Mineralogical and Geophysical Properties of Peat Soil for Sustainable Urban Development in South Kalimantan, Indonesia

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ABSTRACT

Abumbun Jaya Village, Sungai Tabuk District, South Kalimantan, is the focus of urban expansion. This land is vulnerable to settlement under loading because the topography of this area lies at an altitude of 0–10 m above sea level, with a slope of 0–2°, and is formed by alluvial deposits, sandy mud, peat, river deltas, and swamps. This study investigates the soil mineralogy of the region based on geophysical and geochemical properties as a first step towards effective and sustainable land management of two different types of peatlands: degraded and intact peatland. The geophysical properties were determined using the

Wenner configuration geoelectrical method, and geochemical properties using methods such as Infrared spectroscopy, X-Ray Fluorescence (XRF), X-Ray Diffraction (XRD), and Scanning Electron Microscopy (SEM) with Energy-Dispersive Spectroscopy (EDS) mapping. The results of the geophysical test indicate that this land is suitable for conversion because the peat thickness is less than 1.50 m, with resistivity values categorizing it into two types: first, peat with moderate to slow subsidence (20-99 Ωm), geologically interpreted as dense and dry peat with different minerals. Second, peat with minimal subsidence, suitable for light foundations (100-153 Ωm). This behavior is in line with the peat's physical properties, namely sapric peat, and its geochemical properties, which consist of O–H, C–H, C=O, C=C, C–O–C, Si–O, Al–Al–OH, Si–O–Al, and Fe–O functional groups, classifying it as mineral-rich peat that helps maintain soil stability. These scientific findings support urban development planning on peatlands and sustainable land management in peat-rich areas of South Kalimantan.

Keywords-peatland; geophysical; geochemical; mineral; sustainable

I. INTRODUCTION

The rate of population growth [1] and economic development [2] have prompted the South Kalimantan Provincial Government to expand urban areas in various regions, including Banjarmasin, Banjarbaru, and Banjar Regency. Abumbun Jaya Village, Sungai Tabuk, Banjar Regency, has become one of the focus areas for urban development according to Presidential Regulation Number 85 of 2024, concerning the Banjarbakula Metropolitan Urban Area's National Spatial Plan (RTR KSN) [3].

Topographically, this area is situated at an altitude of 0–10 meters above sea level, with a slope of 0–2 degrees, and is characterized by a peat swamp that is consistently flooded. Several areas are periodically inundated due to the ebb and flow of river water and seasonal changes. The soil formation is made up of alluvial deposits consisting of a mixture of clay, silt, and fine sand deposited by the river and the delta, while the Dahor formation consists of quartz sandstone, conglomerate, and soft claystone, with intercalations of lignite, kaolin, and limonite. These deposits are the primary source of peat accumulation in this area, as shown in Figure 1 [4]. This area qualifies as a peat conversion area under articles 9 and 21 of PP 57/2016, which pertain to the Protection and Management of Peat Ecosystems, as the peat thickness is less than 3 m [5]. Some locations have been converted into agricultural land or residential areas, while others remain as pristine peatland.

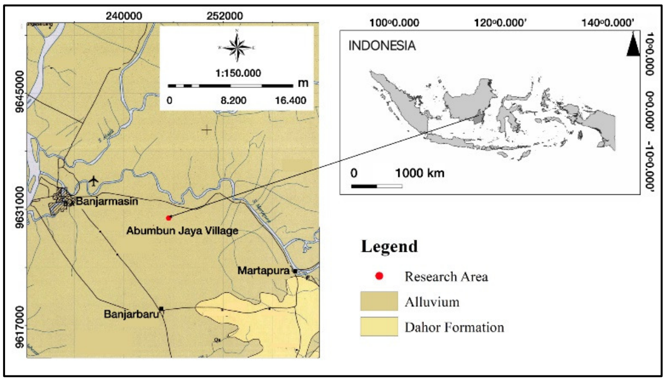


Fig. 1. Geology map of the study area.

Peatlands are not suitable for urban development, particularly for building foundations. Peat is always soft and has a high-water content and porosity. Its density, shear strength, and bearing capacity are low. These properties cause land subsidence. Furthermore, the clay layer beneath the peat layer makes the soil unstable under load. This condition renders the land difficult to use as a foundation for building structures in its natural state [6-8]. The conversion of peatland lowers the water table, which leads to the desiccation of the upper peat layer. As the soil becomes more aerobic, the rate of peat decomposition increases, which accelerates carbon loss and structural deterioration. The peat matrix becomes hydrophobic, which makes it more susceptible to shrinkage and swelling cycles [9, 10]. The rate of decomposition is directly proportional to soil density and inversely proportional to the porosity and water content of the peat soil. The pH and mineral composition of the peat also experience changes [11]. Generally, changes in these properties also impact the stratigraphy and hydrogeology of the soil in the area [12-14]. In 2021, most of the city of Banjarmasin experienced major flooding [15], and several buildings collapsed [16, 17] due to the insufficient consideration of land conversion and post-peatland fires.

Most research on peat soil focuses on its physical and chemical properties, primarily for applications related to land fertility. The density, water content, porosity, and permeability of the soil [18-20], along with nutrient cycles, cation exchange, and root systems in peat soil [21-23], are studied at a depth of 0–0.60 m to prepare the soil for agricultural use. However, the extremely rapid population growth rate has prompted the conversion of this area into an urban development zone. Thus, more complex research on the characteristics of peat soil is being conducted, especially in the investigation of peat soil mineralogy to enhance soil quality before land management and the sustainability of urban development. According to [24], as the population increases, it is necessary to identify soil characteristics for safer construction during geotechnical designs.

Understanding peatland mineralogy is crucial because it is related to the physical, chemical, and lithological properties of the soil. This information is influential in ecosystem management, conservation, rehabilitation, and conversion of peatland. Studies on subsurface properties are conducted using geophysical methods [25]. Soil lithology, peat layer thickness, saturation level, mineral distribution, and indications of potential land subsidence are revealed through soil resistivity tests. The construction of buildings, roads, bridges, and other public facilities then utilizes these data [10, 26]. The condition of the soil lithology is linked to the geochemical properties of peat soil. This information is essential because of the aggressive chemical properties of peat. Techniques, such as Fourier Transform Infrared Spectroscopy (FTIR), XRF, XRD, and SEM, have been employed to gain an understanding of the geochemical properties of peat soil. [27-30].The present study reveals an integrated state of peat soil minerals, which is still rarely discussed, especially for the South Kalimantan region. Conducting this research was necessary for the success of sustainable urban development. The current research requires mineralogical and soil suitability studies, especially on sandy and clay soils, because both its geophysical and mineralogical results will be used as considerations in the development of infrastructure in this area. The mineral composition of the soil and its physical properties greatly influence and impact the safety and stability of building structures.

II. MATERIALS AND METHODS

The study area is located in Abumbun Jaya Village, Sungai Tabuk, South Kalimantan. Drainage channels have been built at this site to lower the groundwater level in the peat. Consisting of partially decomposed plant remains, the peat is highly porous and sponge-like. When drainage channels are built, the water filling these pores flows out with gravity. This loss of water causes the pores in the now dry upper peat layer to collapse. This process is called compaction and it is one of the causes of groundwater level decline, particularly in the peatlands of South Kalimantan [31]. The groundwater level at the research site was found to be at an average depth of 0.40–0.50 m. Figure 2 shows the geophysical positions of measurement using the Wenner configuration of the geoelectrical method with longitude and latitude samples, as shown in Table I. The measurement lines were taken at two different locations; the first at a degraded peatland site and the second at an intact peatland site [32]. The first location is marked with the lines L_A, L_B, and L_C, with a distance of 20 m between measurement lines, while the second location is marked with the lines L_D, L_E, and L_F, with a distance of 40 m between measurement lines. Soil samples for testing the physical and chemical properties were collected at depths of 0.10 m, 0.50 m, 1.00 m, and 1.50 m at drill spots A, B, C, D, E, and F using a peat drill Eijkelkamp. Bulk density and soil pH data were obtained in the field, while the water content and soil geochemical properties were measured in the laboratory.

Fig. 2. Geophysical measurement positions using the Wenner configuration of the geoelectrical method.

TABLE I. LONGITUDE AND LATITUDE OF SAMPLE LOCATIONS

Line	Coordinates	
	Start	End
L_A	3°20'44.70"S – 114°42'29.00"E	3°20'43.40"S – 114°42'29.20"E
L_B	3°20'44.80"S – 114°42'29.65"E	3°20'43.50"S – 114°42'29.88"E
L_C	3°20'44.90"S – 114°42'30.30"E	3°20'43.60"S – 114°42'30.50"E
L_D	3°24'18.00"S – 114°42'5.10"E	3°24'17.8"S – 114°42'8.2"E
L_E	3°24'19.20"S – 114°42'8.30"E	3°24'19.3"S – 114°42'5.8"E
L_F	3°24'20.20"S – 114°42'8.40"E	3°24'21.9"S – 114°42'5.5"E

Soil physical properties, such as water content, were tested in accordance with SNI 03-3637-1994 [33], and bulk density in accordance with SNI 2828:2011 [34]. The geochemical properties measured included soil functional groups with FTIR, elemental composition using XRF, mineralogical composition using XRD, and soil morphology using SEM-Energy Dispersive X-ray spectroscopy (EDX) mapping. Before testing, the peat soil samples were oven-dried at 50–60°C to preserve their chemical integrity, then ground to pass through a 200-mesh sieve, and weighed to 5–7 g for analysis.

III. RESULTS AND DISCUSSION

A. Physical Properties

The physical properties of peat soil are not the same for each sampling point, as presented in Table II. The water content of the sample ranges from 50.42% to 149.18% and the bulk density is approximately 0.32–0.73 g/cm³. Peat soil, which consists of organic matter, can hold up to 200%-1,000% of its dry weight in water, which is much higher than mineral soil [35]. There was a decrease in water content in the sample at a depth of 1.50 m, indicating a change in soil type. This finding shows that at a depth of 1.5 m, the soil was sandy clay, as depicted in Figure 3, and was also consistent with the geoelectric measurement results presented in Table V. Based on the physical properties, the type of peat found at the study area was classified as sapric peat, which has a bulk density higher than 0.2 g/cm³ and a water content of less than 400% [36]. This peat type indicates that the peat soil has undergone decomposition, as evidenced by the finer soil grains and its brownish-black color.

Fig. 3. Sandy clay from the study area.

B. Geochemical Properties

The peat soil acidity (pH) at points A, B, and C ranges from 3.6 to 6.0, while at points D, E, and F it is below 3.0-5.5. Low pH is an inherent characteristic of peatlands that helps prevent decomposition. However, extremely low pH (below 4) in drained peatlands is an indication of severe land degradation due to the oxidation of organic matter and the formation of sulfuric acid [37].

TABLE II. PHYSICAL PROPERTIES OF PEAT SOIL SAMPLES

Sample Identity	pH	Water content(%)	Bulk density(g/cm^3)
A–10	5.5	61.3	0.37
A–50	3.6	73.2	0.42
A–100	3.6	102.5	0.41
A–150	5.8	73.9	0.45
B–10	4.7	80.6	0.32
B–50	6.0	98.2	0.35
B–100	5.9	108.2	0.43
B–150	5.7	101.0	0.46
C–10	4.5	50.8	0.35
C–50	4.8	52.6	0.42
C–100	4.9	57.6	0.48
C–150	5.4	73.5	0.51
D–10	<3.0	50.42	0.71
D–50	<3.0	66.78	0.66
D–100	3.0	123.95	0.67
D–150	3.0	149.18	0.69
E–10	4.1	71.38	0.69
E–50	4.0	99.30	0.73
E–100	3.6	102.46	0.71
E–150	3.2	88.06	0.69
F–10	6.0	57.10	0.65
F–50	5.1	59.83	0.64
F–100	4.0	73.97	0.64
F–150	3.5	99.13	0.71

1) FTIR Analysis

Figure 4 shows the FTIR measurement results, which reveal the functional group spectra of organic and inorganic components.

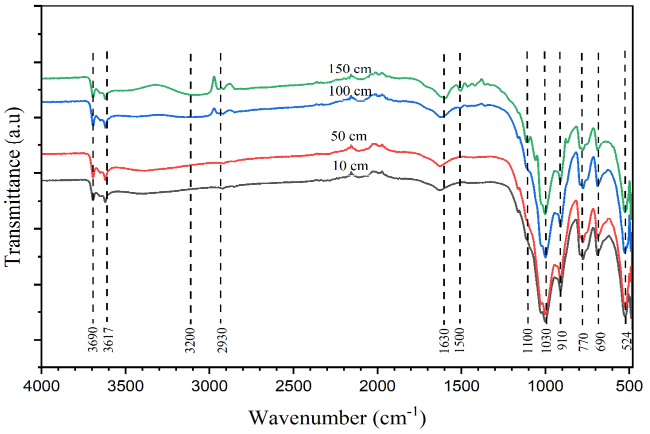


Fig. 4. Infrared spectra of peat soil sample.

The band at 3690–3617 cm^{-1} is related to the stretching hydroxyl group (O-H) found on the inner surface of the soil and is also related to silicate adsorption bands for kaolinite clay [41, 42]. The peak at 3200 cm^{-1} indicates that the peat is dominated by hydrogen bonds (O–H stretching) originating from adsorbed water molecules, polysaccharide hydroxyl groups in cellulose and hemicellulose, phenolic hydroxyl groups in lignin and humic substances, and carboxylic acids. This peak band is very weak and appears very broad, reflecting the moisture level and the abundance of organic functional groups that were originally hydrophilic but have become hydrophobic [38, 39]. The band at 2930 cm^{-1} corresponds to the symmetric and asymmetric C–H stretching vibrations of the CH_2 and CH_3 methylene groups. At depths of 0.10 m, 0.50 m, and 1.00 m, the intensity of this band decreases sharply, directly reflecting the breakdown of decomposed plant biopolymers by microbial activity. The smaller the intensity of this peak, the more it indicates that the peat has undergone decomposition [40].

The bands at 1630 and 1500 cm^{-1} correspond to aromatic C=C compounds found in lignin and humates, as well as C=O groups from amides present in proteins within microbial biomass. The bands at 1100 and 1030 cm^{-1} are related to C–O groups and C–O–C glycosidic bonds of polysaccharides found in cellulose and hemicellulose. A decrease in the intensity of the band indicates that the peat has not yet completely decomposed [40]. The band with a wave number less than 910 cm^{-1} indicates the presence of the identity of the inorganic mineral region in peat. The peak is related to the Al–Al–OH bending vibration in the kaolinite structure [43] and the Fe–O bond [44], where its presence usually coincides with the O–H peak in the region 3690–3617 cm^{-1}. The bands at 770 cm^{-1} show the presence of quartz (SiO_2) and the bending vibrations of Si–O–Si. The peak at 690 cm^{-1} is related to crystalline quartz [45] and Fe–O [46]. The peak at 524 cm^{-1} is related to Si–O–Al bending vibration, which is characteristic of aluminosilicate minerals such as kaolinite and feldspar [41].

2) XRD and XRF Analysis

The identification of peat soil minerals based on XRD analysis is shown in Figure 5. The main components are quartz, kaolinite, and pyrite. In addition, there are other mineral phases, namely ilmenite, goethite, hematite, magnetite, illite, and other trace compounds. The oxide mineral composition of peat soil based on XRF normalized results is presented in Table III. The dominant oxides are SiO_2, Fe_2O_3, Al_2O_3, and SO_3 at several points. Minor oxides include TiO_2, K_2O, CaO, and P_2O_5, and trace oxides such as Cr_2O_3, V_2O_5, CuO, MnO, NiO, Yb_2O_3, SrO, Ag_2O, and ZnO. Based on the oxide profile, the peat soil is classified as peat of rich minerals, formed by silicate and sulphide minerals, reflecting its geological formation. According to the XRD results, clay minerals are composed of aluminum silicate, including kaolinite, dickite, and nacrite. The interaction between iron and sulphur suggests the formation of pyrite (FeS_2), which was detected at depths of 1.00 m and 1.50 m. This is consistent with the geological conditions of the study area. Iron is available in the form of ions (Fe^{2+}) originating from the weathering of minerals in mineral soils (alluvial deposits) [4] located beneath the peat layer. The decline in the groundwater table creates longer and deeper aerobic conditions in the peat, causing sulphuroxidizing microbes to become active and accelerate the sulphide oxidation process. The sulfuric acid resulting from biogeochemical reactions is released and dissolved into groundwater and drainage channels, and then reacts with Fe to form pyrite [47]. Similarly, the higher concentrations of P_2O_5 and K_2O observed in the pristine layer (D, E, and F) indicate that this organic matter has not undergone significant decomposition, whereas in A, B, and C, these oxides are reduced, likely due to mineral degradation influenced by soil management practices [47].

TABLE III. OXIDE COMPOUNDS OF PEAT SOIL FROM ABUMBUN JAYA VILLAGE

Sample identity	**Compound (conc. unit, %)**							
	SiO_2	**Fe_2O_3**	**Al_2O_3**	**TiO_2**	**K_2O**	**CaO**	**SO_3**	**P_2O_5**
A-10	65.40	15.40	14.00	2.85	1.08	0.34	0.00	0.87
A-50	61.10	17.00	17.00	2.60	1.42	0.35	0.00	0.00
A-100	59.10	12.20	18.00	2.72	1.84	0.39	0.00	0.00
A-150	46.30	21.90	14.00	1.84	1.22	0.42	0.04	0.00
B-10	48.50	34.19	11.00	1.92	0.82	0.32	0.00	1.00
B-50	61.10	12.80	20.00	2.82	2.11	0.36	0.00	0.71
B-100	44.60	20.10	15.00	2.18	1.74	0.42	0.00	0.00
B-150	44.50	22.80	14.00	1.91	1.43	0.52	0.00	0.00
C-10	75.20	7.73	12.00	2.80	1.13	0.36	0.00	0.00
C-50	72.20	7.67	15.00	2.82	1.39	0.38	0.01	0.00
C-100	72.40	5.96	16.00	2.87	1.60	0.38	0.00	0.00
C-150	53.00	16.90	14.00	2.34	1.21	0.39	0.03	0.00
D-10	50.47	11.70	12.46	1.77	1.25	0.61	19.09	2.29
D-50	59.96	21.56	11.07	1.93	1.05	0.65	0.00	2.82
D-100	71.61	4.92	14.57	2.51	1.59	0.79	0.00	3.28
D-150	34.01	19.95	8.08	1.52	0.98	0.78	30.47	2.43
E-10	49.46	15.65	12.06	1.85	1.28	0.75	15.36	2.63
E-50	74.15	5.30	11.88	2.73	1.20	0.71	0.00	3.32
E-100	58.49	7.72	13.75	2.95	2.46	1.15	7.90	0.00
E-150	55.17	11.97	13.72	1.97	1.41	0.68	11.59	2.61
F-10	72.52	6.62	11.99	2.69	1.32	0.64	0.00	2.87
F-50	71.99	4.20	14.90	2.61	1.64	0.72	0.00	3.21
F-100	59.83	10.61	13.06	2.05	1.51	0.71	8.58	2.77
F-150	47.77	15.83	13.03	1.76	1.24	0.70	16.18	2.35

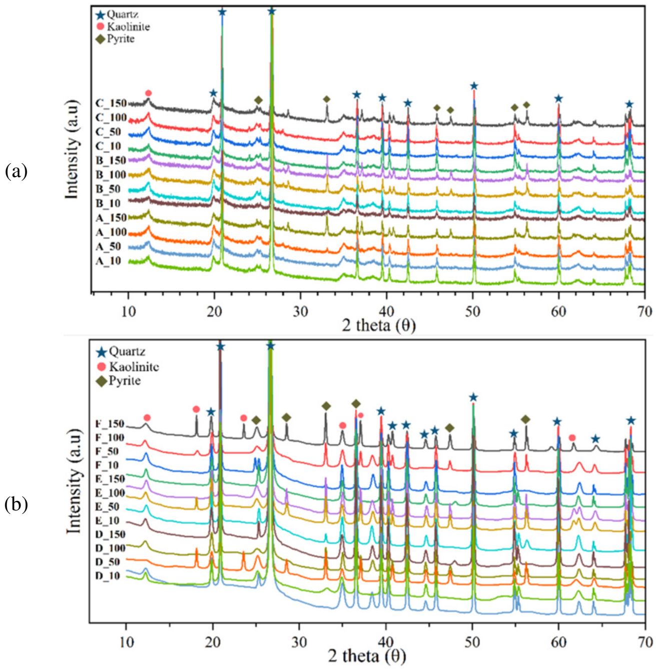


Fig. 5. XRD measurement results of peat soil samples.

3) *SEM Analysis Results*

SEM with EDS mapping exhibits the chemical morphology of peat soil, as shown in Figure 6. This microstructure confirms the geological conditions of the study area. That is, the peat soil is of a sapric type with a granular texture and irregular structure rich in minerals. At a depth of 0.10 m, as presented in Figure 6(a), the dominant elements are O, Si, Al, Fe, and C, while the minor elements are Mg, K, Ti, and Zn. At a depth of 1.50 m, as displayed in Figure 6(b), the dominant elements are O, Si, Al, S, and Fe, while the minor elements are Mg, K, Ti, and Zn. The presence of pyrite indicates the influence of certain geological factors that are characteristic of potential sulphate soils in a tidal swamp environment. Pyrite is observed throughout the soil volume, forming a conductive network of pathways throughout the peat matrix. This phenomenon causes soil conductivity to vary, depending on the level of decomposition and peat water flow [48].

Figure 7 presents an SEM image and the composition of peat soil from location D at a depth of 1.50 m. A honeycomb-shaped porous structure is demonstrated, which is characteristic of diatom shells made of biogenic silica (SiO_2), which are the remains of microscopic algae. Diatoms were also found in the peatlands of Northeastern China [49] and the Hongshuipao peatland, located in the middle of the Greater Hinggan Mountains [50].

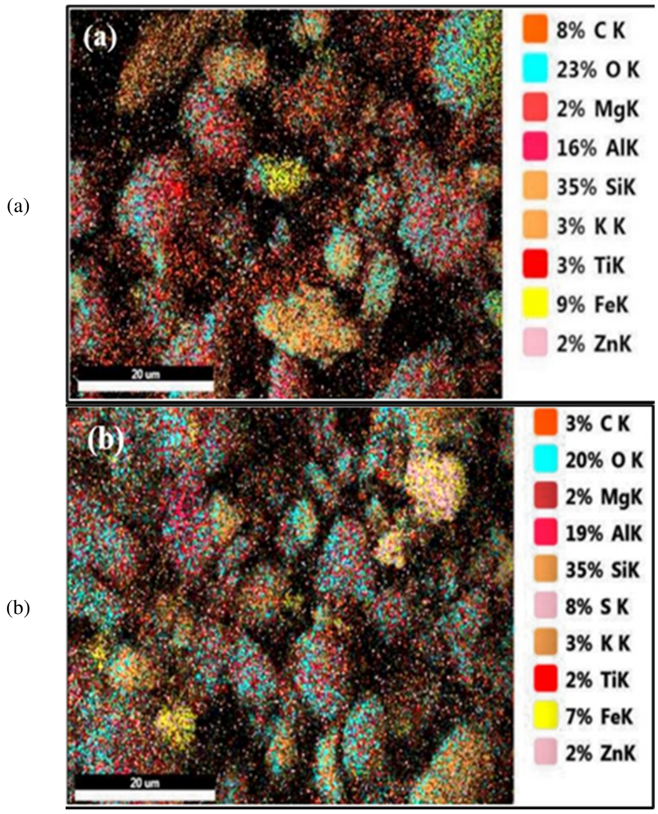
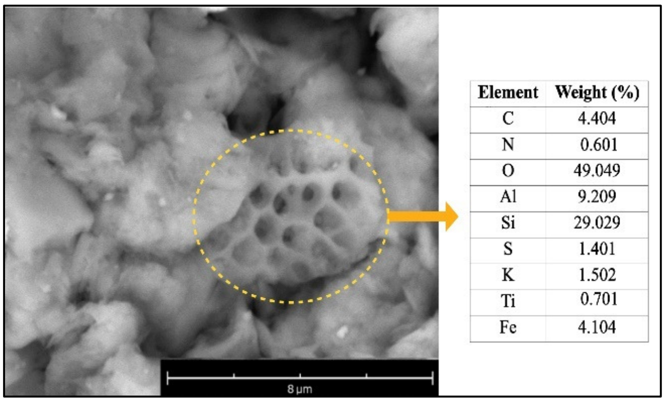


Fig. 6. Mapping SEM-EDX of surface morphology of peat soil at a depth of: (a) 0.10 m; (b) 1.00 m.



Element	Weight (%)
C	4.404
N	0.601
O	49.049
Al	9.209
Si	29.029
S	1.401
K	1.502
Ti	0.701
Fe	4.104

Fig. 7. Morphology of peat soil at a depth of 1.50 m under 10× magnification.

C. *Geophysical Properties*

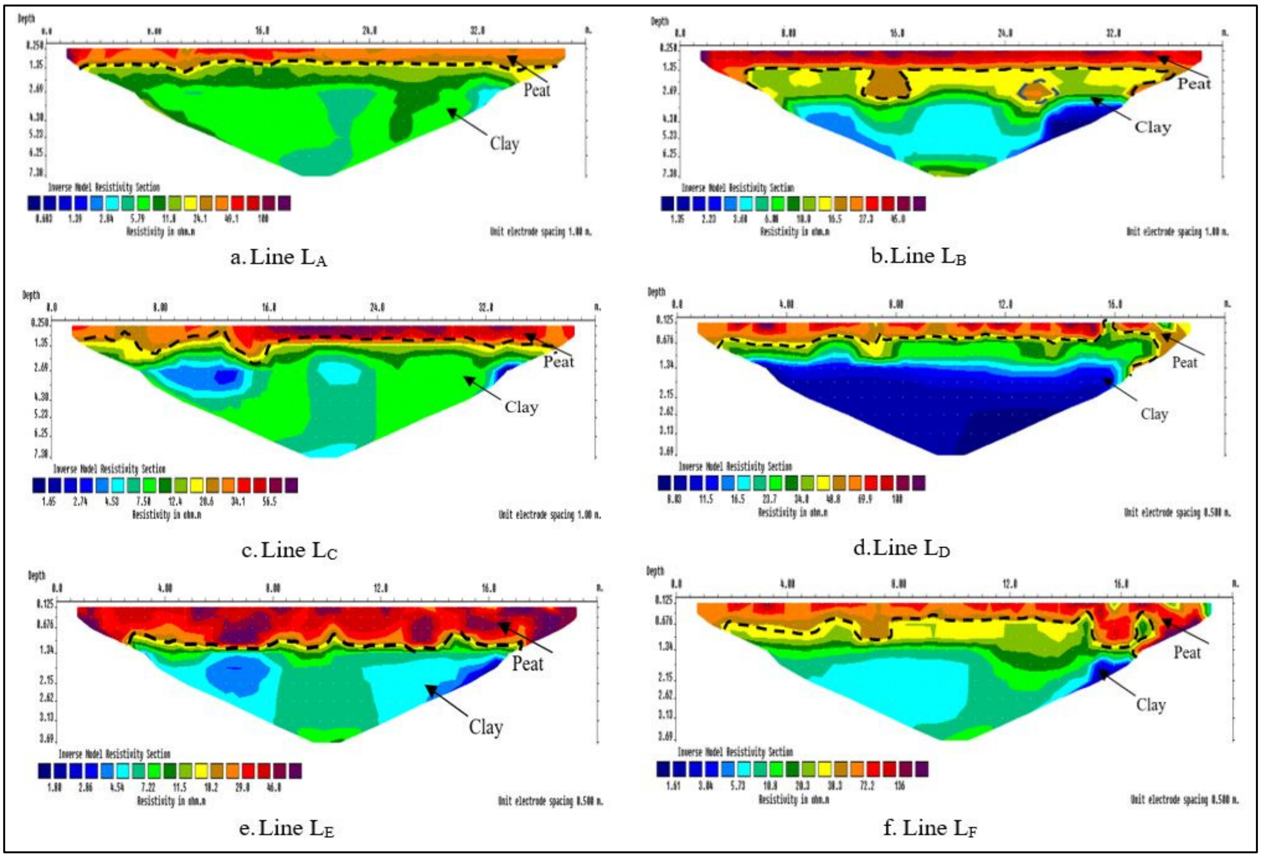
Subsurface lithological interpretation has been carried out based on the electrical resistivity properties of the soil. Figure 8 portrays 2D resistivity cross sections on transects L_A, L_B, and L_C for degraded land and transects L_D, L_E, and L_F for intact peatland. The geophysical measurements presented in Table IV show stratigraphy at a depth of 7.38 m, indicating that the study area has two types of layers: peat and clay. In degraded land, the thickness of the peat layer was found to be around 1.35 m, with peat resistivity ranging from 16.5 to 135.86 Ωm, as reported in [53]. The underlying layer is clay with soil resistivity ranging from 0.57 to 24.10 Ωm, as proposed in [55]. In intact peatlands, the peat layer is thickest/thicker at approximately 1.00–1.25 m with a resistivity of approximately 33.0–153.29 Ωm, and underneath it is a clay layer with a resistivity of approximately 4.81–20.4 Ωm. Based on the thickness of the peat, the peat soil at this location is suitable for conversion because its thickness is less than 3 m, as proposed in [5]. In the context of future infrastructure development in this area, this study focuses on depths up to 1.5 m.

TABLE IV. PEAT SOIL LITHOLOGY BASED ON RESISTIVITY

line	Depth (m)	Resistivities (Ωm)	Layer
L_A	0.00 – 1.35	24.10 – 134.86	Peat
	1.35 – 7.38	0.57 – 24.10	Clay
L_B	0.00 – 1.35	16.50 – 69.72	Peat
	1.35 – 7.38	1.23 – 16.50	Clay
L_C	0.00 – 1.35	20.60 – 69.72	Peat
	1.35 – 7.38	1.25 – 20.60	Clay
L_D	0.00 – 1.34	28.20 – 132.96	Peat
	1.34 – 3.69	1.21 – 28.20	Clay
L_E	0.00 – 1.25	18.20 – 68.66	Peat
	1.25 – 3.69	1.40 – 18.20	Clay
L_F	0.00 – 1.25	28.10 – 153.29	Peat
	1.25 – 3.69	2.86 – 28.10	Clay

Based on resistivity, there are other minerals present in the soil besides peat and clay, such as sand (1–1000 Ωm), saturated gravel (100–600 Ωm, silt (10–200 Ωm) [51], pyrite (0.01–1000 Ωm), and kaolinite (1–150 Ωm) [52]. These results are consistent with the content found in alluvial deposits such as clay, silt, and sand [4]. Variations in soil resistivity lead to soil anisotropy [53], which can cause buildings on anisotropic peat to undergo higher settlement. Furthermore, the difference in resistivity poses a risk when used as a building foundation since it causes uneven soil compaction and is prone to settlement.

Based on geophysical and geochemical studies in the research location, the peat soil is classified as sapric peat. The Fe and S in peat soil contribute to soil stability and also affect the rate of corrosion. The presence of pyrite (FeS_2) oxidizes to form sulfuric acid, thereby lowering soil pH. Thus, infrastructure development on peatlands must pay attention to land preparation, especially in selecting the type and volume of fill soil as a foundation. Table V presents the prediction of peat soil subsidence at the study location based on soil resistivity. In line with these predictions, the study makes geotechnical recommendations for foundation designs, such as the use of slab or raft foundations for light buildings on peat and dense sand layers with resistivity >100 Ωm. Deep foundations, such as precast concrete piles, are proposed for heavier buildings in areas with resistivity <100 Ωm. Meanwhile, acid-resistant concrete or concrete mixed with pozzolanic materials, such as fly ash, is proposed to resist sulphate attack. Epoxy-coated or galvanized steel can also help prevent the corrosion of the reinforcement [54].



a. Line L_A b. Line L_B

c. Line L_C d. Line L_D

e. Line L_E f. Line L_F

Fig. 8. 2D resistivity cross sections on transects L_A, L_B, and L_C for degraded land and transects L_D, L_E, and L_F for intact peatland.

TABLE V. INTERPRETATION OF PEAT SOIL LITHOLOGY BASED ON RESISTIVITY

Resistivity (Ωm)	Interpretation geology	Land subsidence prediction	Reference
< 20	The peat is very saturated and soft	Rapid land subsidence under load, mechanically unstable	[55]
20–99	High mineral content; dry, dense peat	Land subsidence is moderate, slower, weak, and not suitable for engineering practice	[55]
>100–153.29	Most of it is solid mud	Minimal land subsidence, suitable for light foundations	[56]

IV. CONCLUSION

The investigation of peat soil in Abumbun Jaya Village, Sungai Tabuk Regency, South Kalimantan, shows that the soil possesses important physical properties, such as sapric peat, and is also rich in oxide minerals such as SiO_2, Al_2O_3, and Fe_2O_3. These minerals form quartz, kaolinite, amesite, nacrite, illite, ilmenite, hematite, and goethite, which help maintain soil stability. EDX mapping confirms that these elements are evenly distributed throughout the peat soil. However, at depths of 1.00 m and 1.50 m, sulphur made the peat acidic, causing it to react with air to form sulphate and sulphite compounds. At depths of 1.00 m and 1.50 m, sulphur oxides were also detected, causing the soil to become more acidic under drainage or aeration conditions, which produced sulphate and sulphide compounds. This process increased the acidity of the soil, leading to a corrosive environment that could damage building structures and degrade soil structure. Based on the resistivity values measured to a depth of approximately 1.50 m, peat soils are divided into two categories: first, soils with moderate to slow subsidence (resistivity between 20 and 99 Ωm), and second, those with very little subsidence, making them suitable for light building foundations (resistivity less than 100–153 Ωm). The soil with resistivity 50–140 Ωm may undergo moderate compression. If it is filled with dense sandfill (resistivity less than 120 Ωm), it can be made suitable for foundations. Based on the findings of this study, construction on peatlands can be carefully planned. Management of peatlands before conversion ensures sustainable development and protects the environment.

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REFERENCES

[1] I. N. Layli, A. Nur, D. Donny, S. Gibran, R. H. Shandika, and Qomari, "South Kalimantan Province in Figures 2024," South Kalimantan Provincial Statistics Agency, South Kalimantan, Indonesia, Technical Report 63000.24001, Feb. 2024.

[2] "South Kalimantan's Economy Grew 4.81 Percent in the First Quarter of 2025," *Antara News*, Central Jakarta, Indonesia, 2025.

[3] *Presidential Regulation Number 85 of 2024 concerning the Banjarbakula Metropolitan Urban Area's National Spatial Plan (RTR KSN)*, Jakarta, Indonesia: Sekretariat Negara RI, 2024.

[4] R. H. N. Sikumbang, "Geological Map of the Banjarmasin Sheet, Kalimantan," Geological Research and Development Center, Bandung, Indonesia, 1994.

[5] K. Telapak, *Tracing the Path of Peatland Management: Threats, Conflicts, and A Sustainable Future*. Jakarta, Indonesia: Pantau Gambut, 2025.

[6] A. E. Abdel-Salam, "Stabilization of Peat Soil using Locally Admixture," *HBRC Journal*, vol. 14, no. 3, pp. 294–299, Dec. 2018, https://doi.org/10.1016/j.hbrcj.2016.11.004.

[7] M. Fabius, "Peat Unit Weight Effects on Embankment Stabilization," presented at the GeoEdmonton 2008: the 61. Canadian Geotechnical Conference and 9. Joint CGS/IAH-CNC Groundwater Conference, Edmonton, AB, Canada, Sept. 2008.

[8] D. Kurlov and T. Marcovic, "Experimental Study of Improving The Physical Properties of Peat Soil using Sand and Bio-Grouting Techniques with the Assistance of Bacillus Subtilis Bacteria," *Journal of Geoscience, Engineering, Environment, and Technology*, vol. 8, no. 1, pp. 69–76, June 2023, https://doi.org/10.25299/jgeet.2023.8.1.13464.

[9] S. Indahyani, B. Sumawinata, and D. Darmawan, "Measuring Peat Soil Water Retention using a Combination of Three Phase Meters and Ceramic Plates," *Buletin Tanah dan Lahan*, vol. 1, no. 10, pp. 9–14, 2017.

[10] O. B. Olatinsu, S. O. Olawusi, and M. O. Ogieva, "Electrical Resistivity Characterization of Peat and Clay Profiles at a Suburb of Ota, Southwest Nigeria," *Communication in Physical Sciences*, vol. 12, no. 1, pp. 84–102, Feb. 2025, https://doi.org/10.4314/cps.v12i1.8.

[11] S. R. Wahyunto and H. Subagjo, *Map of Peatland Distribution Area and Carbon Content in Kalimantan 2000-2002*. West Java, Indonesia: Wetlands International, 2004.

[12] X. Comas, L. Slater, and A. Reeve, "Geophysical and Hydrological Evaluation of Two Bog Complexes in a Northern Peatland: Implications for the Distribution of Biogenic Gases at the Basin Scale," *Global Biogeochemical Cycles*, vol. 19, no. 4, Dec. 2005, Art. no. 2005GB002582, https://doi.org/10.1029/2005GB002582.

[13] L. D. Slater and A. Reeve, "Investigating Peatland Stratigraphy and Hydrogeology using Integrated Electrical Geophysics," *Geophysics*, vol. 67, no. 2, pp. 365–378, Mar. 2002, https://doi.org/10.1190/1.1468597.

[14] T. Phiranram, P. Chenrai, A. Jirapinyakul, and N. Rachukarn, "Geophysical and Chemical Characteristics of Peatland in Coastal Wetland, Southern Thailand," *Frontiers in Marine Science*, vol. 11, Jan. 2024, Art. no. 1287362, https://doi.org/10.3389/fmars.2024.1287362.

[15] "Impact of the 2021 South Kalimantan Floods: Roads Cut Off, Thousands of Homes Submerged," *Tirta Adi Surya*, Jakarta, Indonesia, 2021.

[16] Maulida, "Not Just Once, here's a List of Buildings in South Kalimantan That Suddenly Collapsed," *Peristiwa Online*, Jakarta, Indonesia, 2022.

[17] "The cause of houses collapsing in Banjarmasin," *Mediakita*, Jakarta, Indonesia, 2021.

[18] A. Kurnain, "Hydrophysical Properties of Ombrotrophic Peat under Drained Peatlands," *International Agrophysics*, vol. 33, no. 3, pp. 277–283, July 2019, https://doi.org/10.31545/intagr/110773.

[19] S. Maysarah, Y. Nugroho, and S. Susilawati, " Analysis of Physical Properties of Soil on Peat Land in Liang Anggang District, Banjarbaru City, South Kalimantan Province," *Jurnal Sylva Scienteae*, vol. 4, no. 1, Apr. 2021, Art. no. 166, https://doi.org/10.20527/jss.v4i1.3104.

[20] F. Dirga Subardi, M. Yusa, and L. Darmayanti, "Study of the Physical Properties of Peat Land Against Electrical Resistivity using Geoelectrical Instruments (Case Study: Lukun Village, Tebing Tinggi Timur District, Meranti Islands Regency)," *Sainstek (e-Journal)*, vol. 10, no. 1, pp. 60–66, June 2022, https://doi.org/10.35583/js.v10i1.9.

[21] Hikmatullah and Sukarman, "Physical and Chemical Properties of Cultivated Peat Soils in Four Trial Sites of ICCTF in Kalimantan and Sumatra, Indonesia," *Journal of Tropical Soils*, vol. 19, no. 3, Oct. 2015, Art. no. 131, https://doi.org/10.5400/jts.2014.v19i3.131-141.

[22] S. Safrizal, O. Oksana, and R. Saragih, " Analysis of the Chemical Properties of Peat Soil in Three Types of Land Use in Pangkalan Panduk Village, Kerumutan District, Pelalawan Regency," *Jurnal Agroteknologi*, vol. 7, no. 1, Jan. 2017, Art. no. 27, https://doi.org/10.24014/ja.v7i1.2461.

[23] N. Huda, Z. T. Mariana, and H. Ifansyah, "Characteristics of Transitional Peat and Inland Peat of South Kalimantan at the Hemic Decomposition Level," *Acta Solum*, vol. 1, no. 1, pp. 36–40, Nov. 2022, https://doi.org/10.20527/actasolum.v1i1.1385.

[24] F. Agus, M. Anda, A. Jamil, and Masganti, *Indonesian Peatlands: Formation, Characteristics and Potential to Support Food Security*, Jakarta, Indonesia: Indonesian Agency for Agricultural Research and Development Press, 2016.

[25] A. Razmyar and A. Eslami, "Geotechnical Characterization of Soils in the Eastern and Western Areas of Tehran," *Engineering, Technology & Applied Science Research*, vol. 7, no. 4, pp. 1802–1810, Aug. 2017, https://doi.org/10.48084/etasr.1200.

[26] O. E. Kanyawan and Z. Zulfian, "Identification of Subsurface Layer Structure using Geoelectric Resistivity Method as Initial Information for Building Foundation Design," *PRISMA FISIKA*, vol. 8, no. 3, Dec. 2020, Art. no. 196, https://doi.org/10.26418/pf.v8i3.43675.

[27] S. T. Gonggo and F. E. D. Suherman, "Physicochemical Characterization of Clay Minerals as a Raw Material of Ceramic Industry in Desa Lembah Bomban Kec. Bolano Lambunu Kab. Parigi Moutong," *J. Akad. Kim.*, no. 2, pp. 105–113, May 2013.

[28] S. A. Akinyemi, O. F. Adebayo, H. Y. Madukwe, A. O. Aturamu, and O. A. OlaOlorun, "Mineralogy and Geochemistry of Shales of Mamu Formation in Nigeria: Effects of Deposition, Source Rock, and Tectonic Background," in *Geochemistry and Mineral Resources*, H. M. Saleh and A. I. Hassan, Eds. IntechOpen, 2022.

[29] A. Mirwan, M. D. Putra, and R. A. Lestari, "Potential Peat Clay for Minerals Source Utilized as Adsorbent and Catalyst," *MATEC Web of Conferences*, vol. 280, 2019, Art. no. 04003, https://doi.org/10.1051/matecconf/201928004003.

[30] O. Iqbal, E. Padmanabhan, A. Mandal, and J. Dvorkin, " Characterization of Geochemical Properties and Factors Controlling the Pore Structure Development of Shale Gas Reservoirs," *Journal of Petroleum Science and Engineering*, vol. 206, Nov. 2021, Art. no. 109001, https://doi.org/10.1016/j.petrol.2021.109001.

[31] A. Hooijer *et al.*, "Subsidence and Carbon Loss in Drained Tropical Peatlands," *Biogeosciences*, vol. 9, no. 3, pp. 1053–1071, Mar. 2012, https://doi.org/10.5194/bg-9-1053-2012.

[32] C. S. Deshmukh *et al.*, "Conservation Slows Down Emission Increase from a Tropical Peatland in Indonesia," *Nature Geoscience*, vol. 14, no. 7, pp. 484–490, July 2021, https://doi.org/10.1038/s41561-021-00785-2.

[33] *Test Method for Bulk Density of Fine-Grained Soils using Test Specimens*," SNI 03-3637, Badan Standardisasi Nasional, Jakarta, Indonesia, 1994.

[34] *SNI 2828:2011 Field Method for Testing Soil Density using a Sand Cone Apparatus*. Badan Standardisasi Nasional, 2011.

[35] R. R. Weil and N. C. Brady, *The nature and properties of soils*, 15th edition. Columbus, OH, USA: Pearson, 2016.

[36] A. Kirana, W. Candra, and H. A. Hayati, "Study of the Wettability of Peat Soil in South Kalimantan," vol. 8, pp. 113–116, Apr. 2023.

[37] H. Joosten, "Global Guidelines for Peatland Rewetting and Restoration," Wetlands Ramsar Technical Report 11, Ramsar Convention on Wetlands, 2021.

[38] R. R. E. Artz *et al.*, "FTIR Spectroscopy can be Used as a Screening Tool for Organic Matter Quality in Regenerating Cutover Peatlands," *Soil Biology and Biochemistry*, vol. 40, no. 2, pp. 515–527, Feb. 2008, https://doi.org/10.1016/j.soilbio.2007.09.019.

[39] R. R. E. Artz *et al.*, "FTIR Spectroscopy can Predict Organic Matter Quality Inregenerating Cutover Peatlands," *Soil Biology and Biochemistry*, Jan. 2008.

[40] A. Samuel Obeng, J. Dunne, M. Giltrap, and F. Tian, " Soil Organic Matter Carbon Chemistry Signatures, Hydrophobicity and Humification Index Following Land Use Change in Temperate Peat Soils," *Heliyon*, vol. 9, no. 9, Sept. 2023, Art. no. e19347, https://doi.org/10.1016/j.heliyon.2023.e19347.

[41] N. Wang, Q. Yin, and X. Du, "Experimental Investigation into the Performances of Water Adsorption in Kaolinite Clay: Implications for Occupational Pneumoconiosis Prevention and Treatment," *Journal of Taibah University for Science*, vol. 16, no. 1, pp. 535–549, Dec. 2022, https://doi.org/10.1080/16583655.2022.2079329.

[42] A. J. Margenot, F. J. Calderón, K. W. Goyne, F. N. D. Mukome, and S. J. Parikh, "IR Spectroscopy, Soil Analysis Applications," in *Encyclopedia of Spectroscopy and Spectrometry*, Elsevier, 2017, pp. 448–454.

[43] M. Morishita and M. Kawahigashi, " Heterogeneity in Peat Decomposition Evaluated by Fourier Transform Infrared Micro-spectroscopy," in *15th International Peat Congress*, Kuching, Sarawak, Malaysia, 2016, pp. 132–135.

[44] X. Min, Y. Li, Y. Ke, M. Shi, L. Chai, and K. Xue, "Fe- FeS2 Adsorbent Prepared with Iron Powder and Pyrite by Facile Ball Milling and its Application for Arsenic Removal," *Water Science and Technology*, vol. 76, no. 1, pp. 192–200, July 2017, https://doi.org/10.2166/wst.2017.204.

[45] R. H. Ellerbrock and H. H. Gerke, "FTIR Spectral Band Shifts Explained by OM–Cation Interactions," *Journal of Plant Nutrition and Soil Science*, vol. 184, no. 3, pp. 388–397, June 2021, https://doi.org/10.1002/jpln.202100056.

[46] B. Gong, D. Li, Z. Niu, Y. Liu, and Z. Dang, " Inhibition of Pyrite Oxidation Using PropS-SH/sepiolite Composite Coatings for the Source Control of Acid Mine Drainage," *Environmental Science and Pollution Research*, vol. 28, no. 9, pp. 11090–11105, Mar. 2021, https://doi.org/10.1007/s11356-020-11310-0.

[47] A. Schlichting, P. Leinweber, R. Meissner, and M. Altermann, "Sequentially Extracted Phosphorus Fractions in Peat-Derived Soils," *Journal of Plant Nutrition and Soil Science*, vol. 165, no. 3, pp. 290–298, June 2002, https://doi.org/10.1002/1522-2624(200206)165:3%3C290::AID-JPLN290%3E3.0.CO;2-A.

[48] R. Q. Muslim and S. Ritung, " Distribution of Pyrite Depth and Soil Properties in Fresh Water Swampland in North Candi Laras Sub-district, South Kalimantan Province," *IOP Conference Series: Earth and Environmental Science*, vol. 648, no. 1, Feb. 2021, Art. no. 012041, https://doi.org/10.1088/1755-1315/648/1/012041.

[49] X. Chen *et al.*, "Diatom-Based Water-Table Reconstruction in Sphagnum Peatlands of Northeastern China," *Water Research*, vol. 174, May 2020, Art. no. 115648, https://doi.org/10.1016/j.watres.2020.115648.

[50] N. Li *et al.*, "Diatom Evidence for Mid-Holocene Peatland Water-Table Variations and Their Possible Link to Solar Forcing," *Science of The Total Environment*, vol. 725, July 2020, Art. no. 138272, https://doi.org/10.1016/j.scitotenv.2020.138272.

[51] J. M. Reynolds, *An introduction to applied and environmental geophysics*, 2nd edition. Chichester, West Sussex Hoboken: Wiley-Blackwell, 2011.

[52] S. Igbani and S. T. Torubeli, "Investigating clay deposit resistance and resistivity using ground tester model 6470-B," *Research Journal of Chemical Sciences*, vol. 8, no. 6, pp. 1–6, Jun. 2018.

[53] S. Soto-Caban and E. Law, "Using Resistivity Measurements to Determine Anisotropy in Soil and Weathered Rock," *Engineering, Technology & Applied Science Research*, vol. 3, no. 4, pp. 483–487, Aug. 2013, https://doi.org/10.48084/etasr.368.

[54] A. M. Neville, *Properties of Concrete*. Harlow Munich, Germany: Prentice Hall, 2011.

[55] U. S. Eze, M. E. Okiotor, J. E. Ighodalo, B. J. Owonaro, A. S. Saleh, and A. S. Jamiu, "Application of 2-D and 3-D Geo-electrical Resistivity Tomography and Geotechnical soil Evaluation for Engineering site Investigation: A Case Study of Okerenkoko Primary School, Warri-Southwest, Delta State, Nigeria," *Advances in Geological and Geotechnical Engineering Research*, vol. 5, no. 2, pp. 1–23, Mar. 2023, https://doi.org/10.30564/agger.v5i2.5382.

[56] O. B. Olatinsu, K. F. Oyedele, and A. A. Ige-Adeyeye, "Electrical Resistivity Mapping as a Tool for Post-Reclamation Assessment of Subsurface Condition at a Sand-Filled Site in Lagos, Southwest Nigeria," *SN Applied Sciences*, vol. 1, no. 1, Jan. 2019, Art. no. 24, https://doi.org/10.1007/s42452-018-0028-5.