C content, acid sulphate soil layer, peat maturity level, peat thickness <3 m, and land ownership conflicts for the dimension of the Criteria of Peatland. Improvements were also made to the sensitive attributes of the Use of Peatland dimension in the form of plant/tree density (ha), drainage, peripheral drain, land clearing without burning, compaction of plant pathways, as well as maintenance and conservation. While the attributes improvement of Guidance and Supervision of Peatland dimension includes the supervision of the authorities, monitoring the restoration of environmental function, supervision of damage prevention, technical guidance, revocation of cultivation rights/HGU, and community empowerment.

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