SAINS TANAH – Journal of Soil Science and Agroclimatology

Journal homepage: http://jurnal.uns.ac.id/tanah

# Identification and characterization of peat soils using a physiographic approach at semi-detailed scale: a case study in Bangka Belitung Islands Province, Indonesia

**Sukarman[1]*, Yiyi Sulaeman[1], Edi Yatno[1], Rachmat Abdul Gani[1], Budiman Minasny[2]**

[1] Research Organization for Agriculture and Food, National Research and Innovation Agency, Indonesia
[2] Sydney Institute of Agriculture & School of Life and Environmental Sciences, The University of Sydney, Sydney, Australia

**ARTICLE INFO**

**Keywords**:
Bangka Belitung
Carbon stocks
Peat soils
Soil characteristics

Article history
*Submitted: 2024-06-04*
*Revised: 2024-09-19*
*Accepted: 2024-09-27*
*Available online: 2024-12-22*
*Published regularly: December 2024*

* *Corresponding Author*
*Email address:*
*suka022@brin.go.id*

**ABSTRACT**

Understanding peatland coverage and characteristics is essential for improved utilization and conservation efforts. Peatlands in Bangka Belitung Islands, Sumatra, are under threat of illegal mining activities. Creating detailed maps is challenging in Indonesia amid low accessibility, yet the physiographic approach provides an alternative strategy in peatland map provision. This research aims to update peat data in the Bangka Belitung Islands Province, create peat soil maps at a scale of 1:50,000, and estimate peat soil carbon stocks. This research started with a base map using a 1:50,000 scale, surveyed and sampled the soil on transects perpendicular to the river, analyzed the samples in the laboratory, and created a peat soil map. Compared with the existing map, the new map improves land unit attributes and peat characteristics as well as improves delineation results. Results show that peat soils cover 24,311 hectares, mostly distributed in Central Bangka and South Bangka Regencies, with depths varying between 50 to < 300 cm. Shallow peats dominate with an area of 13,668 hectares (56.22%). The estimated carbon stock contained in peat is 11.6 million tons C. The peat soils are Organosol Saprik, Organosol Hemik, and Organosol Sulfidik. The soils are acidic with low exchangeable cations and base saturation. The study highlights that deep peat soils under bushes and shrubs should be conserved for forests or reforested. Detailed spatial information on peatlands is useful for policymakers related to local peat soils planning and management.

**How to Cite**: Sukarman, Sulaeman, Y., Yatno, E., Gani, R.A., Minasny, B. (2024). Identification and characterization of peat soils using a physiographic approach at semi-detailed scale: a case study in Bangka Belitung Islands Province, Indonesia. Sains Tanah Journal of Soil Science and Agroclimatology, 21(2): 191-202. https://doi.org/10.20961/stjssa.v21i2.87573

## 1. INTRODUCTION

Peat soils develop through the deposition of organic matter, from the accumulation of decaying plant debris or vegetation in low-lying areas. Under anaerobic conditions, the decomposition of organic matter occurs slowly, leading to the build-up of thick organic layers that can eventually form a peat dome (Page & Baird, 2016). Indonesian peatland covers a total area of 13.43 million ha (Anda et al., 2021; Nurzakiah et al., 2020), distributed on four main islands (in million ha): Sumatera (5.85), Kalimantan (4.54), Papua (3.01) and Sulawesi (0.024).

Bangka Belitung Islands Province, which is part of Sumatra Island, does not yet have detailed data regarding its peatland. Bangka Belitung is one of the provinces in Indonesia that has complex ecological issues. Environmental damage occurs due to uncontrolled tin mining which starts spreading to peatlands (Haryadi et al., 2021). The distribution of peatland in several Regencies, notably Central Bangka and South Bangka, has been documented (Heryanto et al., 2021). Additionally, the significant environmental impact of peat-related issues requires attention, especially in this province where the longstanding problem of former tin mining land has been recognized as environmentally detrimental regency (Sukarman et al., 2020). One of the functions of peatlands is as a hydrological function and as a carbon source that controls $CO_2$ circulation and has a major influence on the carbon balance in earth's atmosphere (Minasny et al., 2024). Therefore, it is very important to know the size of subsurface carbon reserves on peat land (Septian et al., 2023).

In addition to storing C as plant biomass, peat soil stores a much larger amount of C below the ground (Pratama et al., 2021; Rixen et al., 2022). The risk of potential soil emissions is high if land changes occur. In the period 2000-2013, the area of peat forest cleared and used for mining in Bangka Belitung Islands Province was around 475 ha and produced $CO_2$

STJSSA, p-ISSN 1412-3606 e-ISSN 2356-1424
http://dx.doi.org/10.20961/stjssa.v21i2.87573

emissions of 315,230 t $CO_2$ eq. or 3% of total emissions due to mining expansion (Haryati & Dariah, 2019). Therefore, peatlands in Bangka Belitung Island need to be protected so that they do not produce $CO_2$ emissions which will contribute to environmental disaster.

Based on the description above, data on the area and distribution of peat soil in Bangka and Belitung Islands, which was mapped at a broad scale (1:250,000), needs to be updated by conducting more detailed mapping at a semi-detailed scale (1:50,000). This data can be used to calculate carbon stocks more accurately so that recommendations for utilizing and managing peat soil on Bangka and Belitung Islands will be more thorough, targeted, and sustainable. Delineating peatlands would protect them from mining operations.

Spatial identification and peatland mapping can be done using different approaches and techniques. One technique that is suitable for limited accessibility, such as in Indonesia, is the physiographic approach. The physiographic approach uses the landform framework to identify land units in a given study area. Landform classification follows the study of Ritung et al. (2017). By using this approach, lands having similar environmental factors (topography, soil, vegetation, geology/parent material, geomorphology and climate) are related to each other and will result in the same observed pattern and easy to delineate on using satellite images. This approach based on expert knowledge is easier and quicker than the parametric approach, which requires an extended observations and is costly. This study is important because of the method used the physiographic approach is faster and cheaper and produces more detailed data

By using the physiographic approach, this research aimed to update peat soil data by identifying and characterizing peat soil at a scale of 1:50,000 in the Bangka Belitung Islands Province, update the peat soil distribution map at a scale of 1:50,000 in the Bangka Belitung Islands Province, and estimating reserves peat soil carbon in Bangka Belitung Islands Province.

## 2. MATERIAL AND METHODS

### 2.1. Description of the Study Site

This study was conducted in Bangka Belitung Islands Province, Indonesia (Fig. 1). The peatland was mapped at a scale of 1:250,000 scale by Ritung et al. (2011), who indicatively found peat soils in the regency of West Bangka, Bangka, Central Bangka, South Bangka, Pangkal Pinang City, and East Belitung Regency.

### 2.2. Study framework

This study used four main stages, namely: (1) creation of peat soil units, (2) preparation of a provisional peat soil map, (3) field research and soil analysis, (4) finalization of the peat soil map (Fig. 2).

#### 2.2.1. Land Units Compilation

Land unit delineation is done by overlaying the digital elevation models (DEM) with geological maps with the help of satellite imagery and earthquake maps visually on the monitor screen (on-screen) using ArcGIS programs. The delineation of land units on satellite images is based on the appearance of patterns, tones, and colors, following the guidelines put forward by Mulder (1988). For areas that cannot be analyzed on satellite imagery (due to cloud cover), the delineation of land units was assisted using digital elevation, geological maps, and topographic maps. Analysis of land units and naming of landform units, parent material, and relief/slope followed the Landform Classification Guidelines for Land Mapping in Indonesia (Ritung et al., 2017). The results of land unit delineation are depicted on a base map that has been adjusted for coordinates. Furthermore, the land unit analysis map is used as the basis for the field operational plan. The flowchart of the 1:50,000 scale peat soil mapping method is presented in Fig. 2.

The data used includes: (1) the Indonesian Peatland Map, scale 1:250,000 (Ritung et al., 2011), (2) the Geological Map of North Bangka Sheet, scale 1:250,000 (Mangga & Djamal, 1994), (3) the Geological Map of South Bangka Sheet, scale 1:250,000 (Margono et al., 1995), (4) the Geological Map of Belitung Sheet, scale 1:250,000 (Baharuddin & Sidarto, 1995), (5) the Indonesian Topographic Map scale 1:50,000, (7) Landsat-7, SPOT-5, and SPOT-6 images, and (8) SRTM DEM 30 m resolution.

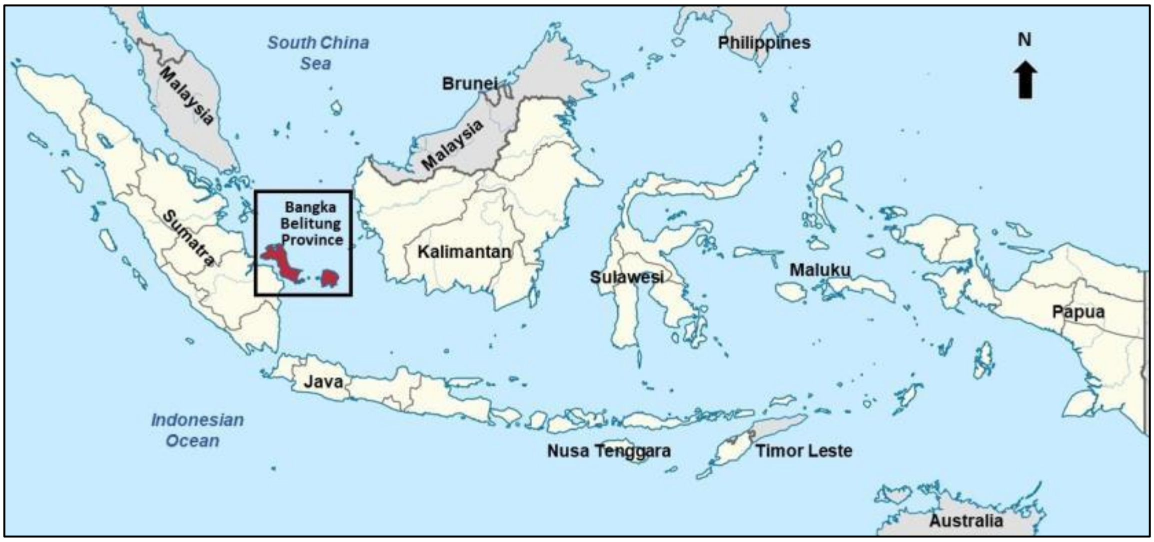



**Figure 1**: Location map of the study area

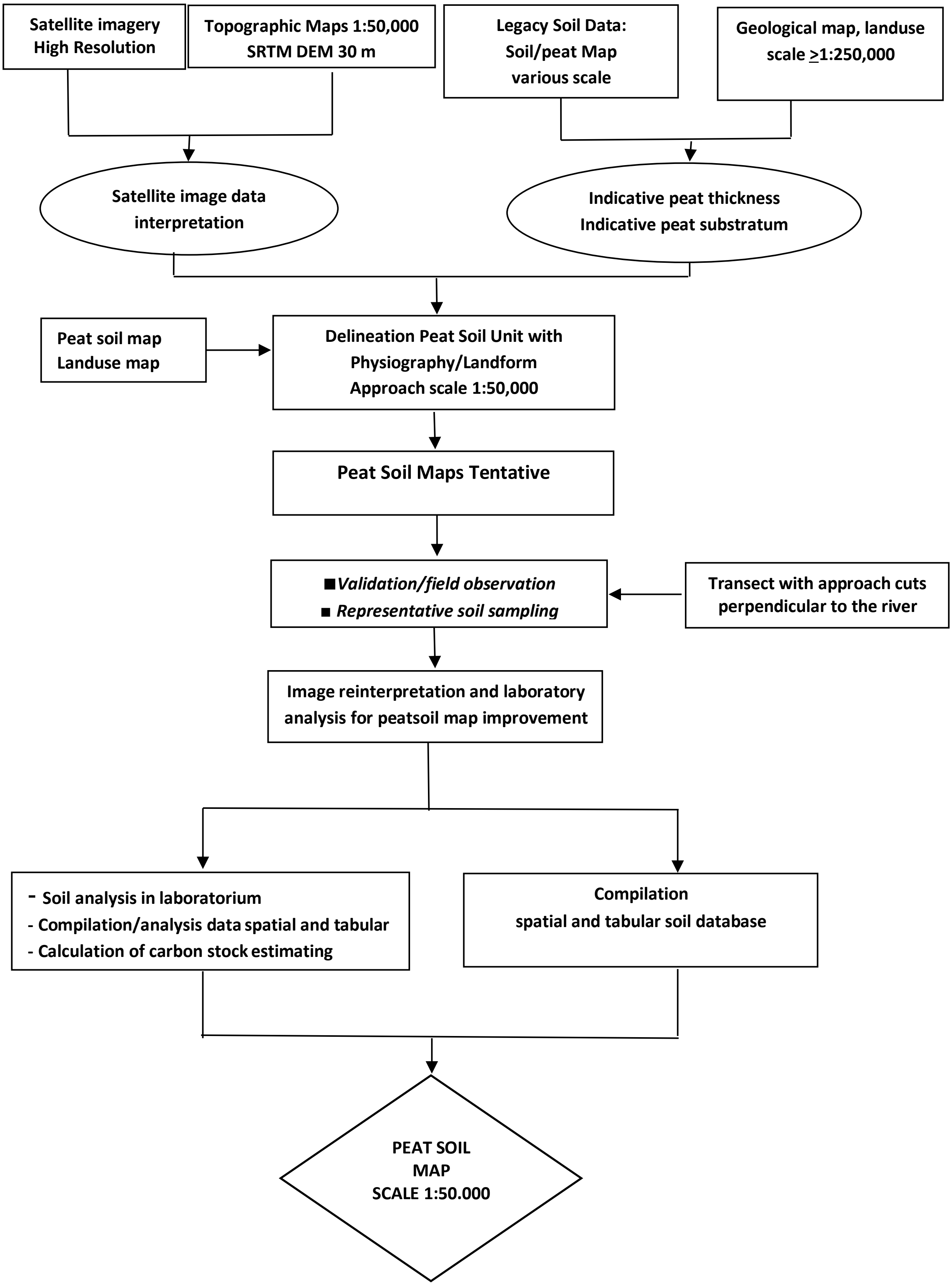



**Figure 2.** Flowchart of 1:50,000 scale peat soil mapping in Bangka Belitung Islands Province (Source: BSN, 2019)

### 2.2.2. Preparation of a provisional peat soil map

The result of the land unit analysis and the 1:250,000 scale peat map formed the provisional peat soil map. This map was used as a basis for checking and taking samples in the field. In addition to checking the accuracy of the results of the analysis with the actual situation in the field, it is also intended to find the relationship between the distribution of peat soil and the attributes of the land unit. Measurements of peat characteristics and observations of other attributes were carried out on each unit of the provisional soil map (Sukarman et al., 2017).

#### 2.2.3. Field research and soil analysis

Field research was conducted in transects perpendicular to the river to determine changes in peat soil properties (thickness, maturity, substratum, etc.). The transect observations were used to estimate the pattern of soil distribution in the field by considering the soil-landscape relationship. The procedure for observing the morphological properties of peat soil follows the Guidelines for Soil Observation in the Field (Sukarman et al., 2017), and the Technical Guidelines for Soil Survey and Mapping at Semidetail Scale 1:50,000 (Wahyunto, Hikmatullah, Suryani, Tafakresnanto, Ritung, Mulyani, Sukarman, Nugroho, Sulaeman, Suparto, et al., 2016) and SNI 8473:2018 (BSN, 2018). Soil samples were taken using an "Eijkelkamp" model peat auger. Sample points represent temporary map units. The number of points observed was approximately 120 points.

Parameters observed were morphological properties of the peat soil, namely thickness, maturity level, sulfidic material, depth to groundwater, presence or absence of mineral soil inserts, soil/water pH, tidal influence, and mineral soil layer substratum). Soil samples from each peat layer and substratum were taken to analyze soil physical and chemical properties in the laboratory. Soil sample analysis procedures followed the Technical Guidelines for Soil, Water, Plant, and Fertilizer Analysis (Eviati & Sulaeman, 2012). Soil properties analyzed included organic C and N content, pH, total and available $P_2O_5$ and $K_2O$, bases (Ca, Mg, K, Na), cation exchange capacity, base saturation, salinity, sulfidic material, electrical conductivity, bulk density (BD), ash content, and fiber content. Carbon stocks are calculated with Equation 1.

$$C_{stock} = \sum(A_i \times h_i \times BD \times C_{org}) \quad \text{[1]}$$

Where: $A_i$ = peatland area for a depth class, $h_i$ = average peat thickness in each thickness, BD = Bulk density for each peat layer thickness, $C_{org}$ = organic C content (Agus et al., 2011).

The soil classification used is the National Soil Classification (Subardja et al., 2016) up to the Soil Type level with additional properties: thickness, maturity, pH, and texture of mineral soil substratum. The international soil classification system is used for comparison, namely the Soil Taxonomy classification system (Soil Survey Staff, 2022) up to the subgroup level and the World Reference Base or WRB system (FAO, 2014). The WRB system is an international soil classification used to name soils and create World Soil Map legends.

#### 2.2.4. Finalizing the peat soil map

The provisional peat soil map is revised based on field observations and laboratory analysis data. Improvements include improving the attributes of land units and peat characteristics as well as improving the delineation results. The provisional peat soil map that has been improved with field data and laboratory results is the map that best matches the actual situation in the field.

Based on the laboratory soil analysis results, field soil classification was also improved at this stage. Soil classification was carried out based on the National Soil Classification for category type (Subardja et al., 2016) and Soil Taxonomy (Soil Survey Staff, 2022) for subgroup category, on each representative profile, as well as on each auger soil data.

#### 2.2.5. Land use recommendations

The results of peatland characterization are then assessed for land suitability based on the Land Suitability Assessment Guidelines for Strategic Commodities at Semi-Detailed Level 1:50,000 Scale and followed by recommendations for its use for agriculture, taking into account current land use conditions (Wahyunto, Hikmatullah, Suryani, Tafakresnanto, Ritung, Mulyani, Sukarman, Nugroho, Sulaeman, Apriyana, et al., 2016).

## 3. RESULTS

### 3.1. Classification of peat soil

The results of the identification and characterization of peat soil in Bangka Belitung Islands Province found that according to the national soil classification (Subardja et al., 2016), there are 3 soil types, namely: Organosol Hemik, Organosol Saprik, and Organosol Sulfidik. Based on the Soil Taxonomy Classification (Soil Survey Staff, 2022) these are equivalent to 3 subgroups, namely: Typic Haplohemists, Typic Haplosaprists, and Terric Sulfihemists. Based on the WRB classification system (FAO, 2014), they are Dystric Hemic Histosols, Dystric Sapric Histosols, and Hemic Thionic Histosols (Table 1).

Based on the level of decomposition or maturity, peat soils in Bangka Belitung Islands Province can be divided into (a) hemic peat (semi-mature) containing fibers between 17-74%; and (b) sapric peat is peat that has been weathered (mature), containing fibers <17% (Table 2). Fabric peat was not found, which is peat that has not been weathered (raw), but, when squeezed, still contains >75% fiber (by volume).

**Table 1.** Classification of peat soil in Bangka Belitung Islands Province

| National Soil Classification (Subardja et al., 2016) Soil Type Level | Soil Taxonomy (Soil Survey Staff, 2022) Sub grup Level | World Reference Base (FAO, 2014) | Area | |
|---|---|---|---|---|
| | | | Ha | % |
| Organosol Hemik | Typic Haplohemists | Dystric Hemic Histosols | 12,900 | 53.06 |
| Organosol Saprik | Typic Haplosaprists | Dystric Sapric Histosols | 10,834 | 44.56 |
| Organosol Sulfidik | Terric Sulfihemists | Hemic Thionic Histosols | 577 | 2.38 |
| Total Peat Soils Area | | | 24,311 | 100.00 |
| Land Area of Bangka Belitung Islands Province | | | 1,642,400 | - |
| Percentage of peatlands to total land area | | | | 1.48 |

**Table 2**. Particle size, pH, organic matter, P contents, fiber content

| Profile/ Horizon | Depth | Particle size | | | Soil Tex-tur | BD | pH | | Organic matter | | | Potential | | Avai-lable | Fiber |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | | | $H_2O$ | KCl | C | N | C/N | $P_2O_5$ | $K_2O$ | $P_2O_5$ | Not crushed |
| | cm | % | | | | g. cm$^{-3}$ | | | % | | | mg.100g$^{-1}$ | | ppm | % |
| KM-1 (2°21'46,03" S; 105°53'31,08" E), Organosol Hemik (Typic Haplohemists) | | | | | | | | | | | | | | | |
| Oa1 | 0-11 | - | - | - | - | 0.11 | 4.3 | 3.6 | 35.71 | 1.19 | 30 | 24 | 27 | 1.4 | 20.47 |
| Oa2 | 11-39 | - | - | - | - | 0.11 | 4.3 | 3.4 | 38.87 | 1.62 | 24 | 22 | 29 | 7.0 | 23.72 |
| Oe1 | 39-70 | - | - | - | - | 0.23 | 4.4 | 3.8 | 30.96 | 0.24 | 33 | 10 | 12 | 4.8 | 25.69 |
| Oe2 | 70-89 | - | - | - | - | 0.23 | 4.5 | 3.7 | 33.28 | 0.97 | 34 | 12 | 12 | 2.9 | 29.71 |
| Cg | 89-120 | 52.7 | 6.3 | 41.0 | SC | - | 4.8 | 4.5 | 1.08 | 0.07 | 15 | 13 | 22 | 8.2 | - |
| KM-2 (2°26'05,3" S; 105°56'52,3" E), Organosol Saprik (Typic Haplosaprists) | | | | | | | | | | | | | | | |
| Oa1 | 0-27 | - | - | - | - | 0.23 | 4.3 | 3.8 | 44.68 | 1.13 | 40 | 14 | 20 | 6.5 | 11.67 |
| Oa1 | 27-50 | - | - | - | - | 0.23 | 4.4 | 4.4 | 41.34 | 0.97 | 43 | 12 | 20 | 5.8 | 12.22 |
| Oa2 | 50-92 | - | - | - | - | 0.25 | 4.3 | 4.3 | 38.19 | 0.87 | 44 | 13 | 2 | 4.8 | 13.76 |
| Oa3 | 92-145 | - | - | - | - | 0.25 | 4.5 | 4.1 | 36.44 | 0.81 | 45 | 14 | 4 | 4.8 | 15.47 |
| Cg | 145-160 | 28.7 | 35.2 | 36.1 | SiC | | 4.5 | 4.1 | 2.02 | 0.09 | 11 | 3 | 3 | 4.6 | - |
| KM-3 (1°46'48,0'S; 105°45'41,6" E), Organosol Sulfidik (Terric Sulfihemists) | | | | | | | | | | | | | | | |
| Oa1 | 0-34 | - | - | - | - | 0.11 | 3.5 | 2.6 | 34.79 | 1.87 | 19 | 17 | 7 | 7.0 | 27.78 |
| Oe1 | 34-58 | - | - | - | - | 0.11 | 3.9 | 3.2 | 34.14 | 0.95 | 36 | 14 | 2 | 9.0 | 26.81 |
| Oe2 | 58-90 | - | - | - | - | 0.11 | 3.6 | 3.3 | 32.43 | 0.75 | 43 | 10 | 7 | 5.8 | 23.43 |
| Cg | 90-115 | 32.8 | 14.5 | 52.7 | C | | 5.0 | 4.3 | 1.04 | 0.10 | 10 | 3 | 1 | 13.0 | - |

**Table 3.** Exchangeable cation, cation exchange capacity, exchangeable Al and Particle size, pH, organic matter, P contents, and ash content.

| Profil/ Horizon | Depth | Exchangeable cations | | | | Sum of Cations | CEC | BS | Al | H | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | Na | | | | | | |
| | cm | cmol$_c$ kg$^{-1}$ | | | | | | % | cmol$_c$ kg$^{-1}$ | | % |
| KM-1 (2°21'46,03" S; 105°53'31,08" E), Organosol Hemik (Typic Haplohemists) | | | | | | | | | | | |
| Oa1 | 0-11 | 11.29 | 3.60 | 0.73 | 0.06 | 15.68 | 87.26 | 18 | 0.97 | 3.96 | 5.95 |
| Oa2 | 11-39 | 7.02 | 3.51 | 0.76 | 0.01 | 79.79 | 79.79 | 14 | 0.77 | 3.73 | 5.66 |
| Oe1 | 39-70 | 5.54 | 2.14 | 0.26 | 0.02 | 7.96 | 53.14 | 24 | 0.81 | 2.61 | 5.96 |
| Oe2 | 70-89 | 2.84 | 2.25 | 0.04 | 0.00 | 5.49 | 59.43 | 9 | 0.71 | 4.86 | 6.32 |
| Cg | 89-120 | 0.44 | 0.08 | 0.41 | 0.00 | 0.93 | 4.26 | 22 | 8.19 | 0.79 | - |
| KM-2 (2°26'05,3" S; 105°56'52,3" E), Organosol Saprik (Typic Haplosaprists) | | | | | | | | | | | |
| Oa1 | 0-27 | 7.63 | 3.62 | 0.72 | 0.00 | 11.97 | 97.87 | 12 | 1.63 | 6.63 | 5.55 |
| Oa1 | 27-50 | 2.84 | 2.25 | 0.40 | 0.00 | 5.49 | 59.43 | 9 | 0.71 | 4.86 | 5.32 |
| Oa2 | 50-92 | 3.81 | 2.23 | 0.22 | 0.01 | 6.27 | 63.86 | 10 | 0.58 | 4.16 | 5.80 |
| Oa3 | 92-145 | 7.85 | 2.95 | 0.13 | 0.07 | 11.0 | 85.85 | 13 | 0.61 | 4.36 | 6.79 |
| Cg | 145-160 | 0.82 | 0.22 | 0.01 | 0.02 | 1.07 | 12.37 | 9 | 5.00 | 0.80 | - |
| KM-3 (1°46'48,0'S; 105°45'41,6" E), Organosol Sulfidik (Terric Sulfihemists) | | | | | | | | | | | |
| Oa1 | 0-34 | 2.05 | 1.25 | 0.40 | 0.01 | 3.71 | 61.51 | 6 | 0.41 | 4.84 | 7.37 |
| Oe1 | 34-58 | 2.56 | 2.24 | 0.33 | 0.01 | 3.30 | 60.46 | 6 | 0.40 | 4.04 | 5.48 |
| Oe2 | 58-90 | 5.83 | 2.75 | 0.23 | 0.07 | 8.88 | 65.54 | 9 | 0.53 | 3.63 | 5.17 |
| Cg | 90-115 | 0.55 | 0.19 | 0.11 | 0.01 | 0.87 | 9.83 | 9 | 7.51 | 0.60 | - |

Note: CEC= cation exchange capacity; BS= base saturation

### 3.2. Physical and chemical properties

Some soil physical and chemical properties representative of peat soil in Bangka Belitung are presented in Table 2 and Table 3. The soil's physical and chemical properties represent (1) Typic Haplohemists or Organosol Hemik, (2) Typic Haplosaprists or Organosol Saprik, and (3) Terric Sulfihemists or Organosol Sulfidik.

The Bulk Density (BD) of peat soil with hemic decomposition (Typic Haplohemists) varied from 0.11-0.23 g cm$^{-3}$, for peat with sapric decomposition (Typic Haplosaprists) it varied from 0.23-0.25 g cm$^{-3}$ and for sulfidic peat (Terric Sulfihemists) it was 0.11 g cm$^{-3}$. The extremely low mass of peat results in its poor bearing capacity, which complicates mechanical tillage. The substratum for Typic Haplohemists peat soil has a texture of sandy clay (SC), the substratum for Typic Haplosaprists soils has a texture of silty clay (SiC), the substratum for Terric Sulfihemists soils has a texture of clay (C).

Based on Table 2, the level of decomposition or maturity of Typic Haplohemist and Terric Sulfihemist peat soil had undecomposed material or fiber, varying from 20.47-29.71%, thus the level of decomposition was considered as hemic or half mature. Typic Haplosaprit had unweathered material or fiber varying from 11.67-15.47%, thus the decomposition level was sapric and considered as mature peat. Soil reaction for Typic Haplohemist was very acid to acid (pH 4.3-4.5) with acid sub stratum (pH 4.8). Typic Haplosaprist was very acid to acid (pH 4.3-4.5), with acid substratum (pH 4.5). While Terric Sulfihemists was very acidic (pH 3.5-3.9), with acid substratum (pH 5.0).

The potential P content of Typic Haplohemist was low to medium (12-29 mg $100g^{-1}$). Typic Haplosaprist was very low to low (2-20 mg $100g^{-1}$), and Terric Sulfihemist was very low (2-7 mg $100g^{-1}$). The cation exchange capacity (CEC) for all soil samples was relatively high (>40 cmolc $kg^{-1}$), but the bases and base saturation (BS) were very low (<20%) (Table 3). The very high CEC and low BS with low pH mean that fertilizer applied to the soil would be relatively difficult for plants to take up. The peats have very high CEC values with low base cations because peats are dominated by hydrogen ions ($H^+$). The CEC value of peat soil is also strongly influenced by the pH of the extracting solution ($NH_4$-acetate) because peat is a variable charge, so measurements with a solution pH of 7 give a bias higher value (Noor et al., 2016).

### 3.3. Distribution and extent

The results of the mapping of peat soil in Bangka Belitung Islands Province, scale 1:50,000 (Fig. 3), found that peat soils in 5 (five) regencies, namely West Bangka, Bangka, Central Bangka, South Bangka, and East Belitung. Peat soils were not found in Pangkal Pinang City and Belitung Regency. The total area of peat soil on these two islands is 24,311 ha. This was almost half of the area estimated from the 2011 data, 42,568 ha, which was mapped based on a broad scale (1:250,000) (Ritung et al., 2011). This difference of 18,257 ha could be due to differences in the scale of the maps and the possibility that peat soil had been lost due to decomposition, erosion, and tin mining processes. However, in terms of accuracy and precision, the data produced through semi-detailed mapping (1:50,000) is higher than the results of observational soil mapping (1:250,000). Peat depth is the only parameter used in the (1:250,000) scale soil map legend. Meanwhile, in soil mapping at a scale of (1: 50,000), the parameters used in the soil map legend are peat depth, drainage class, decomposition, soil reaction, cation exchange capacity, and base saturation. So that the information obtained is more complete.

The mineral soils below the peat (substratum) are sandy clay, silty clay, and pyrite clay (Table 4). Most of these soils contain pyrite, which is indicated by a bubbling reaction and a decrease in soil pH to less than 2.5 after being treated with 30% $H_2O_2$ solution. The substratum at this location is in accordance with the Geological Map of the North Bangka Sheet (Mangga & Djamal, 1994), Geological Map of South Bangka Sheet (Margono et al., 1995), and Belitung Sheet (Baharuddin & Sidarto, 1995) that this location is classified as Qa (Alluvium), which consists of boulders, pebbles, gravel, sand, clay, and peat.

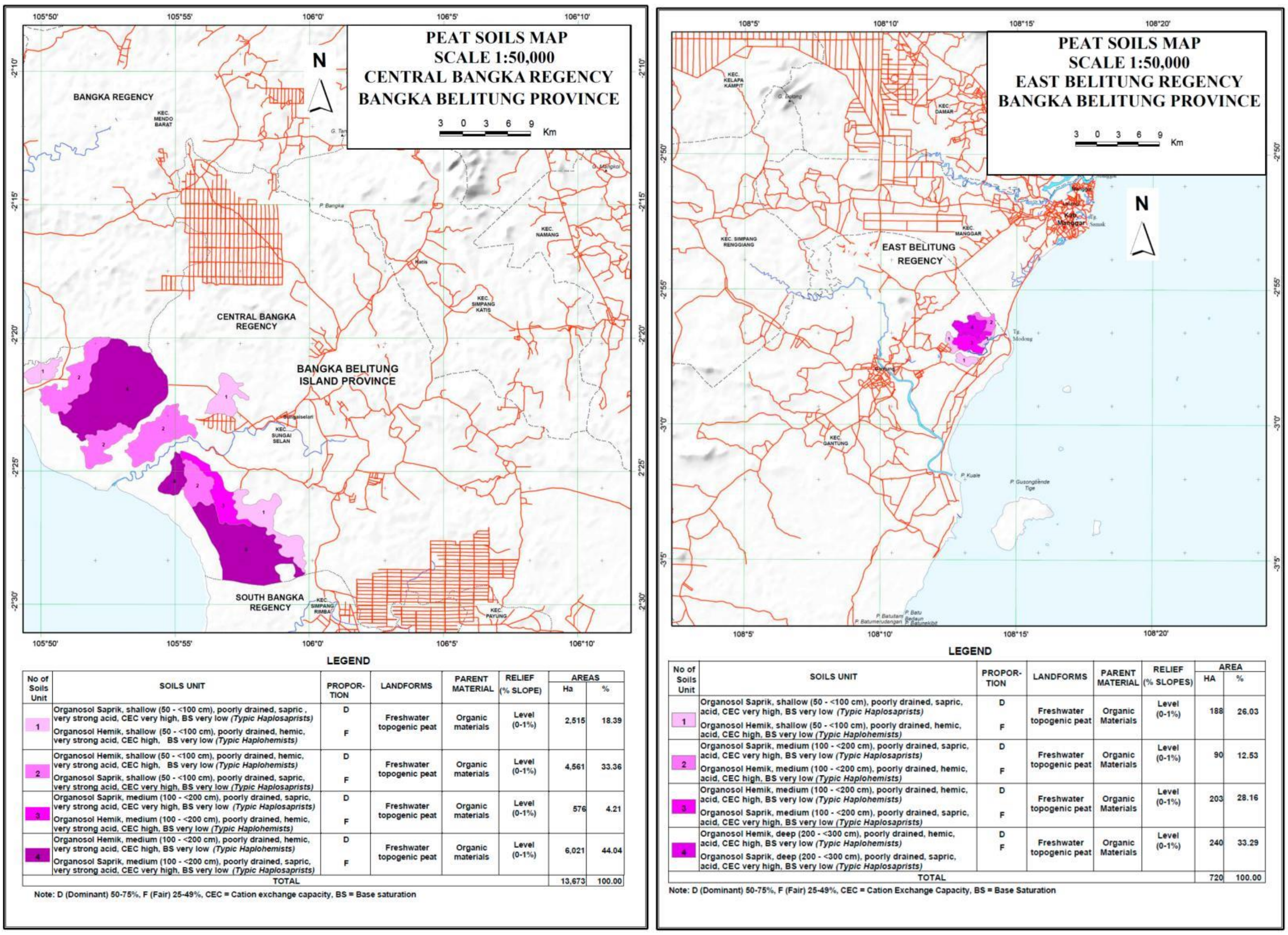



**Figure 3**: Peat soil map at a scale 1:50,000 in Central Bangka and East Belitung Regency.

**Table 4.** Distribution of peat soils based on soil classification in Bangka Belitung Islands Province

| National Soil Classification (Subardja et al., 2016) Soil Type Level | Soil Taxonomy (Soil Survey Staff, 2022) Sub group level | World Reference Base (FAO, 2014) | Sub Stratum | Coverage | |
|---|---|---|---|---|---|
| | | | | Ha | % |
| West Bangka Regency | | | | 3,809 | 15.67 |
| Organosol Hemik | Typic Haplohemists | Dystric Hemic Histosols | Sandy clay deposit | 1,868 | 7.68 |
| Organosol Saprik | Typic Haplosaprists | Dystric Sapric Histosols | Sandy clay deposit | 1,559 | 6.41 |
| Organosol Sulfidik | Terric Sulfihemists | Hemic Thionic Histosols | Pyrite clay deposit | 382 | 1.57 |
| Bangka Regency | | | | 1,079 | 4.44 |
| Organosol Hemik | Typic Haplohemists | Dystric Hemic Histosols | Sandy clay deposit | 583 | 2.40 |
| Organosol Saprik | Typic Haplosaprists | Dystric Sapric Histosols | Silty clay deposit | 302 | 1.24 |
| Organosol Sulfidik | Terric Sulfihemists | Hemic Thionic Histosols | Pyrite clay deposit | 194 | 0.80 |
| Central Bangka Regency | | | | 13,673 | 56.24 |
| Organosol Saprik | Typic Haplosaprists | Dystric Sapric Histosols | Silty clay deposit | 6,087 | 25.04 |
| Organosol Hemik | Typic Haplohemists | Dystric Hemic Histosols | Sandy clay deposit | 7,586 | 31.20 |
| South Bangka Regency | | | | 5,030 | 20.69 |
| Organosol Saprik | Typic Haplosaprists | Dystric Sapric Histosols | Silty clay deposit | 2,542 | 10.46 |
| Organosol Hemik | Typic Haplohemists | Dystric Hemic Histosols | Clay deposit | 2,488 | 10.23 |
| Pangkal Pinang City*) | | | | | |
| - | - | - | - | - | - |
| Belitung Regency*) | | | | | |
| - | - | - | - | - | - |
| East Belitung Regency | | | | 720 | 2.96 |
| Organosol Hemik | *Typic Haplohemists* | Dystric Hemic Histosols | Clay deposit | 377 | 1.41 |
| Organosol Saprik | *Typic Haplosaprists* | Dystric Sapric Histosols | Clay deposit | 343 | 1.55 |
| Total Peat Soils Area | | | | 24,311 | 100.00 |

**Notes**: *) There was no peat soil/Organosols found in Pangkalpinang City and Belitung Regency

**Table 5.** Coverage of peat soil areas based on peat thickness class for each Regency in Bangka Belitung Islands Province.

| No | Regency | Peat thickness class* | | | Total | |
|---|---|---|---|---|---|---|
| | | D1 | D2 | D3 | Hectares | % |
| 1 | West Bangka | 3,809 | - | - | 3,809 | 15.67 |
| 2 | Bangka | 550 | 529 | - | 1,079 | 4.44 |
| 3 | Central Bangka | 7,076 | 6,597 | - | 13,673 | 56.24 |
| 4 | South Bangka | 2,045 | 2,985 | - | 5,030 | 20.69 |
| 5 | East Belitung | 188 | 292 | 240 | 720 | 2.96 |
| Total (Ha) | | 13,668 | 10,404 | 240 | 24,311 | 100.00 |
| Percentage | | 56.22 | 43.80 | 0.98 | | |

**Notes**: *: D1 = shallow (50-<100 cm), D2 = medium (100-<200 cm), D3 = deep (200-<300 cm).

Overall, the area of peatland in Bangka Belitung Islands Province is relatively small, only 24,311 hectares. When compared to the total area of peat soil in Indonesia, which reaches 13,430,517 hectares, the area of peat soil in Bangka Belitung Islands Province is only 0.18% of the total area. When compared to the land area of Bangka Belitung Islands Province, it is only 1.48% (Table 1). In terms of distribution, the most extensive peat soil is found in Central Bangka Regency, covering 13,673 ha or 56.24% of the total peat soil area in Bangka Belitung Islands Province, followed by South Bangka Regency, covering 5,030 ha or 20.69% of the total peat soil area on these two islands (Table 4).

**Figure 4.** Cross-sectional view of peat soil at various depths in Central Bangka Regency

Based on Table 5, 13,668 hectares, or about 56.22% of the peat soil area in Bangka Belitung Islands Province, has a shallow depth or D1 class (50-100 cm). Most of the peat classified as shallow is found in Central Bangka Regency. The smallest area is peat soil with a deep thickness or D3 (200-<300 cm), which covers only 240 hectares or around 0.98% and is in East Belitung Regency. Medium peat or D2 (100-<200 cm) reached 10,404 hectares or 43.88%, with the widest distribution in Central Bangka and South Bangka Regency. Examples of some peat profiles are presented in Fig. 4.

### 3.4. Bulk Density and Carbon Stock

Peat soil's bulk density (BD) varies from 0.11-0.25 g $cm^{-3}$ (Table 6). This value is within the range of results by Faul et al. (2016), namely between 0.054-0.415 g $cm^{-3}$. Based on calculations using the formula described in Materials and Methods and based on soil map units, it is estimated that the carbon stock on 24,311 hectares of peat soil in Bangka Belitung Islands Province is 11.627 million tons with an average of 478.27 tons per hectare. The largest average carbon stock is found in Central Bangka Regency at 5,860,309 tons, while the lowest carbon stock is found in East Belitung Regency at 704,278 tons. The estimated carbon stock of peat soils in Bangka Belitung Islands Province is presented in Table 6.

## 3. DISCUSSION

The results of the identification and characterization of peat soil in Bangka Belitung Islands Province produced 3 types of soil or 3 subgroups, namely Hemic Organosol (Typic Haplohemists), Sapric Organosol ypic Hsplosaprists) and Sulfidic Organosol (Terric Sulfihemsts). The results of this peat soil classification are the same as the results of research by the BBSDLP (2019) and Heryanto et al. (2021). In the mapping carried out by the BBSDLP (2019), the soil classification only uses the Indonesian national soil classification (Subardja et al., 2016), there is no equivalent to the Soil Taxonomy (Soil Survey Staff, 2017, 2022) or the World Reference Base soil classification system (FAO, 2014).

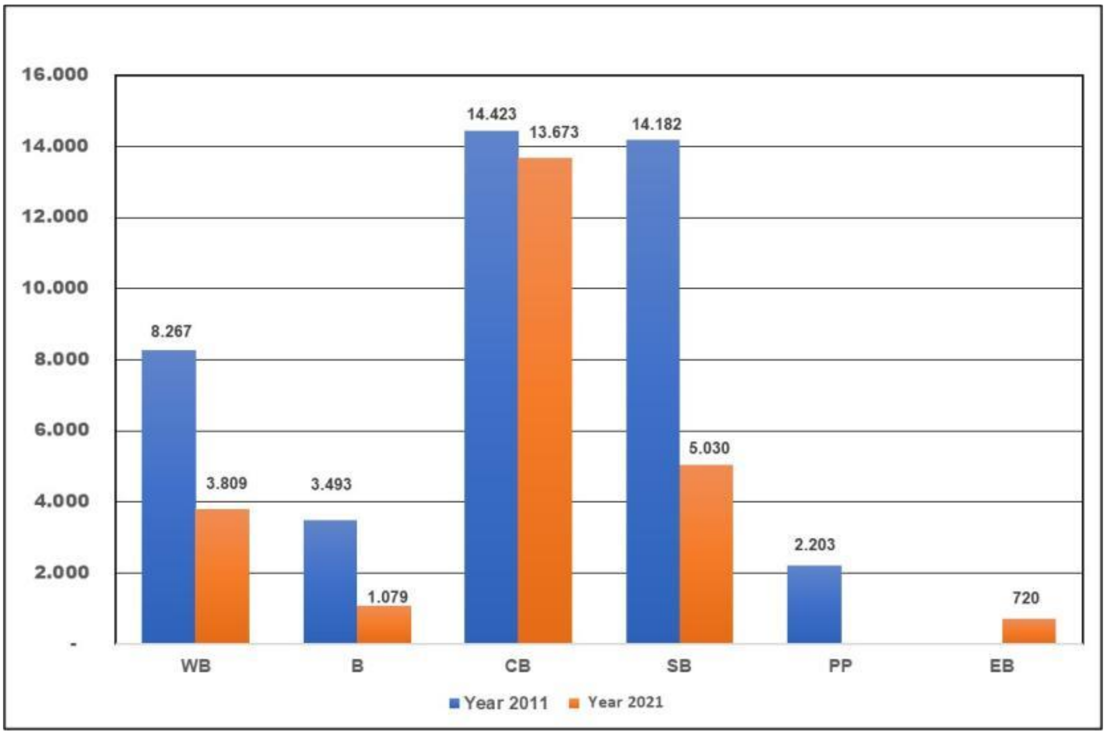
The Bulk Density (BD) of the three soils is: peat soil with hemic decomposition varied from 0.11-0.23 g cm-$^{3}$, for peat with sapric decomposition it varied from 0.23-0.25 g $cm^{-3}$ and for sulfidic peat it was 0.11 g.$cm^{-3}$. Based on the research results of Hikmatullah and Sukarman (2014), the BD value of peat soil in the Bangka Belitung Islands is higher than the BD of peat soil (0.07-0.24 g $cm^{-3}$) in several locations in Central Kalimantan, South Kalimantan, Riau, and Jambi Provinces.

The cation exchange capacity (CEC) for all soil samples is relatively high (>40 cmolc $kg^{-1}$), but the bases and base saturation (BS) are very low (<20%) (Table 3). Soil reaction is classified as very acid to acid (pH 3.5-4.8). The research results of Hikmatullah and Sukarman (2014) found that all the peat soils of four trial sites in South Sumatera, Jambi, Riau dan Central Kalimantan were generally very acid soil reaction with pH ($H_2O$) ranged from 3.3 to 4.2. Ismawi et al. (2012) reported that deforestation of peat swamp forest in Sibu, Serawak, Malaysia decreased significantly the chemical properties including soil pH, soil organic matter, total carbon, total nitrogen, CEC, total P, total K, and C/N ratio.

The Indonesian peatland map (including the Bangka Belitung Islands Province area) at a scale of 1:250,000 (Ritung et al., 2011) only produced data on the area and distribution of peat with characteristic data in the form of peat thickness which is divided into four depth classes. Meanwhile, the peatland map produced in this research with a scale of 1:50,000 in the soil map legend states that the peatland characteristics consist of peat depth, drainage class, decomposition, soil reaction, cation exchange capacity, and base saturation. This shows that the results of the identification and characteristics of peatlands from this activity produce more complete and detailed data.

The results of the identification and characterization of peat soil on the two islands show that the bulk density of the soil is very low and therefore has a low carrying capacity. According to Purnamayani et al. (2022), soil that has a low carrying capacity makes it difficult mechanize agriculture and the carrying capacity for plant growth, so plants easily collapse. The chemical properties of this peat soil have low to very low nutrient content, and acidic to very acidic soil pH. This land characteristics require high doses of fertilization accompanied by liming. Another characteristic of the peat in this area is that it has sapric, hemic and fibric stages development of maturity. According to Subardja et al. (2016) sapric and hemic peat are classified as suitable for agricultural crops (food crops, horticultural crops and plantation crops), while fibric peat is classified as unsuitable for agricultural crops.

The area of peat soils in Bangka Belitung Islands Province based on 2011 data is 42,568 ha (Ritung et al., 2011) while based on this research results it is 24,311 ha. This means that over approximately 10 years there has been a peatland degradation covering an area of 18,257 ha. Over the past 10 years, the area of peatland lost was 42.9 % of the entire peat area in this province. Details of the area of degraded peat per Regency/city are presented in Figure 5. From Figure 5, it can be seen that the most extensive peatland degradation occurred in South Bangka, West Bangka, Bangka and Pangkal Pinang City. The data in Table 6 shows that the average carbon stock in Bangka Belitung Islands Province is 478 tons $ha^{-1}$, so the carbon emitted from degraded peat covering an area of 18,257 is 8,726,846 tons.




**Notes**: WB =West Bangka, B = Bangka, CB = Central Bangka, SB = South Bangka, PP =Pangkal Pinang City, EB = East Belitung

**Figure 5**. Comparison of peat soils area in 2011 and 2021 for each regency/city in Bangka Belitung Islands Province

**Table 6**. Estimated carbon stocks in peat soil of each regency in Bangka Belitung Islands Province

| Regency | Peat Area | BD | Carbon stocks | |
|---|---|---|---|---|
| | Ha | g.cm$^{-3}$ | ton | ton.ha$^{-1}$ |
| West Bangka (WB) | 3,809 | 0.11 – 0.24 | 1,257,728 | 330 |
| Bangka (B) | 1,079 | 0.11 – 0.24 | 873,474 | 810 |
| Central Bangka (CB) | 13,673 | 0.11 – 0. 24 | 5,860,309 | 429 |
| South Bangka (SB) | 5,030 | 0.11 – 0.23 | 2,931,429 | 583 |
| East Belitung (EB) | 720 | 0.12 – 0.25 | 704,278 | 978 |
| Total/average | 24,311 | | 11,627,218 | 478 |

Note: BD= Bulk Density

The degradation of peatlands in Bangka Belitung is due by various aspects, including logging, forest conversion into industrial plantations, drainage, and repeated fires (Dohong et al., 2017). Furthermore, Haryati and Dariah (2019) found that the degradation of peatlands on Bangka Belitung Islands Province was caused by the expansion of tin mining areas. The tin mining area in Bangka Belitung Islands Province is spread in almost all regency and the dominant ones are in Bangka, West Bangka and East Belitung Regencies.

Although the area of peatland on both islands is relatively small, some of the peatlands are under forest cover that is the habitat of various rare plants and stores a large amount of carbon. Based on the distribution of peatlands in each regency, the peat soils in Bangka Belitung have the largest carbon stocks, with the largest average carbon stock in Central Bangka Regency at 5,860,309 tons, while the lowest carbon stock is in East Belitung Regency at 704,278 tons. Meanwhile, the average carbon stock on the island is 478.27 tons.ha$^{-1}$.

Peat soils also store huge amounts of carbon reserves, both above and below ground (Noor et al., 2016; Orella et al., 2022). Peatland ecosystems play an important role in the hydrological system of downstream areas of river basins because they can absorb up to 13 times their weight in water. Peat areas also store very large amounts of carbon reserves, both above and below the ground surface (Fiantis et al., 2024). Therefore, we need to be careful because if it is mismanaged, it will cause damage to the land (irreversibility, subsidence) and the environment (pollution and increased carbon emissions). Currently, peatland use for agriculture is starting to be restricted due to climate change and environmental damage, and regulated by INPRES No. 10/2011 and Presidential Instruction No.6 of 2017, Minister of Agriculture Regulation no. 14/2009.

In terms of use, peat soils in Bangka Belitung Islands Province consist of rice fields, especially in East Belitung, oil palm plantations, dry land crops, shrubs, and forests. For land that has been cleared and cultivated for agriculture, water management and soil fertility are the main factors that need to be implemented. The principle is to make efforts to regulate the groundwater level so that the peats on the surface of the soil remains moist to reduce fire risk and decomposition. Meanwhile, deep peats especially forests, should not be cleared for new agricultural lands.

Peat soil is a resource that has economic functions for the community, government, and the state, in addition to production and environmental functions. Peat soil in Bangka Belitung Islands Province provides jobs, livelihoods, and food. Peat soil is a source of income for people living in peat areas, contributes to food security, and contributes to the country's foreign exchange through the plantation sector (palm oil and rubber). Almost every farm managed on peat soil shows economic feasibility, especially plantations. Therefore, government policies are needed to preserve the environment and ensure the welfare of the community and the national interest (Sari et al., 2019).

For new oil palm plantations, it is necessary to follow Presidential Decree No. 32/1990, that peat soil with a thickness of more than 3 meters is directed for conservation to preserve the environment (Article 10 of Presidential Decree No. 32/1990).

## 4. CONCLUSION

Peatland mapping activities at a scale of 1:50,000 in Bangka Belitung Islands Province have improved peatland area data from 42,569 ha to 24,311 ha, as well as producing information on peatland characteristics in the form of peat soil depth, drainage class, decomposition, soil reaction, cation exchange capacity, and base saturation. Peat soil mapping is required at a detailed level (1:5,000) for more detailed peat soil management planning. The soil types consist of Organosol Saprik (Typic Haplosaprists), Organosol Hemik (Typic Haplohemists), and Organosol Sulfidik (Terric Sulfihemists). The depth is classified as shallow, medium and deep peat, varying from 50-300 cm. The dominant peat is shallow, covering an area of 13,668 ha or 56.22%. Most of peat soil's chemical and physical properties are classified as marginal, making it less suitable for developing agricultural crops. Even though the average carbon stock on Bangka Belitung Island is 478.27 tons $ha^{-1}$ or 11,627,218 tons from total peat soil areas, the peat soil on these two islands needs to be protected because one of the functions of peat soils is as a hydrological function and plays an important role in the local ecosystem. Government regulations on the use and management of peat soil, both from the central and local governments, should always be followed and adhered to so that the use of peat soil is sustainable for the wider community without damaging the environment.

## Acknowledgement

Thanks to the Head of the Center for Agricultural Land Resources Research and Development, Agricultural Research and Development Agency for supporting and funding this activity through the state budget. Thanks also go to the technicians Lili Muslihat, Seprianto, Dwi Kuntjoro Ganef, and Yani Again, who assisted in field research.

## Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear to influence the work reported in this paper.

## References

Agus, F., Hairiah, K., & Mulyani, A. (2011). *Pengukuran cadangan karbon tanah gambut. Petunjuk Praktis*. World Agroforestry Centre-(ICRAF), SEA Regional Office dan Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (BSDLP). https://apps.worldagroforestry.org/sea/Publications/files/manual/MN0051-11.pdf

Anda, M., Ritung, S., Suryani, E., Sukarman, Hikmat, M., Yatno, E., . . . Husnain. (2021). Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. *Geoderma*, *402*, 115235. https://doi.org/10.1016/j.geoderma.2021.115235.

Baharuddin, & Sidarto. (1995). *The Geological Map of the Belitung Sheet, Sumatra. Scale 1:250.000*. Bandung, Pusat Penelitian dan Pengembangan Geologi.

BBSDLP. (2019). *Peatland Map of Indonesia Scale 1:50.000*. Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

BSN. (2018). *SNI 8473:2018. Survei dan pemetaan tanah semidetail skala 1:50.000*. Badan Standardisasi Nasional. http://sispk.bsn.go.id/sni/DetailSNI/11775

Dohong, A., Aziz, A. A., & Dargusch, P. (2017). A review of the drivers of tropical peatland degradation in South-East Asia. *Land Use Policy*, *69*, 349-360. https://doi.org/10.1016/j.landusepol.2017.09.035.

Eviati, & Sulaeman. (2012). *Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk* (2nd ed.). Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

FAO. (2014). *World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps (Update 2015)*. Food and Agriculture Organization of the United Nations https://openknowledge.fao.org/server/api/core/bitstreams/bcdecec7-f45f-4dc5-beb1-97022d29fab4/content

Faul, F., Gabriel, M., Roßkopf, N., Zeitz, J., van Huyssteen, C. W., Pretorius, M. L., & Grundling, P.-L. (2016). Physical and hydrological properties of peatland substrates from different hydrogenetic wetland types on the Maputaland Coastal Plain, South Africa. *South African Journal of Plant and Soil*, *33*(4), 265-278. https://doi.org/10.1080/02571862.2016.1141334.

Fiantis, D., Rudiyanto, Ginting, F. I., Agtalarik, A., Arianto, D. T., Wichaksono, P., . . . Minasny, B. (2024). Mapping peat thickness and carbon stock of a degraded peatland in West Sumatra, Indonesia. *Soil Use and Management*, *40*(1), e12954. https://doi.org/10.1111/sum.12954.

Haryadi, D., Ibrahim, I., & Darwance, D. (2021). Strategic Ecological Issues: Environmental Problems in a Perspective of Regional Development in Bangka Belitung. *E3S Web Conf.*, *241*, 05001. https://doi.org/10.1051/e3sconf/202124105001.

Haryati, U., & Dariah, A. (2019). Carbon emission and sequestration on tin mined land: A case study in Bangka Belitung Province. *IOP Conference Series: Earth* *and Environmental Science*, *393*(1), 012097. https://doi.org/10.1088/1755-1315/393/1/012097.

Heryanto, R. B., Gani, R. A., & Sukarman. (2021). The distribution and characteristics of peat lands in Central and South Bangka Regencies, Bangka Belitung Islands Province. *IOP Conference Series: Earth and Environmental Science*, *648*(1), 012152. https://doi.org/10.1088/1755-1315/648/1/012152.

Hikmatullah, H., & Sukarman, S. (2014). Physical and chemical properties of cultivated peat soils in four trial sites of ICCTF in Kalimantan and Sumatra, Indonesia. *Journal of Tropical Soils*, *19*(3), 131-141. https://doi.org/10.5400/jts.2014.v19i3.131-141.

Ismawi, S., Gandaseca, S., & Ahmed, O. (2012). Effects of deforestation on soil major macro-nutrient and other selected chemical properties of secondary tropical peat swamp forest. *International Journal of Physical Sciences*, *7*(14), 2225-2228. https://academicjournals.org/article/article1380540447_Ismawi%20et%20al.pdf.

Mangga, A. S., & Djamal, B. (1994). *The Geological Map of the Northern Bangka Sheet, Sumatra, Scale 1:250,000.* Bandung, Pusat Penelitian dan Pengembangan Geologi.

Margono, U., Supandjono, R. J. B., & Partoyo, E. (1995). *Geological Map of the Southern Bangka Sheet, Sumatra, Scale 1:250,000.* Bandung, Pusat Penelitian dan Pengembangan Geologi.

Minasny, B., Adetsu, D. V., Aitkenhead, M., Artz, R. R. E., Baggaley, N., Barthelmes, A., . . . Zak, D. (2024). Mapping and monitoring peatland conditions from global to field scale. *Biogeochemistry*, *167*(4), 383-425. https://doi.org/10.1007/s10533-023-01084-1.

Mulder, N. J. (1988). Digital Image Processing, Computer-aided Classification and Mapping. In A. W. Küchler & I. S. Zonneveld (Eds.), *Vegetation mapping* (pp. 269-316). Springer Netherlands. https://doi.org/10.1007/978-94-009-3083-4_26

Noor, M., Masganti, & Agus, F. (2016). Pembentukan dan Karakteristik Gambut Tropika Indonesia. In F. Agus, M. Anda, A. Jamil, & Masganti (Eds.), *Lahan Gambut Indonesia Pembentukan, Karakteristik, dan Potensi Mendukung Ketahanan Pangan* (pp. 7-32). IAARD Press. Badan Penelitian dan Pengembangan Pertanian. https://repository.pertanian.go.id/handle/123456789/9627

Nurzakiah, S., Wakhid, N., & Hairani, A. (2020). Carbon dioxide emission and peat hydrophobicity in tidal peatlands. *Sains Tanah - Journal of Soil Science and Agroclimatology*, *17*(1), 7. https://doi.org/10.20961/stjssa.v17i1.41153.

Orella, J., Africa, D. R., Bustillo, C. H., Pascua, N., Marquez, C., Adornado, H., & Aguilos, M. (2022). Above-and-Belowground Carbon Stocks in Two Contrasting Peatlands in the Philippines. *Forests*, *13*(2), 303. https://doi.org/10.3390/f13020303.

Page, S. E., & Baird, A. J. (2016). Peatlands and Global Change: Response and Resilience. *Annual Review of Environment and Resources*, *41*(Volume 41, 2016), 35-57. https://doi.org/10.1146/annurev-environ-110615-085520.

Pratama, G. W., Adji, F. F., Surawijaya, P., Yulianti, N., & Damanik, Z. (2021). Study of Dissolved Organic Carbon Concentration in KHDTK Forest Peatland Area, Central Kalimantan, Indonesia. *Journal of Tropical Peatlands*, *10*(2), 29-35. https://doi.org/10.52850/jtpupr.v10i2.3034.

Purnamayani, R., Dariah, A., Syahbuddin, H., Tarigan, S. D., & Sudradjat, S. (2022). Best practices pengelolaan air perkebunan kelapa sawit di lahan gambut. *Jurnal Sumberdaya Lahan*, *16*(1), 9-21. https://epublikasi.pertanian.go.id/berkala/jsl/article/view/3315.

Ritung, S., Suparto, Tafakresnanto, C., Sukarman, & Suryani, E. (2017). *Pedoman Klasifikasi Landform*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (BBSDLP), Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

Ritung, S., Wahyunto, Nugroho, K., Sukarman, Hikmatullah, Suparto, & Tafakresnanto, C. (2011). *Lahan Gambut Indonesia Skala 1:250.000 (Indonesian peat land map at the scale 1: 250,000)*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian.

Rixen, T., Wit, F., Hutahaean, A. A., Schlüter, A., Baum, A., Klemme, A., . . . Warneke, T. (2022). 4 - Carbon cycle in tropical peatlands and coastal seas. In T. C. Jennerjahn, T. Rixen, H. E. Irianto, & J. Samiaji (Eds.), *Science for the Protection of Indonesian Coastal Ecosystems (SPICE)* (pp. 83-142). Elsevier. https://doi.org/10.1016/B978-0-12-815050-4.00011-0

Sari, D. A. P., Falatehan, A. F., & Ramadhonah, R. Y. (2019). The social and economic impacts of peat Land palm oil plantation in Indonesia. *Journal of Physics: Conference Series*, *1364*(1), 012017. https://doi.org/10.1088/1742-6596/1364/1/012017.

Septian, A., Junedi, H., & Kurniawan Mastur, A. (2023). Estimasi Cadangan Karbon Bawah Permukaan Lahan Gambut di Desa Catur Rahayu Kecamatan Dendang Kabupaten Tanjung Jabung Timur [Estimation of subsurface carbon stock of peat lands in Catur Rahayu Village, Dendang Regency, East Tanjung Jabung Regency]. *Jurnal Tanah dan Sumberdaya Lahan*, *10*(2), 285-295. https://doi.org/10.21776/ub.jtsl.2023.010.2.12.

Soil Survey Staff. (2017). *Keys to Soil Taxonomy* (12th ed.). Natural Resources Conservation Service-United States Department of Agriculture.

Soil Survey Staff. (2022). *Keys to Soil Taxonomy* (13th ed.). USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/sites/default/files/2022-09/Keys-to-Soil-Taxonomy.pdf

Subardja, D. S., Ritung, S., Anda, M., Sukarman, Suryani, E., & Subandiono, R. E. (2016). *Petunjuk Teknis Klasifikasi Tanah Nasional*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian (BBSDLP), Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

https://repository.pertanian.go.id/items/fe953d9a-006a-48e1-bf6d-ac050bc4c605/full

Sukarman, Ritung, S., Anda, M., & Suryani, E. (2017). *Pedoman Pengamatan Tanah di Lapangan*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian. https://repository.pertanian.go.id/items/e0633ee9-9520-411b-b8de-1cc096fcfa5c

Sukarman, S., Gani, R. A., & Asmarhansyah, A. (2020). Tin mining process and its effects on soils in Bangka Belitung Islands Province, Indonesia. *Sains Tanah - Journal of Soil Science and Agroclimatology*, *17*(2), 10. https://doi.org/10.20961/stjssa.v17i2.37606.

Wahyunto, Hikmatullah, Suryani, E., Tafakresnanto, C., Ritung, S., Mulyani, A., . . . Nursyamsi, D. (2016). *Pedoman Penilaian Kesesuaian Lahan untuk Komoditas Strategis Tingkat Semi Detail Skala 1:50.000*. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

Wahyunto, Hikmatullah, Suryani, E., Tafakresnanto, C., Ritung, S., Mulyani, A., . . . Nursyamsi, D. (2016). *Pedoman Survei dan Pemetaan Sumberdaya Tanah Tingkat Semi Detail Skala 1:50.000*. Balai Besar Penelitian dan Pengembangan Pertanian, Badan Penelitian dan Pengembangan Pertanian.