Subsidence and degradation of peatland conservation in the Musi-Belida peat hydrological unity, Indonesia

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Abstract. One form of conservation and utilization of peatlands in the Musi-Belida Peat hydrological unit in South Sumatra Province is the construction of the Sriwijaya Botanical Garden. Botanical gardens are part of the national wealth, which has many functions, namely, in addition to being a center of botanical knowledge, it is also a nature reserve, a research area, an educational institution, an outdoor recreation area, and an environmental service. The study uses a prospective observation approach in real environmental situations. The analysis is done by comparing data from 2015 and 2021 and other supporting data. Some of the indicators found in the research show that the peatlands in the research site experiencing subsidence are already drained, marked by the presence of channels /troughs, there was tree felling, there is a paving block road, the presence of traces of fire, subsidence.

Keyword: subsidence, degradation, peatland conservation, the Musi-Belida peat hydrological unity

1. Introduction

Degraded peatlands are cultivated or forested areas that have been or are being physically, chemically, and biologically damaged and contain carbon stocks.. According to [1] annual gap-filled CO2 emissions through soil respiration and oxidative peat decomposition were both lower than those in other oil palm plantations on tropical peat. Also, low levels of biodiversity finally endanger the hydrological, ecological, production, settlement, and socio-economic life functions of society. Drains have been laid within such mineral strata there is an increase in soil acidity. During autumnal drainage operations, the environment is therefore optimized for sulfate-reducing bacteria, resulting in acid sulfate soils with increased rates of degradation [2]

One form of conservation and utilization of peat areas is in Musi-Belida peat hydrological unity, South Sumatra Province, is the construction of the Sriwijaya Botanical Gardens. Botanical Gardens are part of the nation's wealth which has many functions, namely, apart from being a center for Botanical knowledge, it is also a conservation area, research area, education, recreational facilities in the open, and environmental services. Sriwijaya Botanical Garden which is a peat land that was once planted with oil palm plantations.

The conversion of peatland into oil palm plantations in the peat swamp ecosystem is the dominant factor causing peatland degradation. The use of peat soil has an impact on the peat itself which results in changes in the physical, chemical, and biological properties of peat. Mean water table depth (WTD) was the best predictor of subsidence rate in both plantation and forest areas. We did not find conclusive evidence that subsidence was intrinsically faster

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under Acacia plantations than under native forests or (by comparison with previous studies) oil palm plantations for the same level of drainage [3]. The estimated trends of subsidence are temporally well correlated with rainfall variation. The significant decrease in rainfall during this period is mainly inferred to decrease peat water levels; therefore, more considerable subsidence occurred [4].

Degraded soils are not only unproductive, but can also be a source of disasters ranging from droughts, floods, landslides to fires, which can accelerate global warming. The subsidence of drained peat soils is caused by the oxidation of the organic matter of the peat soil, the consolidation of the peat layer, and the permanent shrinkage of the upper part of the peat soil above the water table [5]. Peat drainage causes land subsidence and has a number of negative social impacts. Integrated strategies are needed to ensure more sustainable long-term frameworks based on impact assessment models that simulate the interrelated dynamics of water management and land subsidence and determine the spatial and temporal scope of societal impacts [6]. Data and information are needed for the conservation of peatlands in the Musi-Belida peat hydrological unit and for the factors causing land subsidence, among others to support remediation and restoration activities. Knowledge of subsidence data on peatlands will support measures to maintain the sustainability of peatlands by designing a drainage system, estimating the age of soil organic matter, and evaluating the best use of peatlands.

2. Methods

A prospective observational approach in real environmental settings will be used for the study. As many sample points as possible are determined, namely 20 points per 100 hectares of land. The dimensions of the study area are 1,090 meters long x 865 meters wide. To obtain a distance between points of 200 meters on the grid, the length dimension is divided into 5 lanes and the width dimension is divided into 4 lanes, so that there are 5 x 2 = 20 coordinate points that observe the characteristics of the soil. The analysis is done by comparing data from 2015 and 2021 and other supporting data.

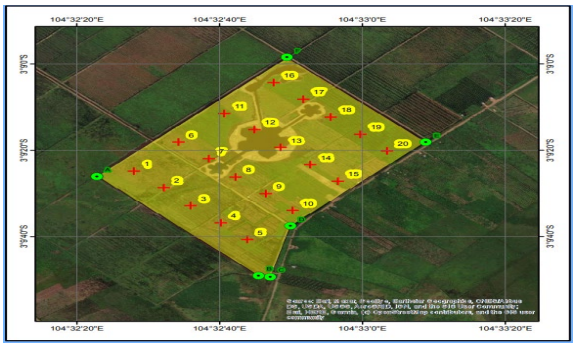

Figure 1. Sampling Location.

3. Results and Discussion

Based on peat depth measurements in March 2015 (table 1.), peat depth was obtained 315 cm – 697 cm, when compared to peat depth measurement data in April 2021, namely 60 cm -

402 cm, there was a subsidence of around 42.3 % - 80.9 %. Land subsidence occurs due to dry peat shrinkage and accelerated peat decomposition caused by oxygen exposure.

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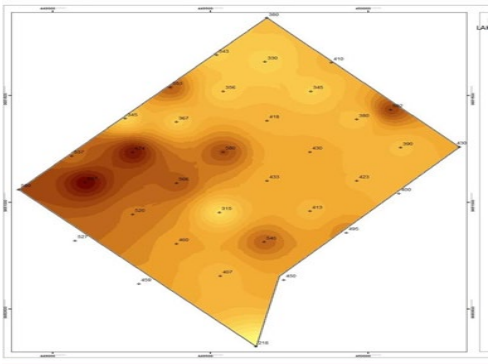

Figure 2. Peat depth distribution map in sampling location in 2015.

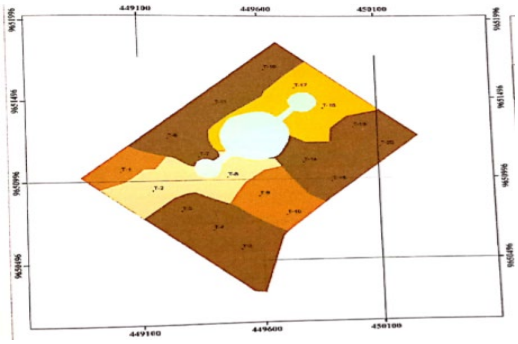

Figure 3. Peat depth distribution map in sampling location in 2021.

Table 1. Peat's Subsidence of 2015-2021

Sampling points	Peat's depth (cm)		Subsidence (□)	Sampling points	Peat's depth (cm)		Subsidence (□)
	2015	2021			2015	2021	
1	697	258	62.98	11	460	382	16.96
2	674	76	88.72	12	315	170	46.03
3	367	385	-4.90	13	433	380	12.24
4	356	360	-1.12	14	430	354	17.67
5	330	302	8.48	15	380	390	-2.63
6	345	318	7.83	16	390	310	20.51
7	418	402	3.83	17	423	175	58.63
8	580	43	92.59	18	413	195	52.78
9	566	250	55.83	19	545	382	29.91
10	520	253	51.35	20	407	356	12.53

Figure 4. Slanted tree due to subsidence.

It can be assumed that compaction of deep peat over the last 1000 years has caused little or no subsidence in areas with high water tables, because deep peat is affected by deep drainage [7]. The loss of water from the peat mass causes physical maturation of the peat, resulting in shrinkage of the peat, while the entry of oxygen into the peat soil can accelerate the decomposition process (chemical maturation). A very important chemical maturation process is the oxidation of the sulphur compounds (mostly pyrites) of the originally reduced sediments to sulphates and sulfuric acid, as well as the cations adsorbed to the clay and humus complex.

Aside from peat's depth measurement, Some some of the indicators were found in the research location shows that the peatlands in the research location are experiencing subsidence are as follows:

i. Already drained, marked by the presence of canals/troughs;

This location had previously undergone a conversion to oil palm plantations, so that many waterways and canals were found. Currently, the hydrological arrangement is further enhanced by the presence of sluice gates, dams, small ponds. This is done to regulate drainage but has an impact on the occurrence of subsidence. It is recommended to shift from a drainage system to alleviate the negative consequences of drainage of peat swamps to shift from a drainage system that focuses on the discharge of excess water to a system that combines drainage and water conservation, allowing the maintenance of constant high groundwater levels and thus reducing subsidence[8]

Figure5. Sampel Canals and Ponds in Musi-Belida peat hydrological unity

ii. There has been tree felling;

This peatland area with designation as a special forest area (KHDTK) was previously converted to oil palm plantations and subsequently placed under conservation, including replacing oil palm plantations with wetlands. According to [9], the long-term perspective for conversion to wetlands, including a higher surface water table, will reduce upward seepage of

brackish and nutrient-rich groundwater and limit greenhouse gas emissions due to peat oxidation. This leads to flooding every time there is a heavy rain.

Figure 6. Flooded conditions during the rainy season in September 2021.

iii. There is a paving block road;

The purpose of the paving stones around the main pool is to fulfil the tourist function of this place. However, it has been found that this development affects the subsidence rate, causing soil degradation.

Figure 7. Paving block road.

iv. The presence of traces of fire;

Degradation of peatlands may be caused by errors in land clearing, construction of drainage canals, and land management. In addition, degradation can also be caused by fires or burning of peatlands.

Figure 8. Fire at Sriwijaya Botanical Gardens in October 2014.

Figure 9. Fire at Sriwijaya Botanical Gardens in September 2019

v. Subsidence

Oxidation may lead to further CO2 emissions from drained peatlands. Soil subsidence was initially strongly influenced by compaction, resulting in changes in bulk density. The rate of subsidence should decrease in the next decades due to the rise of the water table and the increasing supply of biomass [10]. The high subsidence rate at the beginning of the year and its approach will decrease as the soil matures, accompanied by an increase in soil bulk density that characterizes the occurrence of subsidence.

The following are the bulk density conditions at the study site. The lowest value of bulk density is located at observation point 1 with the lowest value, this site is a point adjacent to the worm canal that was previously constructed for irrigation of oil palm plantations. Deforestation and fires near canals increase the bulk density of peat above the minimum water table elevation and increase the density of most of the upper peat layers (Figure 9).

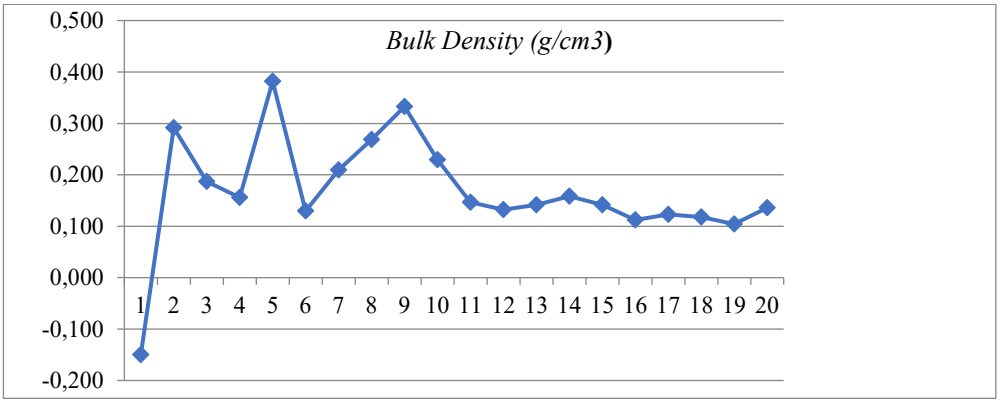

Figure 10. Bulk density conditions at the research site.

The opening of the channel also caused a subsidence of the land surface. This subsidence was caused by the weathering of the raw peat layer on the ground surface. This occurs because the species and population of soil microorganisms change as a result of temperature and moisture fluctuations in the uppermost layer. Environmental changes that occur when peat swamp forests are cleared, such as planting non-plant species on peat bogs, agricultural operations, including plantation operations, affect the reduction of the resistance of organic matter in peat to the decomposition process. Changes in conditions from anaerobic to aerobic due to the construction of drainage channels favour the process of overhaul of organic matter very quickly, which in turn can lead to a reduction in the surface area of peatlands

4. Conclusion

Degraded soils are not only unproductive, but can also be a source of disasters ranging from droughts, floods, landslides to fires that can contribute to the acceleration of global warming. Some of the indicators found at the study site that show that the peatlands at the study site are affected by subsidence are already drained, characterized by the presence of canals/troughs, trees have been cut down, there is a paved road, the presence of burn marks, subsidence. Sriwijaya Botanical Garden as a form of conservation and use of peatlands in the Musi-Belida Peat hydrological unit in South Sumatra Province needs to prioritize its conservation role to reduce land degradation at this site.

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