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Application of electrical resistivity test to estimate carbon storage of tropical peat deposit (Case study of Bengkalis island)

Muhammad Yusa^{1,*}, Ari Sandyavetri¹, and Sigit Sutikno¹

¹Department of Civil Engineering, Universitas Riau, Pekanbaru, Indonesia

Abstract. Indonesia has approximately 21 million hectares (ha) of tropical peat land, equivalent to 80% of peat deposit in Southeast Asia. It was estimated that Indonesia has 1.5 Giga tonne of carbon stock. However the estimation is still rough because there was no calculation of volume yet. This study explain the use the geophysical method of electrical resistivity test (ERT) combined with real time kinematic (RTK) and laboratory test to estimate the volume of peat deposit. Direct boring was also done to verify the ERT results. The location of study is in Bengkalis Island, Riau-Indonesia. Twelve (12) locations of ERT has been conducted covering area of 127164.667 ha. Visual observation from boring sample reveal that the peat in generally are fibric to hemic or H2-H6 according to Von Post classification. The peat layer has resistivity value range between 20-150 ohm meter. In general the peat can be classified as very deep peat with average thickness of 6.4 m. The ERT revealed that average lateral variability of peat thickness electrode line is less than 0.6 m. The estimated peat volume is 6803206275.152 m³. The average ash content is 6.5% which equivalent to 53.9% of carbon content. The average bulk density is 0.09 tonne/m³. It was estimated the carbon sink of the location is 330023536.41 tonnes which equivalent to 2595.3 tonne/ha.

1 Introduction

It is well established that peatland has a very strategic function as a hydrological unit, carbon storage, and biodiversity. Despite only cover little 2-3% of earth land, peatland can peatland contain up to 30% of the global soil carbon [1]. Furthermore, tropical peatland, 11% of global peatland, was estimated to store more than 30% of the global peatland carbon or about 50 [2] to 105 [3, 4] Gigatons of carbon. Degradation of tropical peatland releases greenhouse gases with a significant effect on global environmental change processes. Huijnen [5] reported that Indonesia peatland fire in September to October 2015 results in 11.3 Tg/day of CO₂ emission which exceeded the fossil fuel CO₂ release rate of the European Union, i.e., 8.9 Tg/day. Also, the total current CO₂ emission from degraded peat area equal almost 8% of global emission from fossil fuel burning [6].

^{*} Corresponding author: m.yusa@eng.unri.ac.id

On the other side, Indonesia is one of the country in the world which has a large area of peat, i.e., 20.6 million hectares or about 11% of its land area. The area covers almost 38% of world tropical peatland and 80% of Southeast Asia peatland [7]. However, in term of the volume, the estimation is still very rough because of limited data of peat thickness. Existing Indonesia's peat map has 1:250000 scale [8], with very rough peat thickness estimation, based only two categories, i.e., shallow (< 3 m) and deep (≥ 3 m) peat. This, in turn, results in a very rough estimate of carbon sink of Indonesia peatland.

Conventional peat volume estimation utilizes 'gridding system' of visual inspection of peat boring sample. Agus et al. [9] reported that the variation of peat thickness in 50 m could range 10-50 cm which implies grid spacing less than 50 m. The method is deemed reliable to identify peat depth but labor and time-consuming. Considering the wide area of Indonesia's peatland, the method will require much time and cost. This study attempted to utilize a combination of the geophysical method using electrical resistivity test (ERT), global stationing position (GPS) geodetic and peat boring. It is expected that the method will minimize the number of direct boring hence faster results, relatively cost-effective.

2 Methodology

2.1 Location

The location of this study is in Bengkalis Island, Riau Province-Indonesia. Bengkalis is an island which located at the eastern coast of Sumatra Island, i.e., $1^{\circ}30'0''$ N and $102^{\circ}15'0''$ E. Figure 1 shows the location of the study. Based on the geological map, the lithology of the site is quaternary alluvial composed of clay, silt, clean gravel, vegetation raft, and peat swamp. The aquifer can be classified as moderate to low transmissivity, depth to water table varies and well generally yield less than 5 liters/sec[10].



Fig. 1. Location of study.

2.2 Equipment

Basically there are three equipment used in this study. They are GPS geodetic, peat sampler and ERT. Detail each equipment is described in the following subsection.

2.2.1 Electrical Resistivity Test (ERT)

ERT is one of a non-destructive method to investigate the sub stratigraphy profile. It uses the fact that each material has a certain range of electrical resistivity. By injecting electrical

Current into the ground, the voltage difference between electrode pairs is measured. Numerical methods are used to solve the Poisson equation relating to the theoretical voltage at the electrodes to the distribution of subsurface resistivity. After that, inverse methods are applied to match the subsurface resistivity model to measured field data. The results, i.e., resistivity structure describes the ability of the subsurface to conduct electrical current. The resistivity is very much affected by water content, the chemical composition of the water and particle size distribution.

The ERT used in this study is ARES advance multi channel automatic resistivity, manufactured by GF instrument (Fig. 2). It mainly consists of transmitter and receiver. The transmitter has power up to 850 W, current up to 5 A (24 bit resolution) and 2000 voltage. Whilst the receiver has 10 channel, input voltage ± 20 V and input impedance of 20 M Ω .

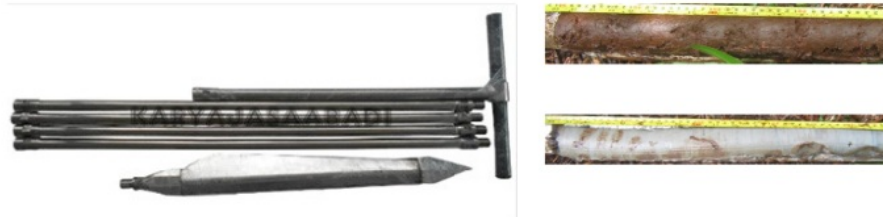
In this study, Wenner method was chosen as it had the fast time response and provided a relatively good resolution. There were 48 electrodes used with 1.5 m interval spacing which gave 72 m of path length. The configuration gave maximum depth of about 12 m. The direction of the electrode line is north-south. The analysis and inversion process was performed using RES2DINV software developed by Loke [11].



Fig. 2. ERT.

2.2.2 Peat sampler and index properties

In every electrode path of ERT, one point of boring was conducted at approximately 2 meters from the middle of the electrode path to validate the result of ERT. Boring was done using special hand boring, i.e., Eijkelpamp peat sampler as shown by Fig. 3. The lowest part of the equipment is half cylindrical cone which closes and contain the peat sample when the rod handle is rotated. Sample observation was conducted at interval 50 cm. Peat layers were described in the field as peat, clayey peat and clay. Classification of peat was done according to Von Post's classification [12]. 5 cm of the representative sample was taken, the weight was measured directly in the field. The sample then sent to soil mechanic laboratory further tests such as ash content and bulk density.



(a)Eijkelpamp peat sampler.

(b) Obtained samples.

Fig. 3. Peat sampler and sample.

2.2.3 GPS Geodetic

The GPS geodetic is used to determine the location of the boring and ERT path. The GPS is real-time kinematic (RTK) manufactured by Sokkia and has the accuracy up to one centimeter. The equipment consists of the transmitter and receiver as shown by Fig. 4. The survey was conducted along the electrode path and ERT cable.



Fig. 4. Real time kinematic GPS.

2.3 Points of investigation

Before the field tests commenced, a literature study was done which includes the geological map, topographical map, land use map, and previous study to determine the proposed location. Also, some interview with the local people was also conducted regarding the site and estimated peat depth. In total there are twelve locations in this study. Fig. 5 shows the site of all points boring in this study. The planar area of the location is 127,164.667 ha.

3 Results and discussion

3.1 General

On average it took about 25-30 minutes to conduct the ERT along 72 m electrode line. On the other hand, one point of direct boring took about more than 30-60 minutes. It was not uncommon after some depth, the peat sampler hit wood trunk and cannot be penetrated further thus the location of direct boring had to be moved.



Fig. 5. Points of investigation.

Groundwater table was encountered at 5-130 cm from the ground surface. Boring results reveals that the thickness of peat varies from 0.5 m to 9.5 m (Table 1). Peat thickness from direct boring is shown in the 4th column of the table. Average peat thickness (5th column of the table) was calculated considering the lateral variation from the

interpretation of ERT result, as exemplified in sub-section 3.2. Generally, the peat can be classified as very deep peat (> 3 m) peat except for IPP-02 which is deep peat (2-3 m). Using the planar area the average thickness (considering lateral variability) of peat is 6.4 m. The average lateral variation of peat thickness from direct boring is generally less than 0.6 m. In term of peat classification, the peat in this study range from young/ fibric to intermediate (hemic) or H2-H6 according to Von Post classification.

Table 1. Peat thickness.

ID	Coordinate		Thickness based on boring (m)	Lateral depth variability based ERT (m)		Average thickness, based on ERT and boring (m)
	X	Y				
IPP-02	165,535.577	197,064.458	2.8	1.6	3.8	2.7
IPP-03	165,735.980	165,660.471	6	7.3	8.0	7.1
IPP-09	164,150.266	209,973.221	4.4	4.8	5.4	4.9
IPP-10	169,612.090	209,738.600	6	7.3	7.3	6.8
IPP-11	166,333.748	213,465.540	4.2	5.9	5.9	5.4
IPP-13	154,288.763	206,714.559	6	4.8	5.3	5.4
IPP-14	154,589.046	209,682.726	7	4.8	5.7	5.8
IPP-21	155,880.317	215,046.709	7	7.3	6.8	7.1
IPP-25	147,346.7725	213,151.990	6.2	7.3	7.9	7.1
IPP-27	149,333.743	218,481.465	9.5	9.4	10.1	9.7
IPP-29	148,281.997	218,947.606	9	9.4	9.4	9.3
IPP-30	146,413.295	220,475.673	6	6.6	6.0	6.2
		average	6.2	6.4	6.8	6.4

ERT results show that of the resistivity of peat layer range from 20-150 ohm meter. This range is consistent with the result from Comas et al. [13] which based on Borneo's peat properties. Laboratory result shows that the ash content ranges from 3.4 to 12.2 with an average of 6.5% or average organic content of 93.5%. The bulk density vary from 0.08 to 0.14 tonne/m³ which is consistent with published literature such as Walter et al. [14]

3.2 Result example of one location

Due to pages limitation, only one location (IPP 21) is described here as an example. The site is within a coconut farm, about 60 meters from the local road. The ground surface is dry. The groundwater level was encountered at 50 cm below the ground surface. Fig. 6 shows subsurface resistivity distribution along with the boring location. The figure shows one major advantage of ERT compares one discrete point of boring, i.e., that lateral ground variability can be identified along the 72 m electrode line. Visual observation from direct boring sample reveals that the ground profile consists of the 7 m thick of peat followed by a layer of clay. The peat layer can be classified as fibric (young) to hemic (intermediate) or H2-H4 according to Von post Classification. It can be seen from the figure that the range of resistivity values of the peat layer is 25-90 ohm meter. Based on the range in this location, the thicknesses of the peat to the left side and right side are estimated 7.3 m and 6.8 m. The figure reveals that the lateral peat thickness variability along the electrode line is less than 0.5 m. Thus for this location, the average thickness along the 72 m electrode line is approximated equal to 7.03 m. The procedure is repeated from the other's location.

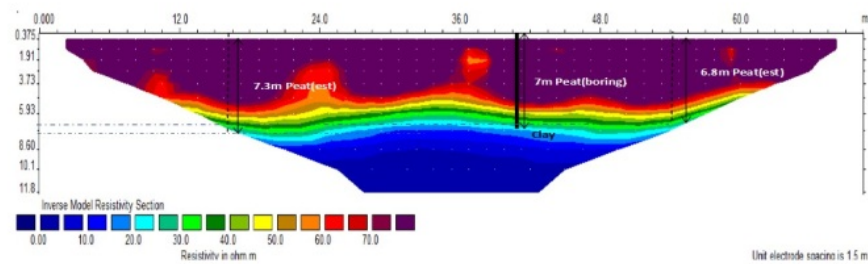
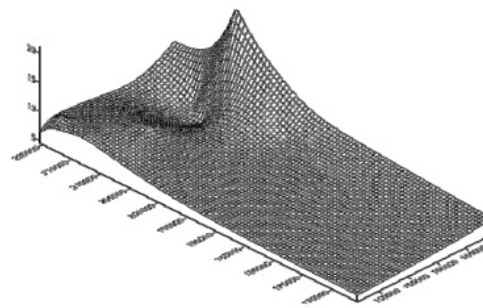
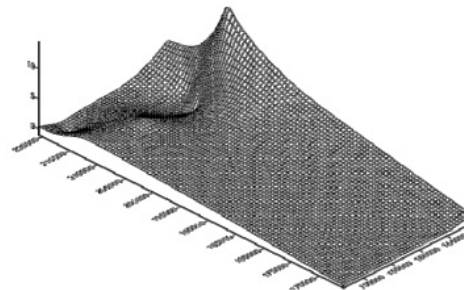


Fig. 6. Real time kinematic GPS.



(a)



(b)

Fig. 7. Surface of (a) topography and (b) peat depth.

3.2 Peat volume estimation

Based on the topographical coordinates and the average peat depth from all locations, contour surfaces are drawn using topographical software. Fig. 7 (a) presents an upper surface, i.e., topographical surface and Fig. 7(b) shows peat depth surfaces. The volume between two surfaces is calculated by dividing the area of interest up into small rectangular pieces, and then the sum volume of the small three dimension rectangles between them. Utilizing the automatic tools in the software, it can be calculated that the volume between the upper and lower surface is 6,803,206,275.152 m³.

3.3 Estimation of carbon storage

Carbon storage (C_s) can be empirically estimated by equation below

$$C_s = V \cdot C_d \quad (1)$$

where V is the estimated peat volume and C_d is the multiplication of carbon content and unit weight of peat.

The average bulk density is taken as 0.09 tonne/m^3 . As the the equipment for total C analysis (elemental CN analyzer) was not available, the carbon content, C_d , is estimated from the results of ash content test and previous literature of organic content to carbon content ratios. The average ash content is taken as 6.5% thus average organic content is 93.5%. Klingenfab et al [15] reported that for fibric to hemic peat the ratio of organic content to carbon content is 1.73-175. Hence the carbon content is this study is 53.6-54.2%. The is in the lower side of the published average C_d values of Indonesia's peat which range 54.5-69.8% [16]. Taking 53.9% as the average, the estimated carbon stock for this study is 3,520,251,055.015 tonnes. Using the plannar area of the location of study i.e .127164.667 acre then the carbon sink is estimated 2595.25 tonnes/ha. This number is consistent with by Agus and Subiksa's finding[17] who reported that carbon stock range 300-700 tonne/ha/m peat depth I.e for average peat thickness of 6.4 the range is 1920 tonne/ha to 4480 tonne/ha.

4 Conclusions

Combination of ERT and direct boring can identify peat volume better because the ERT account for lateral variability in peat thickness. The method c₁ minimize the number of boring. The range of resistivity of the peat layer in this study is between 20-150 ohm meter. Based on the thickness, the peat can be classified as very deep peat with an average depth of 6.4m. The estimated peat volume is 6,803,206,275.152 m³. The average ash content is 6.5% which give approximately 53.9% of carbon content. Using the average bulk density of 0.09 tonne/m³, it was estimated the carbon sink for the location of this study is 3,520,251,055.015 tonnes.

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