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A Review of Topogenous Peatland Management in Humbang Hasundutan Regency

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Abstract.
Indonesia possesses a substantial expanse of peatland, including an area of over 265,500 square kilometers throughout the islands of Sumatra, Kalimantan, and Papua. Humbang Hasundutan Regency, located in North Sumatra, encompasses a total area of 2358 ha of peatland, making it a significant carbon reservoir worldwide. Peatlands within a district can be classified into two main types: topogenic and upland. This research aims to review issues related to peatlands in Humbang Hasundutan Regency and their sustainable management. The study was conducted using a systematic review method using e-books and journal articles to support a review that includes observational studies. E-books and journal articles were searched in online databases such as Google Scholar using the keywords: “Humbang Hasundutan,” “peatland,” and “topogenic.” The downloading process was done independently by the authors. This resulted in 5 e-books and 27 journal articles, 6 of which were observational or experimental studies conducted in the Humbang Hasundutan Regency while the rest discussed peatlands outside of Humbang Hasundutan Regency. Moreover, 20 articles discussed peatland management. This systematic review proves that many factors must be considered in good peatland management. These include the physiographic, topographical, and hydrological characteristics of the land, as well as fire prevention measures, the selection of appropriate materials and fertilizers, the use of geospatial technology, the adoption of adaptation strategies for peatland use, the way communities view peatlands, and the economic importance of peat ecosystems.

Keywords: Humbang Hasundutan, peatland, topogenic

1. INTRODUCTION

Indonesia has a vast expanse of peatlands, spanning more than 265,500 km^2 over the islands of Sumatra, Kalimantan, and Papua. This substantial coverage establishes Indonesia as one of the most prominent tropical countries with the third-largest peatland globally. Indonesian bogs harbor approximately 50% of peat found in tropical regions. According to conditional statistics for 2008, Indonesian peat had the third largest carbon stock globally, weighing approximately 54,016 tons [1]. Indonesia is behind Canada and

Russia in terms of the magnitude of its carbon stock. Humbang Hasundutan Regency, located in North Sumatra, Indonesia is recognized as one of the districts encompassing peatland and is estimated to cover an area of approximately 2,358 hectares [2]. The road traversing this settlement is flanked by extensive peat soil deposits, estimated to span hundreds of hectares [3].

Peat regions are present in several districts within Humbang Hasundutan, such as Dolok Sanggul, Pollung, and Lintong Ni Huta. The peatland in the Humbang Hasundutan Regency is classified as topogenic peat, alternatively referred to as upland peat. The identified peat variety possesses several notable benefits, such as its capacity to effectively sequester carbon stocks, and its role as a crucial water catchment zone for Lake Toba. The extraction of peat in Humbang Hasundutan Regency has been a matter of concern because of the substantial emissions generated by these operations and their detrimental impact on carbon sequestration capacity [2].

2. METHODOLOGY/ MATERIALS

This is a systematic review that uses e-books and journal articles to support a review that includes observational studies. The authors explored evidence in the scientific literature that has been reviewed by previous researchers related to peatlands. In this review, the authors focused on peatland issues in Humbang Hasundutan Regency and the environmental conditions and recommendations for peatland management. E-books and journal articles were searched in online databases such as Google Scholar using the keywords: Humbang Hasundutan, peatland, and topogenic. The downloading process was done independently by the authors. The articles were downloaded from March to August 2023. The authors screened the selected articles using time constraints, selecting only articles published from 2010 to 2022 to make the review more updated. Initial results, including titles and abstracts, were quickly reviewed to determine if the information in the paper was relevant, and relevant papers that were relevant were then read in full and included in the review. Given the geographic focus of this project, we not only prioritized papers from Humbang Hasundutan, where available, but also drew on evidence from other peatland regions where appropriate. From the initial search, 50 articles were deemed relevant enough for further reading. Next, the authors selected the titles, read the abstracts and full texts of the articles to determine the 32 articles that were included in the qualitative research in this systematic review.

3. RESULTS AND DISCUSSIONS

This resulted in 5 e-books and 27 journal articles, 6 of which were observational or experimental studies conducted in the Humbang Hasundutan Regency and the rest discussed peatlands outside Humbang Hasundutan Regency. 20 of these articles discussed peatland management. These articles show that there are several ways to conduct sustainable peatland management that can be applied in Humbang Hasundutan Regency.

3.1. Issues in the Peatlands of Humbang Hasundutan

Agricultural utilization of peatlands has been observed in Humbang Hasundutan Regency of North Sumatra [4]. The peatland was initially employed for rice cultivation to fulfill the dietary requirements of nearby people. Over time, individuals have realized that the practice of rice cultivation has become inadequate to meet the growing demands and aspirations of their households. Consequently, it is their contention that transitioning towards the cultivation of Arabica coffee and horticultural crops such as tomatoes, onions, chilies, and various types of vegetables would yield greater productivity and economic benefits. Many individuals have been transforming peatlands once used for rice cultivation in coffee and horticultural plantations. This process underwent a significant shift over a considerable period of time [5].

The alteration of land use in the Humbang Hasundutan Regency has resulted in the adverse consequences of land degradation [6]. The diminished productivity of land is a consequence of its degradation, which subsequently diminishes its overall quality. BPS data from 2013 provided evidence of a decrease in food crop output in the Humbang Hasundutan Regency. Specifically, the production of milled dry unhusked rice declined from 111,181 tons in 2007 to 103,410 tons in 2011. These data confirm the aforementioned statement. Another indicator is the matter of environmental vulnerability in certain hilly regions, namely the districts of Pakkat, Parlilitan, Tara Bintang, Onanganjang, and Baktiraja. These areas were classified as locations by the BPBD Humbang Hasundutan, necessitating a heightened awareness of the potential risk of landslides. The clearance of peat vegetation for agricultural purposes results in loss of vegetation, which leads to drainage and a subsequent decrease in groundwater levels. This phenomenon results in deterioration of the structural integrity of the peat ecosystem, a reduction in its ability to sequester carbon, and an increase in its susceptibility to fire.

3.2. The Policy of Framework for the Management of Peatlands

The Indonesian government established the Peat Restoration Agency (BRG) and Presidential Regulation Number 1 of 2016 related to its creation and operation. The establishment of the BRG represents a governmental endeavor aimed at mitigating climate change and forestalling the occurrence of wildfires. The primary duty of the BRG is to undertake efforts aimed at restoring peatland ecosystem functionality, while concurrently ensuring the preservation and regulation of its natural water system. Restoration of peatlands by the BRG encompasses three primary strategies: revegetation, rewetting, and local economic stimulation. BRG engages in the restoration of peatlands within community-owned, maintained, and conserved zones. The BRG adhered to the guidelines set forth by Presidential Regulation Number 71 in 2014 and Presidential Regulation Number 57 in 2016. The aforementioned regulation employs a KHG-derived methodology to categorize peatlands into distinct roles, namely, production and protection. A fundamental framework for the management and conservation of the peat environment was established by implementing a Peat Hydrological Unit (KHG) [7]. Based on the provisions outlined in Presidential Regulation Number 71 of 2014, in conjunction with No. 57/2016, the peat ecosystem fulfills dual functions: cultivation and protection. The objective of peatland management within the agricultural context is to mitigate the adverse impacts on these ecosystems. Peatlands with farming purposes can be protected if they meet the criteria outlined in Government Regulation Number 57 of 2016 [8].

3.3. Government-led Initiatives

The conversion of peatlands into plantations and agricultural land is pursued to enhance the welfare of individuals in the realms of food production and economic growth. In anticipation of prospective food scarcity, Indonesia is currently focusing on expanding the food estate sector within peatland areas [9]. In parallel, a multitude of peatlands inside the Humbang Hasundutan Regency, which are presently contributing to the enhancement of community well-being, have undergone conversion into agricultural areas and plantations. Nevertheless, the government has thus far failed to implement tangible measures aimed at restoring the exploited peatlands. According to the official website of Humbang Hasundutan Regency government, the administration is committed to advocating the rights of the community regarding residential areas and communal land that are encompassed within the peatland indication map by the end of 2022. This phenomenon arises from the challenges individuals encounter when endeavoring to initiate a commercial venture or secure a financial loan, as their possessions are explicitly delineated on the map. In addition, the task of accurately documenting government properties is complicated by the fact that the peatland map, which serves as an indicator, also includes various other government assets, such as offices and schools.

3.4. Environmental Conditions

The land-use patterns in Humbang Hasundutan Regency are undergoing changes owing to the expansion and development activities that have taken place in the area. Humbang Hasundutan Regency experiences adverse environmental consequences owing to alterations in land utilization, notably the degradation of land resulting from deforestation. Specifically, the area of peatland in this regency had decreased from 2,330 Ha in 2003 to the remaining 1,304 Ha by 2013. From 2003 to 2013, the peatland area of Humbang Hasundutan Regency decreased by 1,026 Ha [6].

Humbang Hasundutan Regency encompasses peatlands that span an extensive region measuring 6,289.08 hectares. Dolok Sanggul District, Pollung District, and Lintong Ni Huta District are the three districts within the Humbang Hasundutan Regency that encompass areas characterized by the presence of peatlands. Dolok Sanggul District exhibits a peatland coverage of approximately 45%, Pollung District shows a peatland coverage of approximately 26%, and Lintong Ni Huta District has peatland coverage of approximately 29%. The peat soil found in Humbang Hasundutan Regency is classified as ombrogenous peat, because it is mostly influenced by rainwater. The weight measurements of peat in Humbang Hasundutan Regency exhibited a range of 0.12 to 0.309 tons/m^3. According to his assertion, the peat region in question exhibits a substantial bulk density. A high unit weight number indicates low water content, solid texture, and ability to withstand substantial subsidence [10].

The range of organic carbon content observed in the study varied from 6.13% to -17.81%, along with the measurement of bulk density. The peat in Humbang Hasundutan Regency has low organic carbon content. Humbang Hasundutan Regency experiences air temperatures between 17 - 29°C, accompanied by an average humidity of 85.94%. These climatic conditions contributed to the presence of organic matter that was not completely decomposed. When comparing peat ecosystems, particularly those found in lowland areas, these conditions generally result in a reduced rate of organic matter breakdown [11].

3.5. Peatland Management that can be Implemented

3.5.1. Water Management Requires the Consideration of Physiographic, Topographical, and Hydrological Factors

Effective management of water systems inside peatlands is a fundamental aspect of establishing a sustainable peatland management system. The objective of managing the water system in peatlands is to sustain the requisite conditions for plant development while mitigating the adverse effects on environmental functions resulting from the reduction in groundwater levels during drainage activities [12]. The hydrological system has undergone modifications owing to land clearance and canalization endeavors. The characteristics of peatlands are significantly affected by the regulation of macro- and microwater systems. The degradation of peat in terms of subsidence and irreversible drying processes is significantly affected by groundwater levels [13].

Water availability plays a crucial role in the restoration of the peatlands. The implementation of management measures is necessary to mitigate water loss and ensure sustainable water supply for Sphagnum and other plant species. This is particularly crucial, because harvested peatlands have experienced a decline in their inherent ability to hold water and regulate variations in water levels. The restoration plan must include a comprehensive inventory of potential water losses resulting from both surface and subsurface drainage as well as the identification of potential sources of water ingress into the restoration site [14]. To ensure the productivity and sustainability of agricultural land, it is imperative to manage peat in accordance with its inherent fragility and qualities, while also considering its hydrological circumstances [15].

3.5.2. Fire Prevention

Indonesia has experienced a significant annual incidence of forest and land fires that predominantly occur during the dry season. Peat areas are characterized by previous conditions, primarily consisting of highly combustible peatlands and wooded regions [16]. The conversion of forests into agricultural land or other land use types often leads to a heightened occurrence of fires. Moreover, excessive drainage of peatlands has the potential to increase their susceptibility to fires. The combustion of peatlands has the potential to decrease the carbon stocks in both peat and plant tissues, leading to increased emissions from these sources. Land fires diminish the integrity of the peat layer, thereby accelerating the process of exposing the underlying mineral soil layers, which are characterized by a lack of essential nutrients. Consequently, plants exhibit impaired growth and fail to reach their full developmental capacity [17]. The groundwater level (GWL) has served as a predictive factor for fire events. The recommended maximum GWL depth in peatlands is 40 cm, with particular emphasis on the need for a minimum GWL of 10 cm in highly degraded peat areas to mitigate the risk of surface peat fire. Peat fires are a result of arid conditions found in degraded peatlands, which facilitate the propagation of fires into the underlying peat layers [18].

3.5.3. Materials and Fertilizers Employed in the Amelioration Process

The use of ameliorants can potentially improve the physical and chemical properties of peat soils. Some examples of ameliorating materials include ACS, manure, and dolomite lime. These three distinct ameliorants have the potential to elevate the pH and increase the concentration of bases in the soil. Peatlands require fertilization because of the significant dearth of essential minerals and nutrients required by plants. Peatlands, particularly those that contain nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), zinc (Zn), and boron (B), require comprehensive fertilizers [19].

The addition of dolomite to peat soils can effectively increase pH levels, thereby facilitating the growth and development of shallots [20]. The application of rice husk ash ameliorants significantly increased the P content, transitioning from a low level to a very high level [21]. The ability of the ameliorant to prevent P from being fixed in peat soil by acid cations makes more P available in the soil. The potassium (K) content of peat soil increases with the application of rice husk ash [22]. The observed increase in carbon content can be attributed to the direct application of rice husk ash, which exhibited a relatively high carbon concentration of 24.9%. The application of rice husk ash decreases the C/N ratio in peat soils [23].

The organic acids present in peat soils can form chemical bonds with sawdust ash. Sawdust ash can modify the chemical properties of soil, including pH levels. This renders it a highly effective ameliorant for peat soil, because it also enhances the abundance of productive tillers in rice plants cultivated under such soil conditions [24]. Mineral soil ameliorants can be used at rates between 10 and 20 t ha^{-1} $year^{-1}$ to reduce the negative effects of phytotoxic organic acids, make more essential macro and micronutrients available, and increase the pH and alkalinity of the soil [25]. The utilization of volcanic dust significantly enhanced the abundance of vegetative and productive tillers, augmented plant productivity, and increased the proportion of filled grains [26]. The introduction of sea mud into peat soils at a proportion of 20% (equivalent to 80 tons/ha) resulted in enhanced cation availability [27].

3.5.4. Utilizing Geospatial Technology

Location-specific technology refers to a technological approach that encompasses resources derived from farmers themselves or externally introduced, and is consistently internalized to foster farmers' ingenuity. This technology exhibits a strong capacity to adapt to local agro-ecosystems and sociocultural contexts, effectively addressing specific challenges that may arise. Moreover, it yields superior outcomes compared with general technology and is driven by the interests and needs of the local community [28]. To enhance plant and land productivity, it is imperative to employ site-specific methodologies. Several site-specific citrus cultivation procedures can be employed in peatlands, including the utilization of high-quality seeds, lime treatment, balanced fertilizer, garden sanitation and weeding practices, branch pruning, fruit thinning, harvesting technology, and postharvest techniques [29].

3.5.5. Utilization of Several Varieties Adaptively

Accurate categorization of commodity types and varieties is of utmost importance in the advancement of agribusiness in peatlands as it enables the attainment of optimal outcomes [30]. This is due to the fact that the distinctive characteristics of such lands necessitate the cultivation of certain commodity types and varieties that are capable of thriving and yielding favorable results under these unique conditions. Utilization of plant species with adaptive characteristics is recommended for the cultivation of peatlands to enhance operational efficiency and reduce the costs associated with production facilities. There are two distinct approaches for cultivating plants in peatlands: one involves utilizing indigenous and resilient rice and sago plants derived from the peat swamp species Metroxylon sago, which are well-suited for natural drainage conditions, while the other involves implementing artificial drainage conditions [31].

3.6. The Perception of Peatlands within the Community

The perception of peatlands within a community can exert a substantial influence on the efforts aimed at their management and preservation. Research on peatlands encompasses an examination of individuals' evaluations of the ecological and economic advantages associated with these ecosystems, their attitudes towards the restoration of peatlands, and their perspectives regarding the management strategies employed in peatland conservation. The level of education, life experience, and access to knowledge are just a few variables that affect how societies view peatlands. Based on empirical evidence, individuals with higher levels of education and wealth of life experience exhibit a heightened understanding of the benefits and importance associated with the conservation of peatlands. The perception of canal-blocking activities in peatlands is influenced by various factors, including knowledge, education, financial resources, and property ownership [32].

4. CONCLUSION

The peatland located in Humbang Hasundutan Regency was previously utilized for agricultural purposes, but it was subsequently converted to more economically beneficial practices, including the cultivation of Arabica coffee and horticulture crops. The alteration of land use in Humbang Hasundutan Regency has resulted in adverse consequences of land degradation, primarily due to deforestation. The Humbang Hasundutan Regency Government is actively engaged in safeguarding the community's entitlements pertaining to residential properties and land, as delineated on the peatland map. Peatland management is influenced by various factors, including water regulation, fire prevention, application of ameliorants and fertilizers, utilization of site-specific technology, adoption of adaptable peatland types, and public perception of peatlands.

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