pantau gambut

DROWNED PEATLAND

More Than Just Fires Threaten Peatland Ecosystems

A Study on Flood Vulnerability in Peat Hydrological Units (KHG) of Indonesia.

2025

Pantau Gambut is a non-govermental organization that networks in nine provinces which focuses on research and advocacy, and campaigns for the peatland protection and sustainability in Indonesia.

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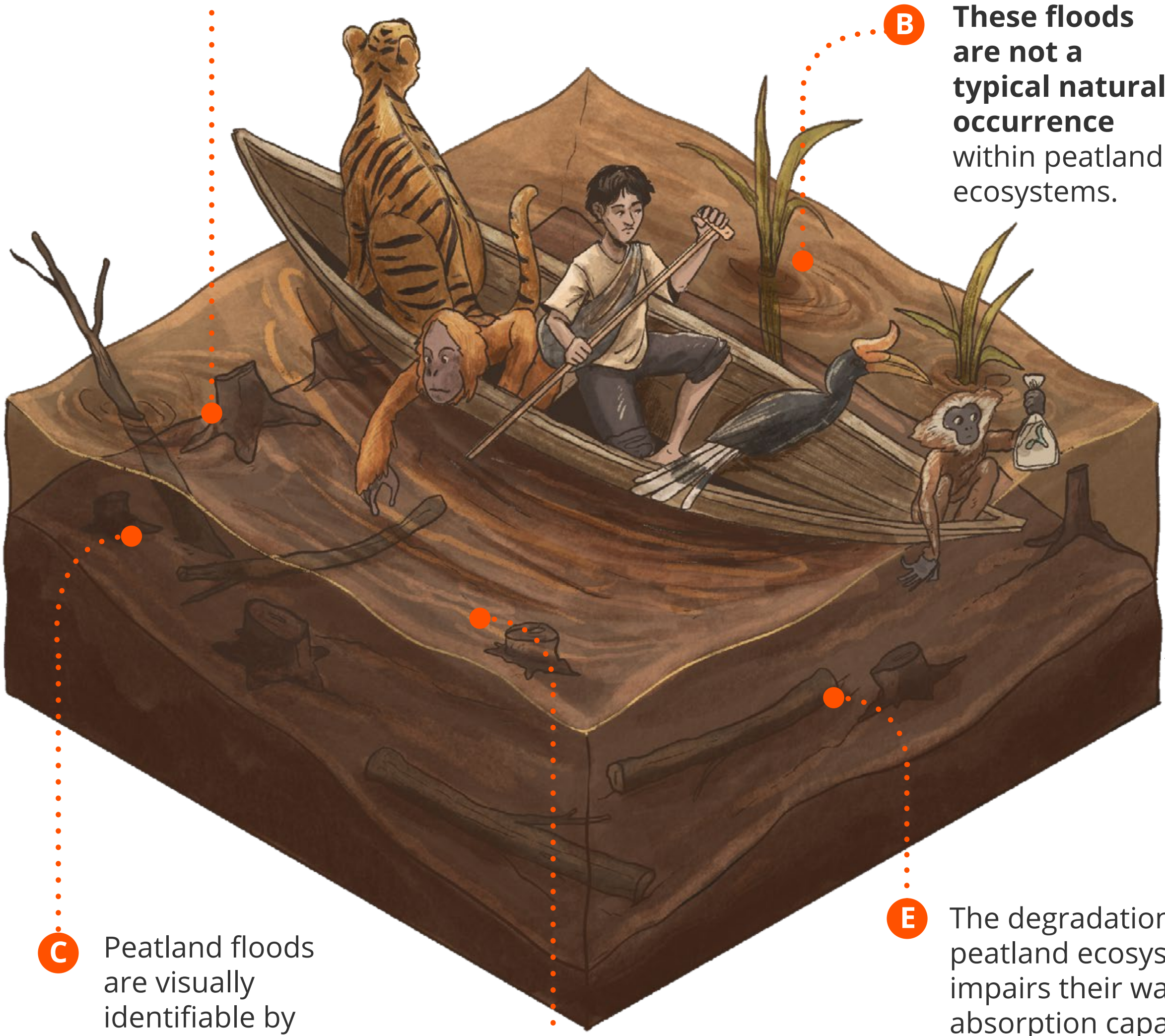
Peat 101

Flood in Peatland Ecosystem

Not only are endemic flora and fauna threatened, but floods caused by peatland degradation also have a direct impact on human livelihoods. Everyone bears the same burden when peatland ecosystems are damaged.



EXECUTIVE SUMMARY

> **Degradasi lahan gambut tidak hanya memicu kebakaran hutan, tetapi juga meningkatkan risiko banjir.**

As part of the wetland ecosystem, peatlands should function as water buffers. However, land conversion and unsustainable canalization methods have disrupted peatlands' hydrological functions. Consequently, peatlands that should be absorbing water have instead become a source of flooding. This situation is exacerbated by Indonesia's high rainfall, making floods more frequent and widespread, particularly in areas with degraded peatlands.

To understand this issue, Pantau Gambut conducted research on three regional Peat Hydrological Units (PHU). Observations were carried out using the Multi-Criteria Evaluation (MCE) method in conjunction with Geographic Information Systems (GIS). The findings of this study aim to provide specific recommendations for local and central governments in developing spatial planning and disaster mitigation strategies to reduce flood risks and protect both communities and the environment.

Key Findings

1. The degradation of peatlands due to land conversion and unsustainable drainage methods has altered Indonesia's hydrological landscape, particularly in regions with high peatland concentrations such as Kalimantan and Sumatra. **The damage has resulted in a loss of water absorption capacity**, increasing the risk of flooding.

2. **Significant peatland subsidence further intensifies flood risks,** the inability to retain rainwater worsens, causing surface runoff to escalate and triggering widespread flooding.

3. The degradation of coastal peatlands has led to significant land subsidence, making the region increasingly vulnerable to tidal flooding.

4. Central Kalimantan, West Kalimantan, and South Sumatra are among the provinces most vulnerable to severe flooding due to peatland destruction.

Recommendations

Pantau Gambut demands that local and national governments enforce strict measures to prevent further destruction of peatland ecosystems by implementing hydrology-based management strategies. Peatland conservation must go beyond fire control and prioritize its essential function in maintaining water balance and reducing flood risks.

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1. BACKGROUND

In addition to forest and land fires—which have long been the primary concern—flooding poses a significant threat resulting from peatland ecosystem degradation. As part of wetland ecosystems, peatlands are naturally meant to remain waterlogged. However, when peatland degradation occurs, their ability to absorb water is significantly diminished. This irreversible drying process disrupts water retention, leading to uncontrolled flooding and extensive environmental damage.[1]

As a nation with a tropical climate and frequent heavy rains, Indonesia is naturally prone to flooding. However, peatland conversion has become one of the key factors worsening the country's flood problems, making them more frequent and widespread. Much like the haze from forest fires that disregards administrative boundaries, floods also know no borders.

In South Kalimantan, 21 lives were lost to the relentless floods of 2021,[2] a grim reminder of ecological destruction. A trans-provincial road connecting Riau and West Sumatra was also completely cut off by the same forces in 2023.[3] Most recently, in January 2025, land conversion led to the submergence of 1,707 homes across several areas in Central Kalimantan.[4] This does not merely deepen the vulnerability of communities and their fragile ecosystems, where human lives hang in the balance.

Flooding also leaves lasting damage to peatland ecosystems. Flood runoff can trigger nutrient leaching, leaving peat soils barren and nutrient-deficient. In addition to becoming infertile, dried-out peatlands become highly flammable.[5] The problem worsens when floodwaters mix with pollutants from large-scale land exploitation—such as industrial plantations—further contaminating aquatic ecosystems and threatening all life dependent on them.

The increasing frequency of floods caused by land conversion, particularly in peatland areas, has prompted Pantau Gambut to analyze flood runoff vulnerability across three regional Peat Hydrological Units (PHU). The findings of this study are expected to provide specific recommendations for local and central governments in developing spatial planning and disaster mitigation strategies to minimize flood risks while safeguarding both communities and the environment.

1 Parish, F., Quoi, L. P., Yan, L. S., Global Environment Centre, & The Regional Coordination Unit. (2020). *Sustainable Management of Peatland Ecosystems in Mekong Countries Training Module 1A: Peatland Identification: Definition, Characteristics and Identification of Peatlands*. https://hazeportal.asean.org/wp-content/uploads/2024/12/1a-Peatland-identification-characteristics-and-identification-of-peatland.pdf

2 Prabowo, D. (21 Januari 2021). *Teka-teki Penyebab Banjir Besar di Kalimantan Selatan.* kompas.com. https://nasional.kompas.com/read/2021/01/21/08535951/teka-teki-penyebab-banjir-besar-di-kalimantan-selatan?page=all

3 Helindro, G. (28 Desember 2023). *Walhi Sumbar: Alih fungsi Hutan Penyebab Jalan Sumbar-Riau Putus*. betahita.id. https://betahita.id/news/detail/9691/walhi-sumbar-alih-fungsi-hutan-penyebab-jalan-sumbar-riau-putus.html?v=1703709912

4 Putri, G. S. (5 Februari 2025). *Banjir Kalteng, Alih Fungsi Hutan untuk Sawit dan Tambang Jadi Sorotan*. kompas.com. https://regional.kompas.com/read/2025/02/05/101820778/banjir-kalteng-alih-fungsi-hutan-untuk-sawit-dan-tambang-jadi-sorotan

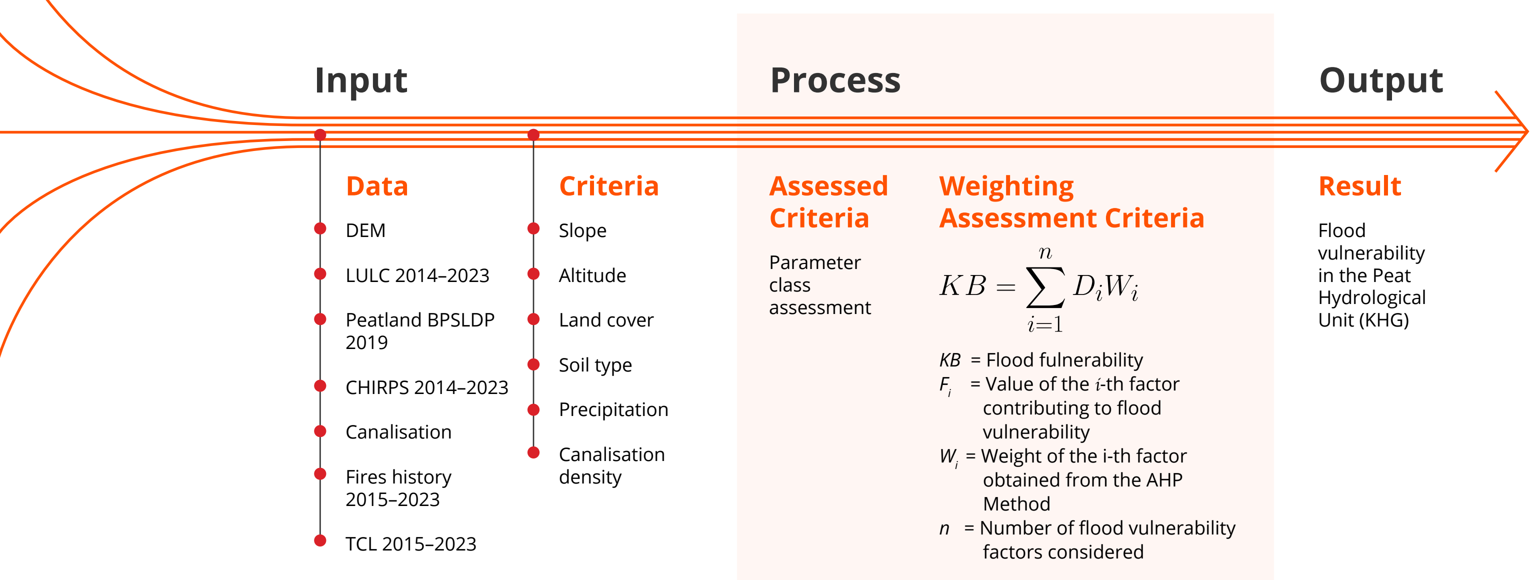
5 Agus, F., Anda, M., Jamil, A., & Masganti. (2014). *Lahan Gambut Indonesia: Pembentukan, Karakteristik, dan Potensi Mendukung Ketahanan Pangan*. IAARD Press. https://nasih.staff.ugm.ac.id/wp-content/uploads/Lahan-Gambut-Indonesia.-Pembentukan-Karakteristik-dan-Potensi-Mendukung-Ketahanan-Pangan.-2014.pdf

2. METHODOLOGY

2.1. Research Methods

Pantau Gambut conducted research to analyze flood vulnerability in three major Peat Hydrological Unit (PHU) regions in Indonesia, covering Sumatra, Kalimantan, and Papua. These three regions were chosen based on the distribution of peatland areas and variations in topography and climate. This approach allows for a more comprehensive and precise analysis, recognizing that each region possesses different environmental characteristics and risk factors. By integrating topographic, climatic, and peatland condition data using Geographic Information Systems (GIS), the study aims to generate a more accurate flood vulnerability map.

Figure 1 Data Processing Flow



In flood vulnerability analysis contexts multiple factors, including topography, land use, and precipitation levels must be considered simultaneously. The Multi-Criteria Evaluation (MCE) method was chosen for its ability to incorporate various factors at once. MCE has been widely recognized for its effectiveness, particularly given that around 80% of decision-making data are geographically based.[6] With the support of GIS, criteria such as slope gradient, soil type, and proximity to rivers can be integrated to produce a more comprehensive and accurate flood vulnerability map.[7]

This study utilizes the **Expert Adjustment** method to determine the significance of each parameter influencing flood runoff. Experts provide assessments for predefined parameters, which are then integrated into a flood runoff prediction model using Geographic Information

6 Malczewski, J. (1999). *GIS and Multi-Criteria Decision Analysis*. Wiley: New York, NY, USA.

7 Singha, C., Swain, K.C., Saren, B.K. (2019). *Land Suitability Assessment for Potato Crop using Analytic Hierarchy Process Technique and Geographic Information System*. J. Agric. Eng. 56, 78–87.

Systems (GIS). This integration allows for the identification of high-risk flood zones and supports the formulation of targeted mitigation strategies.

To ensure that expert assessments are conducted systematically and measurably, this study employs the **Analytical Hierarchy Process (AHP)**.[8] This method allows for a structured comparison of the relative importance of each criterion influencing flood vulnerability through pairwise comparisons.[9] Experts rank the relative importance of each criterion and sub-criterion using a scale from 1 to 9, ensuring a data-driven and objective analysis.

The comparison results are then processed to determine the weight of each criterion. The consistency of expert assessments is tested using the **Consistency Ratio (CR)**, where a score of ≤0.1 indicates an acceptable level of consistency, while higher values suggest increasing inconsistencies. Once validated, the weighted criteria are integrated into GIS analysis to produce a more accurate flood vulnerability map. This approach enables the identification of the most at-risk areas[10] and the development of more effective mitigation strategies.

2.2. Research Limitation

As peatland ecosystems are inherently wetlands, flooding here is defined as occurrences beyond natural cycles, arising from degradation that impairs water absorption and hydrological functions, and leads to the ecosystem's functions being misallocated.

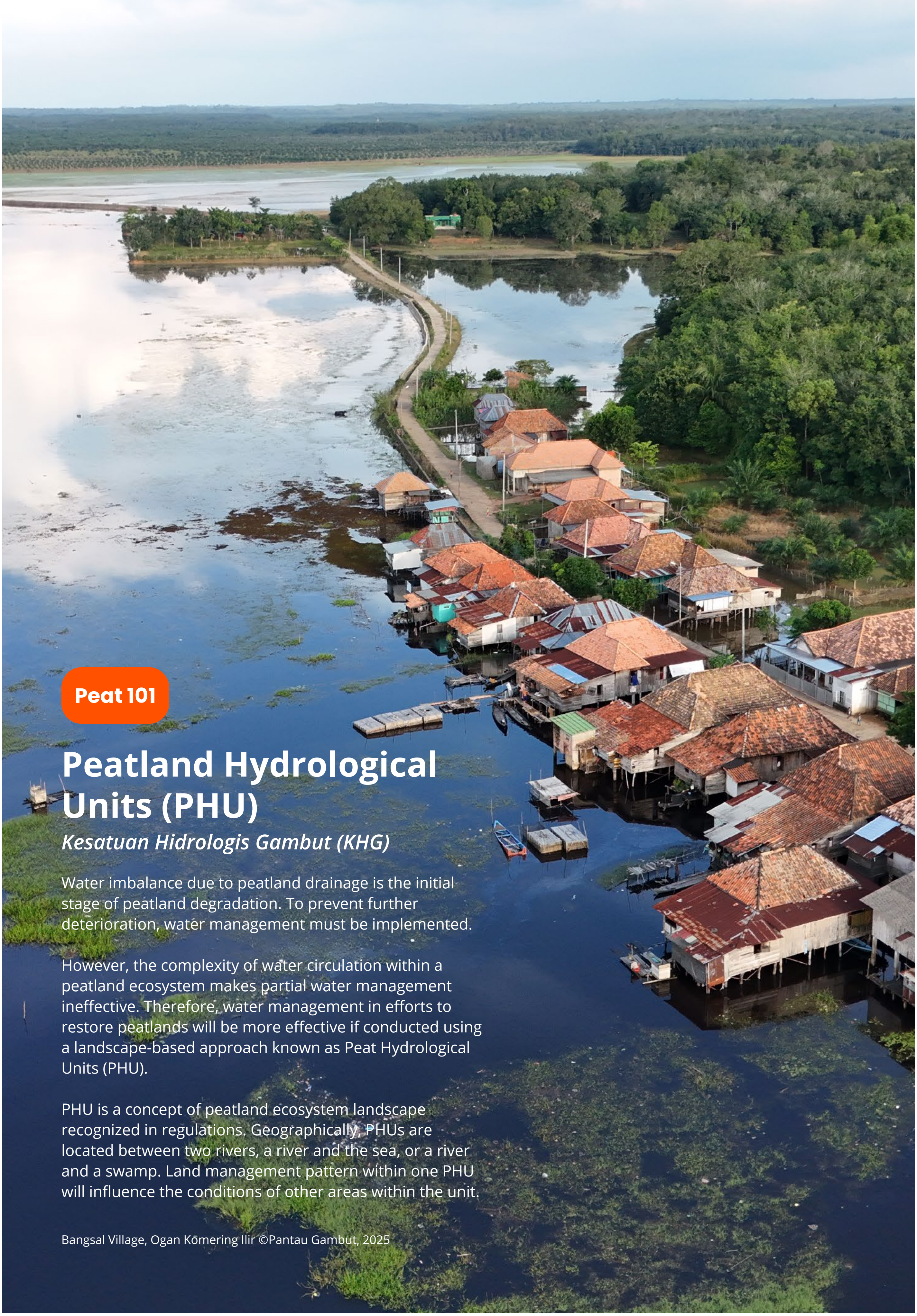
Due to the varied and interdependent complexities of peatland ecosystems, studies are limited, yet opportunities arise for expanded research, while acknowledging limitations such as:

1. The research focuses on environmental factors influencing flood vulnerability within Indonesia's Peat Hydrological Units (PHU).
2. The study relies on annual average rainfall data from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) for the period 2015–2023.
3. Peatland classification is categorized into three types: healthy peat, degraded peat, and mineral soil.
4. Data on canal distribution is obtained from BRGM's official records and satellite imagery from Planet NIPCI.
5. The vulnerability assessment employs expert adjustment techniques, ensuring each parameter is evaluated based on specific regional characteristics.

8 Ho, W. (2008). *Integrated Analytic Hierarchy Process and its applications: A literature review*. Eur. J. Oper. Res. 18, 211–228.

9 Drobne, S.; Lisec, A. (2009). *Multi-attribute decision analysis in GIS: Weighted linear combination and ordered weighted averaging*. Informatica, 33, 459–474.

10 Yashon O. Ouma. (2014). *Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric AHP and GIS: Methodological Overview and Case Study Assessment*. Water, 6, 1515-1545; doi:10.3390/w6061515.



Peat 101

Peatland Hydrological Units (PHU)

Kesatuan Hidrologis Gambut (KHG)

Water imbalance due to peatland drainage is the initial stage of peatland degradation. To prevent further deterioration, water management must be implemented.

However, the complexity of water circulation within a peatland ecosystem makes partial water management ineffective. Therefore, water management in efforts to restore peatlands will be more effective if conducted using a landscape-based approach known as Peat Hydrological Units (PHU).

PHU is a concept of peatland ecosystem landscape recognized in regulations. Geographically, PHUs are located between two rivers, a river and the sea, or a river and a swamp. Land management pattern within one PHU will influence the conditions of other areas within the unit.

Bangsal Village, Ogan Komering Ilir ©Pantau Gambut, 2025

3. FINDINGS

3.1. Vulnerability by Province

The findings of this research reveal the flood vulnerability levels across three regional distributions of the Peat Hydrological Unit (PHU) in Indonesia. A total of 25% of PHU areas are highly vulnerable to flooding, while 18% fall under the moderate category, and 57% are categorized as low risk.

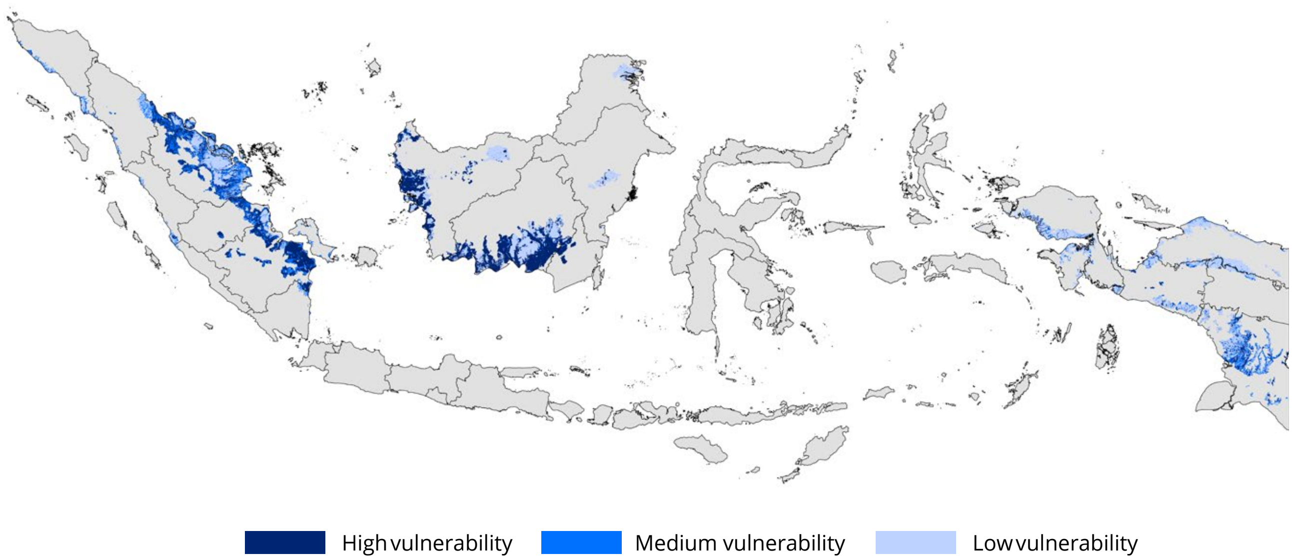
25% high vulnerability

18% medium vulnerability

57% low vulnerability

Among these regions, Kalimantan has the highest flood vulnerability, followed by Sumatra and Papua. The provinces most at risk include Central Kalimantan, West Kalimantan, South Sumatra, and Riau.

Figure 2 Map of Flood Vulnerability Distribution in Peat Hydrological Units (PHU) Across Indonesia



While Central Kalimantan is notorious for its forest fires, it is also grappling with a growing flood crisis. The degradation of peatlands caused by large-scale plantation activities has altered the landscape of this region. The excessive canalization has stripped the land of its natural water retention ability, making floods increasingly frequent.

Drainage activities also weaken the structure of peat and lead to land subsidence. Excessive drainage can lower peatlands below the level of nearby rivers or the sea, stripping them of their ability to absorb water and triggering severe environmental problems. Like an overfilled bathtub, degraded peatlands can no longer hold back rainfall. This issue is further worsened by climate change, which brings rising sea levels and increasingly extreme rainfall patterns.

Table 1 Flood Vulnerability by Province (Ha)

No	Province	Low	Medium	High
Sumatra Region				
1	Aceh	263,436.52	64,699.04	4,843.44
2	Bengkulu	12,042.20	1,948.20	15.33
3	Jambi	314,243.94	393,339.56	153,147.89
4	Riau	2,728,297.30	1,634,378.93	579,755.88
5	West Sumatra	12,791.51	24,609.94	6,043.49
6	South Sumatra	359,077.34	697,203.47	1,031,244.46
7	North Sumatra	366,036.15	130,713.12	25,950.37
8	Bangka Belitung Islands	73,283.57	22,198.23	604.82
9	Riau Islands	13,653.74	2,239.12	2.01
10	Lampung	65,361.84	29,659.16	1,585.74
Kalimantan Region				
11	West Kalimantan	1,375,641.51	146,398.81	1,242,371.62
12	South Kalimantan	20,313.97	14,927.12	199,784.56
13	Central Kalimantan	2,133,727.37	161,928.22	2,358,743.52
14	East Kalimantan	197,488.97	115,434.49	16,731.02
15	North Kalimantan	339,555.88	108.94	4,409.72
Papua Region				
16	Papua	1,104,251.48	41,633.85	2,845.56
17	West Papua + Southwest Papua	1,329,843.45	76,587.11	27,141.35
18	Highland Papua	353,399.74	31,522.94	5,215.69
19	South Papua	1,836,121.27	548,394.63	230,560.03
20	Central Papua	701,268.61	11,193.94	37,866.36

Peatland damage—such as subsidence—is irreversible, meaning it cannot be restored. This condition leads to increasingly widespread flooding, especially during the rainy season. Freshwater reserves are also diminished due to seawater intrusion into groundwater, and infrastructure like buildings and roads suffers damage. Consequently, the land becomes more vulnerable to flooding, particularly in coastal areas.[11] Land productivity also threatens the livelihoods of communities that depend on peatlands.[12]

Bengkalis Island serves as a stark example of how peatland subsidence due to ecosystem damage can threaten the survival of coastal communities.[13] Land loss and coastal abrasion not only harm the environment but also cause significant economic losses for communities reliant on fisheries and tourism.[14] This issue is further compounded by recurring tidal floods during

11 Banerjee, R. (2012). *Climate change in Indonesia: A glimpse of Riau and East Kalimantan*. Journal of Resources Energy and Development, 9(2), 89–99. https://doi.org/10.3233/red-120097

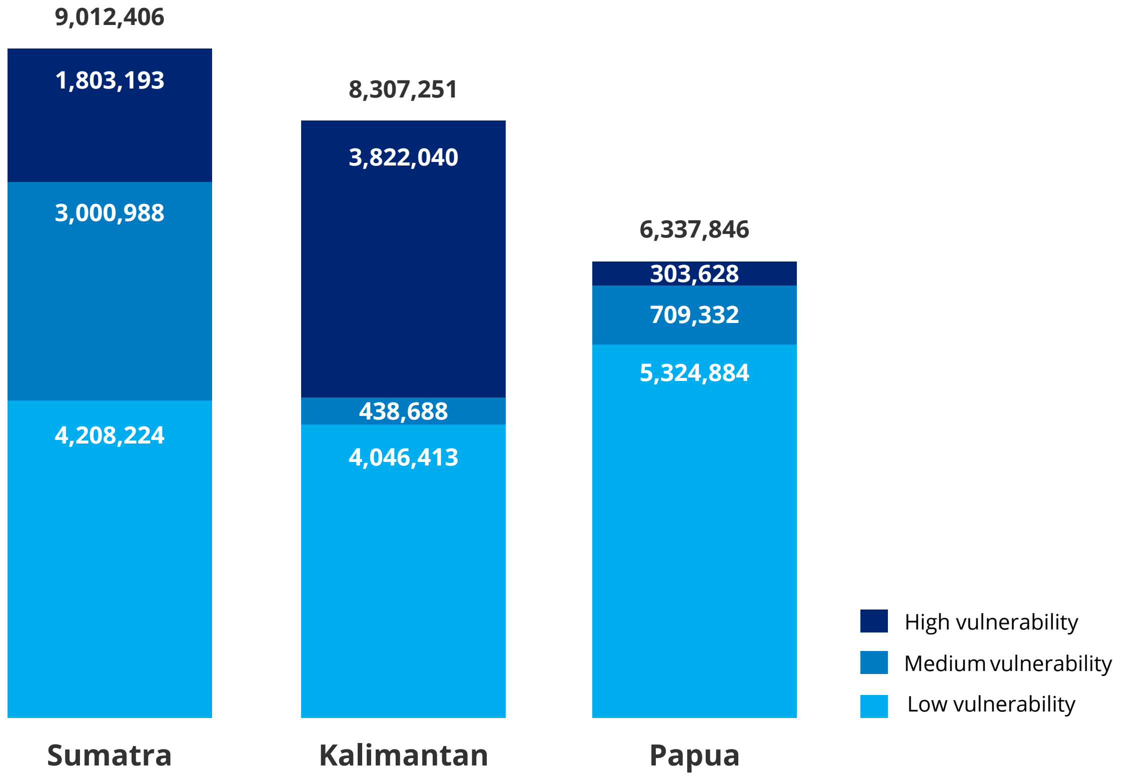
12 Sulaeman, D. (5 Oktober 2023). *Apa itu Subsidensi Gambut dan Bagaimana Negara-Negara Dapat Mencegah Bencana Lingkungan ini?*. WRI Indonesia. https://wri-indonesia.org/id/wawasan/apa-itu-subsidensi-gambut-dan-bagaimana-negara-negara-dapat-mencegah-bencana-lingkungan-ini

13 Ratri, Dhiptya & Mizuno, K & Martono, Dwi. (2021). *The effectiveness of breakwaters decreasing the peat shoreline change in Bengkalis Island*. IOP Conference Series: Earth and Environmental Science. 802. 012007. 10.1088/1755-1315/802/1/012007.

14 Ibid.

specific months.[15]

Figure 3 Flood Vulnerability by Region (Ha)



The Bengkalis Island case is not an isolated incident, but reflects a broader problem in Indonesia. Peatland acquisition through concession—particularly for plantations and Industrial Timber Estates (HTI)—has reached approximately 48% of the total Peat Hydrological Unit (PHU) area in Indonesia, with the largest concentration in Sumatra and Kalimantan.[16] Satellite imagery analysis confirms significant peatland ecosystem damage within concession areas, marked by fire scars and loss of tree cover.

3.2. Vulnerability by Peat Hydrological Unit (PHU)

Pantau Gambut conducted a derivative analysis to identify Peat Hydrological Units (PHU) with a high level of flood vulnerability. The analysis results indicate that PHU with high flood vulnerability are heavily concentrated in the Central Kalimantan and South Sumatra regions. In fact, in these two regions, highly vulnerable PHU tend to be clustered together, forming extensively at-risk areas.

Table 2 Top 10 Flood Vulnerability by PHU

No	Peatland Hydrological Unit	Province	Vulnerability Area (Ha)
1	Sugihan River–Lumpur River PHU	South Sumatra	427,759.55
2	Kahayan River–Sebangau River PHU	Central Kalimantan	388,251.04

15 Damaywanti, K. (2013). *Dampak Abrasi Pantai terhadap Lingkungan Sosial (Studi Kasus di Desa Bedono, Sayung Demak)*. Seminar Nasional Pengelolaan Sumberdaya Alam Dan Lingkungan. http://eprints.undip.ac.id/40689/1/055-Kurnia_Damaywanti.pdf

16 *Kerentanan Karhutla dan Konsesi di Dalamnya*. (18 Juni 2024). Pantau Gambut. https://pantaugambut.id/kabar/kerentanan-karhutla-dan-konsesi-di-dalamnya

3	Kahayan River–Kapuas River PHU	Central Kalimantan	264,003.04
4	Pukun River–Mentaya River PHU	Central Kalimantan	235,239.58
5	Kapuas River–Barito River PHU	Central Kalimantan	222,666.26
6	Katingan River–Sebangau River PHU	Central Kalimantan	209,018.82
7	Buluh Besar River–Seruyan River PHU	Central Kalimantan	170,502.89
8	Katingan River–Mentaya River PHU	Central Kalimantan	140,311.24
9	Kapuas River–Ambawang River PHU	Central Kalimantan	124,946.37
10	Saleh River–Sugihan River PHU	South Sumatra	117,764.87

For instance, in Central Kalimantan, the Kahayan–Sebangau River PHU, Kahayan–Kapuas River PHU, and Kapuas–Barito River PHU, located in Pulang Pisau and Kapuas regencies, exhibit a high level of flood vulnerability. These three PHU are not only geographically adjacent but also share similar vulnerability characteristics, with almost their entire areas classified as highly vulnerable.

In South Sumatra, a similar situation is observed. Most PHU in this region have high flood vulnerability, with the most notable being the Sugihan–Lumpur River PHU and Saleh–Sugihan River PHU in Ogan Komering Ilir (OKI). These two PHU also exhibit significant flood susceptibility, requiring special attention in restoration efforts.

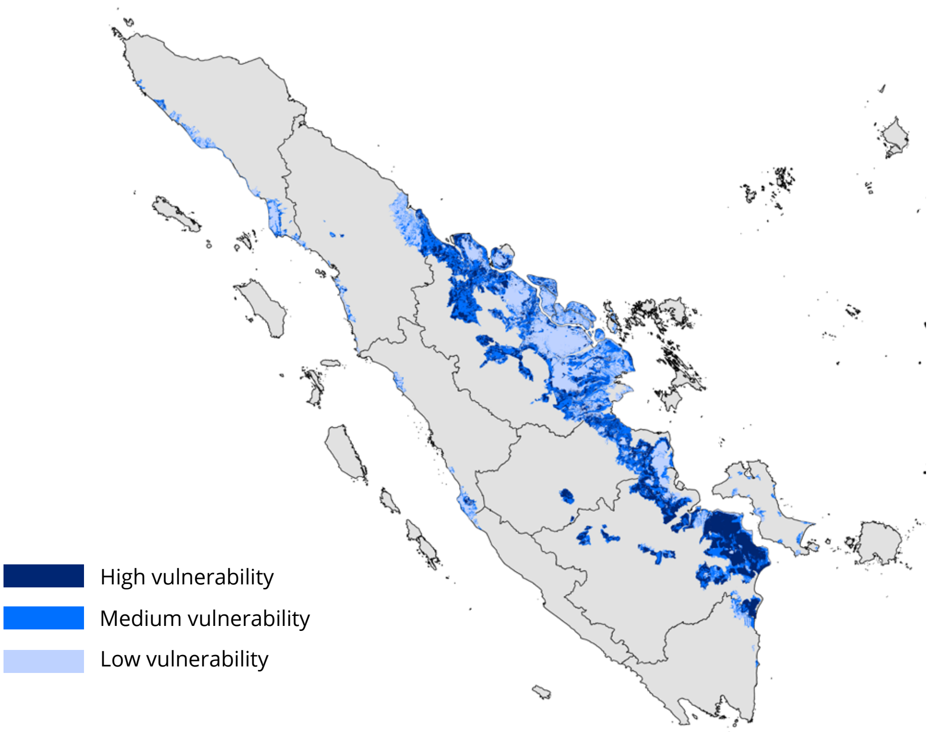
3.3. Flood Vulnerability in Sumatra Region

The Sumatra region is home to the largest distribution of peatlands and Peat Hydrological Units (PHU) in Indonesia. Most of Sumatra's peatlands are located in the eastern region, near the Malacca Strait. The peatlands in this area fall under the category of coastal peat, situated at low elevations with relatively flat topography and minimal slopes.

Sumatra's climate is heavily influenced by monsoonal wind patterns and sea surface temperatures, particularly the Indian Ocean Dipole (IOD) phenomenon in the Indian Ocean. Rainfall across Sumatra varies significantly depending on the region's topography. In the western Bukit Barisan area, annual precipitation can exceed 6,000 mm, whereas in the eastern coastal regions, it is relatively lower, averaging around 1,500 mm per year. However, on a broader scale, 70% of Sumatra receives over 2,500 mm of rainfall annually.[17]

The dry season in Sumatra generally occurs between December and March, driven by the northeast monsoon. Meanwhile, the main rainy season takes place during the transitional periods before the northeast monsoon and after the southwest monsoon, typically between May and September.[18] This rainfall variability affects peatland hydrological dynamics, particularly in terms of moisture and flood potential.

Figure 3 Distribution of Flood Vulnerability in Sumatra Region



Based on flood vulnerability analysis, the Sumatra region exhibits varying levels of flood-prone land distribution. In total, 4.2 million hectares fall under the low vulnerability category, 3 million hectares under medium vulnerability, and 1.8 million hectares under high vulnerability.

17 Marzuki, M., Yusnaini, H., Tangang, F., Muharsyah, R., Vonnisa, M., & Harmadi, H. (2022). *Land–sea contrast of diurnal cycle characteristics and rain event propagations over Sumatra according to different rain duration and seasons*. Atmospheric Research, 270, 106051.

18 Whitten, Tony., Sengli J.D., Jazanul A., Nazaruddin H. (2000). *The Ecology of Sumatra*. Singapura. Periplus Edition Ltd.

Tabel 3 Provinces with Flood Vulnerability Distribution in the Sumatra Region

No	Province	High Vulnerability Area (Ha)	Percentage of Flood-Vulnerable PHU Areas (%)
1	South Sumatra	1,031,244.46	49.40
2	Jambi	153,147.89	17.79
3	Riau	579,755.88	11.73
4	North Sumatara	25,950.37	4.96
5	West Sumatra	6,043.49	3.99
6	Lampung	1,585.74	1.64
7	Aceh	4,843.44	1.45
8	Bangka Belitung Islands	604.82	0.63
9	Bengkulu	15.33	0.11
10	Riau Islands	2.01	0.01

Flood Vulnerability Area in the Sumatra Region

!!! **1.8 milion Ha**
high vulnerability

!! **3 milion Ha**
medium vulnerability

! **4.2 milion Ha**
low vulnerability

South Sumatra and Jambi provinces have extensive areas classified as highly and moderately flood-prone. This contrasts with Riau, where peatlands are widely distributed across the province, but most areas fall under the low to moderate vulnerability category, although a significant portion remains highly vulnerable.

The conversion of Sumatra's peatlands into large-scale oil palm and acacia plantations has transformed its carbon-rich landscape into a major source of emissions. The overlap between Peat Hydrological Units (PHU) and concession areas has further exacerbated the situation. Intensive drainage practices and land clearing have disrupted the natural balance of the peatland ecosystem.

Case Study

Unprecedented Flooding in Riau Province

As a region dominated by coastal peatlands, Riau is highly susceptible to tidal flooding due to peatland degradation. Every year, thousands of homes in the Meranti Islands and Dumai are inundated by tidal floods. In January 2023, the Head of Riau Province's Regional Disaster Management Agency (*Badan Penanggulangan Bencana Daerah*/BPBD) stated that the tidal flooding in the Meranti Islands was triggered by rising sea levels combined with heavy rainfall.[19] The flood submerged three districts: Tebing Tinggi Barat, Rangsang Barat, and Pulau Merbau.

The subsidence of peatland surfaces has significantly altered the coastal landscape. **Peatlands, which once served as a natural barrier against seawater intrusion, now exacerbate tidal flooding issues, as seen in the Meranti Islands and Dumai City.** With the loss of peatlands' ability to absorb water, seawater easily inundates land, threatening residential areas, agricultural lands, and coastal ecosystems.

Similar to the Meranti Islands, Dumai City in Riau frequently experiences tidal flooding, locally known as pasang keling. In September 2024, tidal floods submerged coastal areas and the banks of the Dumai River. Uniquely, this flooding was not preceded by heavy rainfall.[20]

> “ **There was no heavy rain, yet there was flooding.**
> – Dahrin, Dumai citizen

A local resident named Anwar added that this time, the floodwaters were particularly high, preventing him and his colleagues from going to work as they were unable to access their workplace. Two schools in Pangkalan Sesai Village were also affected, with floodwaters entering classrooms and disrupting teaching and learning activities.

With peatlands covering 80% of Dumai City's total area, the extent of peatland degradation has had a significant impact on urban areas. The ongoing degradation has led to severe land subsidence, increasing the risk of tidal floods. As a result, various public infrastructures have been paralyzed, forcing Dumai residents to contend with multiple challenges, including damaged homes, economic disruptions, and a decline in quality of life.

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19 *Meranti Dihajar Banjir Rob, BPBD Riau Minta Jajaran di Daerah Pesisir Siaga*. (24 Januari 2023). cakaplah.com. https://www.cakaplah.com/berita/baca/94644/2023/01/24/meranti-dihajar-banjir-rob-bpbd-riau-minta-jajaran-di-daerah-pesisir-siaga#sthash.y38Z5xxw.dpbs

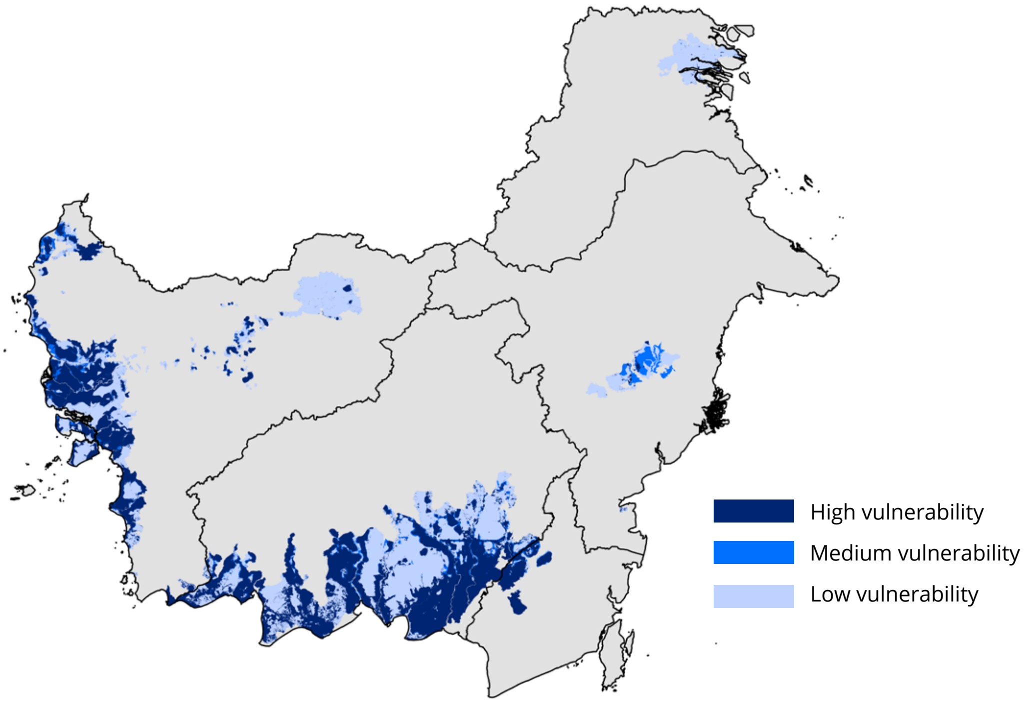
20 Ramlan, S. (20 September 2024). *Banjir Rob Kepung Dumai*. riaupos.co. https://riaupos.jawapos.com/dumai/2255108878/banjir-rob-kepung-dumai

3.4. Flood Vulnerability in Kalimantan Region

Kalimantan Island has extensive peatland areas, mainly in both inland and coastal regions. Generally, peat distribution is found at elevations of 0–50 meters with gentle slopes, predominantly concentrated in West Kalimantan and Central Kalimantan, as indicated by Digital Elevation Model Nasional (DEMNAS) data.

With a humid tropical climate and high temperatures, Kalimantan is affected by monsoon winds that cause fluctuations in rainfall. The western monsoon from the Indian Ocean brings the rainy season, whereas the eastern monsoon from the Australian continent leads to the dry season. However, rainfall across the region varies greatly and remains difficult to predict,[21] with differing intensities across locations and even over short periods.

Figure 4 Distribution of Flood Vulnerability in Kalimantan Region



Peatland degradation in Kalimantan began with the Mega Rice Project in 1995. This project involved large-scale peatland clearing to fulfill President Soeharto's ambitions. The condition of Kalimantan's peatlands worsened as various plantation companies began actively exploiting the region. As a result, the peatlands suffered severe degradation due to extensive canalization.

The destruction of this peatland ecosystem has led to recurring floods and forest fires in Kalimantan. All provinces in Kalimantan with peatlands are now under concession control, exacerbating environmental damage and threatening local communities' livelihoods.

This analysis indicates that West Kalimantan and Central Kalimantan have extensive peatland areas with high flood vulnerability, reaching approximately 3.8 million hectares, while medium

21 *Why does it rain so frequently in the rainforests?*. (12 Juni 2007). TheOS.IN. https://theos.in/science/reason-for-high-rainfall-in-rainforests/

Flood Vulnerability Area in the Kalimantan Region

3.8 milion Ha
high vulnerability

438 thousand Ha
medium vulnerability

4 milion Ha
low vulnerability

vulnerability covers 438 thousand hectares. However, South Kalimantan stands out as the province where nearly all of its Peat Hydrological Units (PHU) are highly prone to flooding. This situation results from severe peatland degradation due to extensive canalization, particularly in South Kalimantan, West Kalimantan, and Central Kalimantan.

On the other hand, around 4 million hectares of peatland in Kalimantan have low flood vulnerability. Nevertheless, it is important to note that areas classified as having medium vulnerability also require attention, as they remain at risk of flooding if proper mitigation measures are not implemented.

Tabel 4 Provinces with Flood Vulnerability Distribution in the Kalimantan Region

No	Province	High Vulnerability Area (Ha)	Percentage of Flood-Vulnerable PHU Areas (%)
1	South Kalimantan	199,784.56	85.01
2	Central Kalimantan	2,358,743.52	50.68
3	West Kalimantan	1,242,371.62	44.94
4	East Kalimantan	16,731.02	5.08
5	North Kalimantan	4,409.72	1.28

Despite peatlands naturally being waterlogged, the degradation of peatlands significantly impairs their ability to absorb water.

Case Study

The Great Flood of South Kalimantan

The largest flood in the history of South Kalimantan occurred in early 2021, with water levels reaching up to 3 meters in some areas.[22] A total of 11 districts/cities, including Banjarmasin and Banjarbaru, were submerged.[23] The Agency for the Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi/BPPT) estimated that approximately 24,379 houses were submerged, forcing 39,549 residents to evacuate, and resulting in 15 fatalities.[24] The economic losses from this disaster were estimated at IDR 1.34 trillion, covering infrastructure damage, reduced productivity, and disruptions to economic activities.[25]

Kisworo Dwi Cahyono, Director of the Indonesian Forum for the Environment (*Wahana Lingkungan Hidup Indonesia*/WALHI) of South Kalimantan for the 2021–2024 period, stated that the floods and landslides in the region were the result of severe environmental degradation.[26] Hundreds of unreclaimed mining pits[27] and the conversion of 3.7 million hectares of land for mining and palm oil plantations have damaged ecosystems and significantly reduced the land's ability to absorb water.

Losses from the 2021 South Kalimantan Floods

Financial losses amounted to
Rp1.34 Trillion

15
people lost their lives

>39.000
residents are evacuated

He emphasized that the flooding in South Kalimantan was not solely caused by high rainfall. A comprehensive environmental analysis, from upstream to downstream, is necessary. Furthermore, the increasing frequency of extreme rainfall due to climate change has aggravated the situation. Data shows that forest cover in South Kalimantan has drastically declined from 1.18 million hectares in 2005 to just 0.92 million hectares in 2019. As a result, surface runoff has increased and further elevates flood risks.

Analysis results by Pantau Gambut indicate the three studied Peat Hydrological Units (PHU) face an extremely high flood risk. This is primarily due to severe peatland degradation caused by land-use changes, such as plantations and mining activities. For instance, in South Kalimantan, approximately 80% of PHU areas have experienced degradation, making them highly susceptible to flooding. Damaged peatlands lose their ability to absorb water, causing rainwater to accumulate and trigger floods.

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22 Haryanto, A. (14 Januari 2021). *Berita Banjir di Kalsel: Air Capai 2 Meter, Warga Butuh Pertolongan*. tirto.id. https://tirto.id/berita-banjir-di-kalsel-air-capai-2-meter-warga-butuh-pertolongan-f9dX

23 Idhom, A. M. (14 Januari 2021). *Info Banjir Kalsel Terbaru 2021: Penyebab & Daftar Daerah Terendam*. tirto.id. https://tirto.id/info-banjir-kalsel-terbaru-2021-penyebab-daftar-daerah-terendam-f9eT

24 Junita, N., & Junita, N. (17 Januari 2021). *10 Kabupaten/Kota Terdampak Banjir di Kalsel, 15 Orang Meninggal dan 24.379 Rumah Terendam.* Bisnis.com. https://kabar24.bisnis.com/read/20210118/15/1344140/10-kabupatenkota-terdampak-banjir-di-kalsel-15-orang-meninggal-dan-24379-rumah-terendam

25 *Banjir di Kalsel Akibatkan Kerugian Mencapai Rp1,349 Triliun*. (25 Januari 2021). tirto.id. https://tirto.id/banjir-di-kalsel-akibatkan-kerugian-mencapai-rp1349-triliun-f9Aa

26 *Banjir Kalsel, Walhi Ingatkan soal Kerusakan Lingkungan*. (16 Januari 2017). CNN Indonesia. https://www.cnnindonesia.com/nasional/20210116102955-20-594505/banjir-kalsel-walhi-ingatkan-soal-kerusakan-lingkungan

27 Hardiyanto, S. (15 Januari 2021). *Banjir Kalsel, Meluasnya Lahan Sawit, dan Masifnya Pertambangan*. kompas.com. https://www.kompas.com/tren/read/2021/01/15/083100265/banjir-kalsel-meluasnya-lahan-sawit-dan-masifnya-pertambangan?page=all

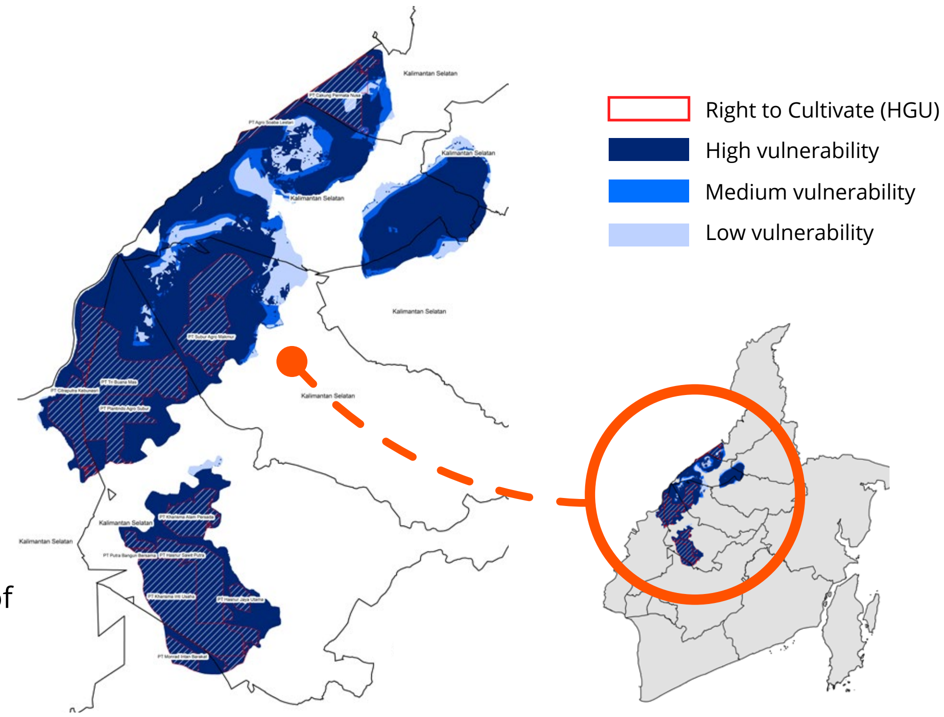
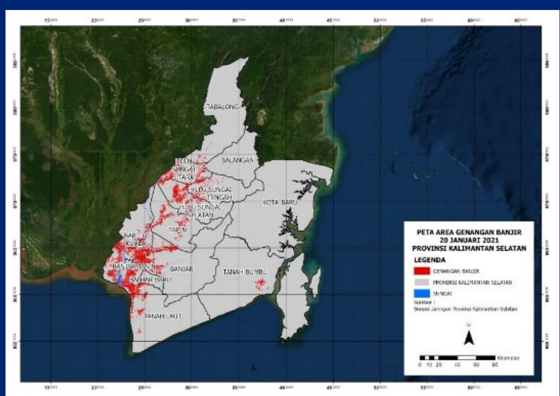


Figure 5 Distribution of Flood Vulnerability in South Kalimantan

Meanwhile, a study by Filsa Bioreista (2021) reported that the January 20, 2021, flood in South Kalimantan inundated an area of 226,905 hectares.[28] The most severely affected regions were in the western part of the province, including Banjarmasin City, Barito Kuala Regency, Tapin, Banjar, Banjar Baru, and the Hulu Sungai Tengah, Utara, and Selatan regions. Satellite imagery analysis revealed that these areas experienced significant water outpouring.

Gambar 6 Flood Stagnation Map of January 20, 2021, Overlaid with River Patterns
(Source: Filsa Bioreista)



Further analysis shows that most of the flooded areas are within the Peat Hydrological Units (PHU) of the Barito-Alalak River, Barito-Taping River, and Utar-Serapat River. Peatland degradation in these three areas is caused by the expansion of oil palm plantations. Corporate groups such as Genting, Jardine, and Amara (figure 5) which are involved in these activities, have increased flood vulnerability. Peat depth in this region varies between 50 and 700 cm, but in general, land degradation has reduced the peat's ability to absorb water, worsening flood problems.'

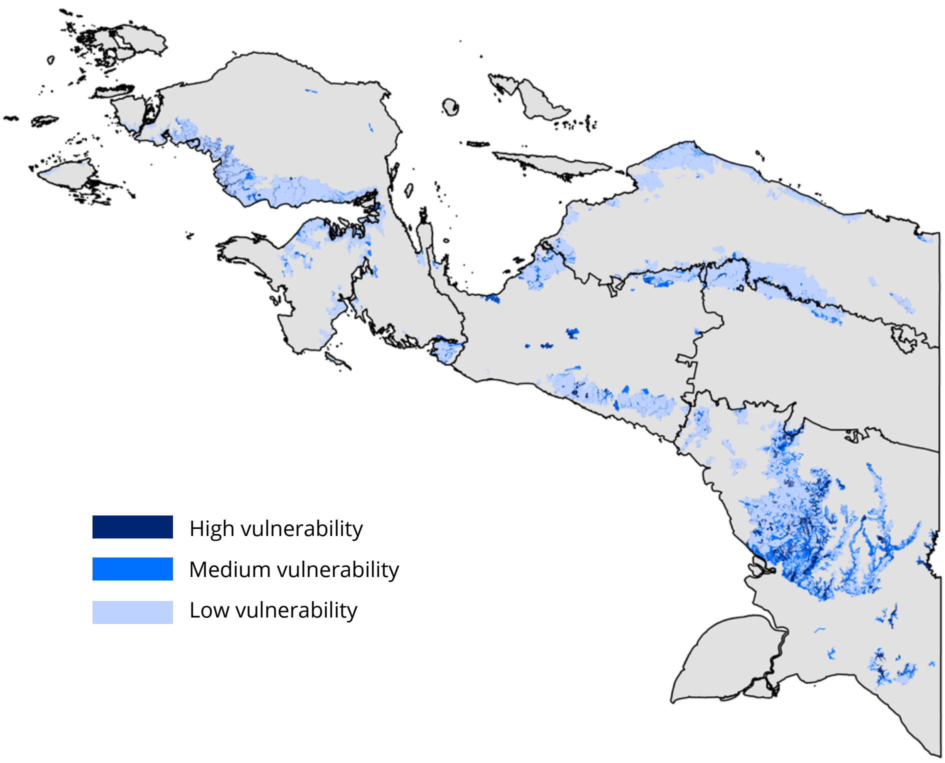
28 Bioresita, F., Ngurawan, M. G. R., & Hayati, N. (2022). *Identifikasi Sebaran Spasial Genangan Banjir Memanfaatkan Citra Sentinel-1 dan Google Earth Engine (Studi Kasus: Banjir Kalimantan Selatan)*. Geoid, 17(1), 108. https://doi.org/10.12962/j24423998.v17i1.10383

3.5. Flood Vulnerability in Kalimantan Region Papua

Papua is known as one of the wettest regions in the world, with annual rainfall averaging between 2,500–4,500 mm. In some areas, such as Tembagapura, it can even exceed 7,000 mm per year.[29] This heavy rainfall is concentrated along the northern and southern slopes of Papua's main mountain range, including the Baliem Valley and Timika.

Generally, the northwest monsoon (January–April) brings the wettest season, while the southeast monsoon (May–August) is the driest. However, this pattern does not apply uniformly across Papua. In the southern part of the region, for example, rainfall is actually higher during the southeast monsoon due to the influence of southeast trade winds carrying moisture from the Pacific Ocean.[30] These variations are influenced by factors such as topography, mountain presence, and regional air pressure systems.

Figure 7 Distribution of Flood Vulnerability in Papua Region



The high rainfall in Papua increases the risk of natural disasters such as erosion and flooding. Flood vulnerability analysis in Papua's KHG areas indicates that approximately 5.3 million hectares of land have a low vulnerability level. However, South Papua, Central Papua, and West Papua contain more vulnerable areas, with around 303,000 hectares classified as highly vulnerable and 709,000 hectares as moderately vulnerable. These figures highlight that these regions are particularly susceptible to flooding, especially during extreme rainfall events.

This high vulnerability is influenced by various factors, including the diverse characteristics of peatlands, which range from mountainous, inland, to coastal areas. Mountain peatlands

29 Prentice, Michael L. and Geoffrey Hope. (2007). *Climate of Papua*.
30 Ibid

are found in the central and highland regions of Papua, while inland peatlands dominate the southern areas. In the western part, coastal peatlands are commonly found in West Papua and Southwest Papua. This diversity reflects the island's complex geographical and climatic conditions.

Flood Vulnerability Area in the Papua Region

!!! **303 thousand Ha** high vulnerability

!! **709 thousand Ha** medium vulnerability

! **5.3 milion Ha** low vulnerability

Table 5 Provinces with Flood Vulnerability Distribution in the Papua Region

No	Province	High Vulnerability Area (Ha)	Percentage of Flood-Vulnerable PHU Areas (%)
1	South Papua	230,560.03	8.82
2	Central Papua	37,866.36	4.46
3	West Papua + Southwest Papua	27,141.35	1.89
4	Highland Papua	5,215.69	1.34
5	Papua	2,845.56	0.25

> Coastal peatland degradation has resulted in significant land subsidence and increased the risk of tidal flooding.

Case Study

Flood Documentation in Peatland Ecosystems

Pulang Pisau Regency, Central Kalimantan
March 2024
(*Source: Trans Hapakat*)

Dumai, Riau
October 2024
(*Source: Riau Pos*)

Meranti Islands Regency, Riau
January 2023
(*Source: Cakaplah*)

Kapuas Regency, Central Kalimantan
January 2025
(*Source: Tribun Kalteng*)

Tapin Regency, South Kalimantan
January 2025
(*Source: Bakabar*)

Kabupaten Kubu Raya, Kalimantan Barat
Januari 2025
(*Sumber: Suara Kalbar*)

4. CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

Peatland ecosystem degradation is often measured solely based on forest and land fires, highlighting policymakers' limited understanding of the complexity of peat ecosystems. Indonesia's Enhanced NDC document (2022), for example, assesses greenhouse gas emissions from the peat sector only in terms of fire incidents, without considering other factors such as ecosystem degradation due to canalization, land conversion, and land subsidence.

This study reveals that 25% of Peat Hydrological Unit (KHG) areas in Indonesia fall into the high flood vulnerability category, 18% are classified as moderately vulnerable, and 57% have low vulnerability. Regionally, Kalimantan ranks highest in flood vulnerability, followed by Sumatra and Papua.

The findings confirm that peatland ecosystem degradation directly correlates with flood vulnerability, as observed in Riau and South Kalimantan. Peatland conversion leads to the loss of its natural capacity to absorb and regulate water, increasing the risk of hydrometeorological disasters, including flooding.

Therefore, it is crucial for stakeholders to reassess policies related to peatland ecosystem protection and management at both national and international levels.

4.2. Recommendations

4.2.1. Policy Recommendations and Commitments

A. Recommendations for Global Commitments

1. **A more comprehensive understanding of peatland ecosystems** is essential in shaping global environmental policies for:
    - State actors involved as both producers and consumers of products linked to peatland ecosystems. This also includes regional actors such as the European Union, which recently enacted the EU Deforestation Regulation (EUDR).
    - Corporate actors, including multinational corporations, corporate associations, and global certification bodies such as the Forest Stewardship Council (FSC), Roundtable on Sustainable Palm Oil (RSPO), and The Consumer Goods Forum (CGF), among others.
    - Global financial institutions, particularly those that claim to adhere to green standards.

2. **The definition of "deforestation" needs to be more comprehensive and inclusive of complex hydrological ecosystems**, such as peatlands. For instance, the EU Deforestation Regulation (EUDR) adopts the FAO's definition of deforestation, which primarily focuses on Tree Canopy Cover and technical criteria for forest function changes.[31] However, it overlooks the intricate hydrological systems that must also be considered.

B. Recommendations for National Commitments

3. **Ensure the integration of peatland protection policies into strategic development planning,** such as the National Medium-Term Development Plan (Rencana Pembangunan Jangka Menengah Nasional/RPJMN). Embedding peatland protection policies within RPJMN will facilitate cross-sectoral coordination and ensure implementation through more technical regulations.

4. **Incorporate technical variables related to flood indicators in assessing peatland ecosystem degradation** as part of the revision of Government Regulation No. 57 of 2016 *jo.* PP No. 71 of 2014 on Peatland Ecosystem Protection and Management. The regulation's preamble currently focuses on the large-scale forest and land fires of 2015–2016, leading to a regulatory framework primarily centered on fire prevention and mitigation. However, this study highlights that peatland degradation not only causes fires but also significantly contributes to flooding.

5. **Ensure the standard for groundwater table levels (Tinggi Muka Air Tanah/TMAT) remains consistent with the requirement to keep peatlands saturated,** regardless of ongoing discussions or proposed changes to adjust the standard threshold beyond 40 cm.

6. **Expanding legal accountability for peatland damage.** Currently, corporate liability for peatland ecosystem damage is mostly limited to fire-related cases. Regulations should be expanded to include other impacts, such as flooding caused by peatland drainage.

7. **Incorporating peatland hydrological governance indicators into regulations for the financial services sector.** The development of Indonesia's Sustainable Finance Taxonomy (Taksonomi Keuangan Berkelanjutan Indonesia/TKBI) Version 2 by the Financial Services Authority (Otoritas Jasa Keuangan/OJK) currently lacks sufficient consideration of peatland hydrological governance indicators.

C. Integration of Disaster Policy with Peatland Ecosystem Mitigation

8. **Disaster regulations must recognize peatland ecosystem degradation as a key factor** in increasing hydrometeorological disaster risks.

9. **Hazard maps should be updated to include risk level indicators** resulting from peatland degradation, covering both fire and flood hazards.

31 FAO. (2018). *Terms and definitions – FRA 2020*. Forest Resources Assessment Working Paper 188. Rome. https://www.fao.org/3/I8661EN/i8661en.pdf

4.2.2. Nomenclature and Institutional Recommendations

10. **The Importance of a Dedicated Institution for Peatland Ecosystems.** Currently, authority over peatland ecosystems is fragmented across numerous institutions, tending to be partial. The lesson from the change of the Peatland Restoration Agency (BRG) to the Peatland and Mangrove Restoration Agency (BRGM) through Presidential Regulation 120/2020 demonstrates a weakening of authority in handling peatland ecosystems in concession areas. This change ultimately eliminated the supervisory authority clause over concessions.

11. **A cross-sectoral institution or authority is necessary.** Since peatland ecosystems are not confined to administrative boundaries (district, province, or concession vs. non-concession), their management must be based on Peatland Hydrological Units (PHU). A more comprehensive institutional framework would reduce policy fragmentation and enhance the effectiveness of peatland restoration and protection.

To prevent further degradation of peatland ecosystems, a hydrological ecosystem-based approach must serve as the primary reference in policy formulation. Peatland management should not solely focus on wildfire mitigation but must also consider its impact on the hydrological cycle and the increasing risk of flooding. Additionally, there is a need for stronger regulations and institutional frameworks that can comprehensively address peatland ecosystem issues.

Without these efforts, not only will endemic flora and fauna be at risk, but human livelihoods will also be directly affected by flooding caused by peatland degradation. When a peatland ecosystem is damaged, the burden falls on everyone.The very ecosystem that was meant to stay wet will instead drown, unable to withstand the relentless destruction any longer.

GLOSSARY

AFOLU
(Agriculture, Forest, and Other Land Uses)
A category used by the IPCC for the calculation, inventory, and mitigation of greenhouse gas emissions, encompassing economic sectors and human activities related to land use, such as agriculture and forestry.

AHP
(Analytical Hierarchy Process)
A decision analysis method used to solve complex problems by structuring criteria and alternatives into a hierarchy and then evaluating their weights and priorities.

CHIRPS
(Climate Hazards Group InfraRed Precipitation with Station data)
A global rainfall dataset that integrates satellite data with ground station observations to monitor and analyze precipitation patterns.

Consistency Ratio
A ratio used in AHP to measure the consistency of judgments within a pairwise comparison matrix. A lower ratio indicates a higher level of consistency.

DEMNAS
(Digital Elevation Model Nasional)
A digital elevation model covering the entire territory of Indonesia, used for topographic analysis and mapping.

ENDC
(Enhanced Nationally Determined Contribution)
An enhanced commitment by a country to reduce greenhouse gas emissions and adapt to climate change in accordance with the Paris Agreement.

EUDR
(European Union Deforestation Regulation)
European Union regulations aimed at reducing deforestation and forest degradation by regulating trade in commodities linked to deforestation.

Expert Adjustment
Adjustments made by experts to data or models to improve accuracy or relevance based on knowledge and experience.

GIS
(Geographic Information System)
A system used to collect, store, analyze, and visualize geographic and spatial data.

Seawater Intrusion
The process of seawater infiltrating freshwater layers on land, typically occurring in coastal areas. It is usually caused by excessive groundwater extraction or rising sea levels.

IOD

(Indian Ocean Dipole)

A climate phenomenon in the Indian Ocean characterized by differences in sea surface temperatures between the western and eastern parts of the ocean, influencing regional weather patterns.

Irreversible Drying

A condition in which peatlands that have been excessively drained lose their moisture and ability to retain water permanently, leading to ecosystem degradation that cannot be restored.

PHU

(Peatland Hydrological Unit)

A management unit or designated area governed as a single hydrological entity within the peatland ecosystem, regulated and established by the government.

MCE

(Multi-Criteria Evaluation)

An analytical method used to assess and compare various alternatives or options based on multiple relevant criteria. This method is commonly applied in complex decision-making processes where several factors need to be considered simultaneously.

Leaching

The process of nutrient or chemical loss from the soil due to water movement, which can lead to decreased soil fertility or groundwater contamination.

Subsidence

The gradual sinking of the ground surface, often caused by groundwater extraction, mining, or natural compaction. In peatlands, subsidence is typically driven by land drainage or fire.

TKBI

*(Taksonomi Keuangan Berkelanjutan Indonesia/*Indonesian Sustainable Finance Taxonomy*)*

A classification framework used to identify and categorize sustainable economic activities in Indonesia, supporting green financing initiatives.

TMAT

*(Tinggi Muka Air Tanah/*Groundwater Table Level*)*

An indicator of peatland dryness, measured from the peat surface to the groundwater level.

pantau gambut