Properties of soils from different landform and parent material in Kundur Island, Kepulauan Riau Province

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Abstract. Information on soil properties derived from different landform and parent material can be used to establish an agricultural development strategy. This study aimed to determine the properties of the soil in Kundur Island. The soil survey was conducted to determine soils distribution and properties. A total of 24 samples from 8 pedons representing each landform and parent material were taken for laboratory analysis. The results showed that soils in Kundur Island were lying in granite intrusion, alluvial, peat, fluviomarine, and marine landform. The soil classifications were Dystrudepts, Hapludults, Udipsamments, Haplohemists, Haplosaprist, and Endoaquepts. The peat soil land was acidic to very acidic (pH 2.6-3.5) with very high Al saturation (62-81%) due to mineral enrichment. Udipsamments derived from granite intrusion have higher carbon content and slightly lower base saturation than Dystrudepts and Hapludults, which were derived from the same parent material. The soil in fluviomarine landform contains very high exchangeable Na (12.9-18.0 cmol, kg⁻¹) due to the influence of saline water. For the agricultural development in Kundur Island, soil derived from granite intrusion and peatland need liming to suppress soil acidity while soil derived from clay and sand deposits in alluvial and fluviomarine landform should consider saline water intrusion.

1. Introduction
Kundur Island is located in Karimun Regency, Kepulauan Riau Province, with an area of 315.4 km² [1]. There are three subdistricts on Kundur Island, namely North Kundur, Kundur, and West Kundur. The north of Kundur Island is bordered by Karimun Island, the south is bordered by Pelalawan Regency, the west is bordered by Mendol Island, while the east is bordered by Bela Island. Kundur Island is known as a producer of tin and superior durian [2-3]. As a border area in the form of a small island, Kundur Island has a granite-filled landscape with peatland all around the area. Based on Siaksiindrapura and Tanjung Pinang geological maps [4], Kundur Island consists of four geological formations. There were Mtikn formation, Qp formation, Qh formation, and Mtp formation. Mtikn, which was defined as Kundur granite, lay in the center of Kundur Island. Meanwhile Qp formation, a formation of older superficial deposits of clays, silts, clayey gravels, vegetation rafts and granite sands in Kundur Island and Karimun Island, fully spread around Mtikn.

The soil has an essential role in environmental functions. Soil characteristics differ from one region to another [5]. The broad characteristics of parent material would influence the properties of the soil [6]. Many studies discussed the properties and characteristics of soil in Indonesia, but none have yet explained soil comprehensively in Kundur Island. Information on how soil properties vary in landform
and parent material can be used to better understand the potential of the land. This study aims to understand the characteristics of the soils at Kundur Island.

2. Materials and methods
The study area was located in Kundur Island, Karimun Regency, Kepulauan Riau Province, with coordinate location on 0°53'52.097" to 0°38'8.563" Northern and 103°16'47.042" to 103°31'7.24" Eastern. This region has a tropical climate with D1 rainfall type according to the Oldeman climate classification system [7]. The average annual rainfall was 2,253 mm per year. The highest rainfall is in November and the lowest rainfall is in July. The average air temperature was 26.1-27.2 °C and the average air humidity varies from 74-86% [1].

A preliminary soil map has been prepared before the soil survey was conducted. Soil samples were collected from each horizon from the representative profile or minipit or boring, which represented the landform and parent material [8]. Figure 1 shows the map of Kundur Island with marks of the soil survey area and the sampling point.

![Figure 1. Location of soil observation and soil sampling in Kundur Island. (a) The position of the study area, (b) the observation points and sample points.](image)

| Pedon | Parent material         | Landform            | Coordinate             | Land use         |
|-------|-------------------------|---------------------|------------------------|------------------|
| P1    | Granite                 | Intrusion plain     | 103° 22'47.006” E 0° 42’45.673” N | Rubber plantation |
| P2    | Granite                 | Intrusion plain     | 103° 24'16.063” E 0° 50’8.200” N | Rubber plantation |
| P3    | Granite                 | Intrusion plain     | 103° 22’58.796” E 0° 51’39.506” N | Rubber plantation |
| P4    | Organic deposits        | Topogenous peat     | 103° 21’11.804” E 0° 47’30.638” N | Palm oil plantation |
| P5    | Organic deposits        | Topogenous peat     | 103° 29’12.228” E 0° 45’25.312” N | Shrub |
| P6    | Clay deposits           | Aluvial             | 103° 26’47.900” E 0° 48’31.727” N | Paddy field      |
| P7    | Clay and sand deposits  | Aluvial             | 103° 21’28.062” E 0° 49’21.328” N | Rubber plantation |
| P8    | Clay and organic deposits | Fluviomarine    | 103° 25’30.623” E 0° 38’48.491” N | Palm oil plantation |
A total of 24 samples from 8 pedons was then analyzed in the laboratory. Information on the coordinates location and land use of studied pedons was presented in table 1. The physical and chemical analyses were conducted to determine the nature of the soil. The analyses were performed according to the guidelines summarized by Eviati and Sulaeman [9] included texture, pH (H₂O), organic carbon, potential P and K, cation exchange rate, cation exchange capacity (CEC), base saturation, and Al saturation. Soil pH was measured in the ratio of 1:5 liquid:soil (supernatant suspension) that was shaken for 30 minutes. Organic carbon was determined according to Walkley and Black methods. The total P₂O₅ and total K₂O content were measured in HCl 25% extract. Exchangeable cations, cation exchange capacity, and base saturation were extracted by NH₄-Acetat 1N pH 7.

3. Results and discussion
The area of Kundur Island is 31,333 ha based on estimation on the map of Kundur Island. There were three parent materials, namely granite, alluvium, and peat. The soils lay in five landforms, namely alluvial, fluviomarine, marine, peat, and volcanic. The most expansive area is volcanic landform with granite parent material in an area of 15,572 ha afterward alluvial with clay and sand deposits parent material in an area of 6,232 ha, peatland in an area of 3,190 ha, alluvial with clay deposits parent material in an area of 2,206 ha, fluviomarine with clay and organic deposits in an area of 1,935 ha.

3.1. The morphological and physical attribute
Result showed that soils derived from granite parent material have higher sand content compared to other soils. In addition, sand content in topsoil was higher than in subsoil (P1, P2, P3). The textures of granite parent material soils in P1, P2, P3 were loamy sand, sandy loam, sandy clay loam, with clay content less than 42%.

The texture of the soil is greatly influenced by parent material. Among soils from granite parent material, Regosol was undeveloped mineral soil while Kambisol and Podsolik were developed mineral soil [10]. The soil development could be seen from the texture of the soil. The more developed the soil was, the less sandy the texture was. Regosol has loamy sand texture, Kambisol has sandy loam to sandy clay loam texture, and Podsolik has sandy clay loam to sandy clay texture. The colors of all pedons derived from granite parent material were 7.5YR and 10YR hue. The depth, color, and texture of each pedons were presented in table 2.

Soils in alluvial landform (P6, P7) have a noticeable difference in texture. The soil derived from alluvial parent material was influenced by the river channel’s location or water source. The further a location from the river channel, the higher clay content and lower sand content [6]. P6, which was derived from clay deposits, has silty clay loam and silty clay textures. This texture may due to its location which was far from a river channel. The color of P6 was very dark gray to gray. As P6 land use was rice fields, the soil was in water-saturated conditions which caused the soil to turn grayish. P7 derived from clay and sand deposits has sandy loam, sand, and loamy sand texture. P8 derived from clay and organic deposits have silt loam, sandy clay loam, and silty clay texture. According to Siaksrindrapura and Tanjung Pinang geological maps [7], P7 and P8 were located in Qp formation where there was granite sands material into the formation. In addition, the location of P7 and P8 may be influenced by the texture of the soils from the granite parent material.

As in Hikmatullah and Sukarman [12] study, the peat soil colors were generally dark in all horizons due to the high organic matter content. The maturity of P4 was hemic and P5 was sapric.
Table 2. Morphological and physical attribute of pedons.

| Pedon     | Soil classification USDA [11]/KTN [10] | Horizon | Depth (cm) | Matrix color          | Texture/maturity |
|-----------|----------------------------------------|---------|------------|-----------------------|------------------|
| P1        | Typic Udipsamments/Regosol Distrik     | Ap      | 0-21       | 10YR 3/1              | very dark gray    | loamy sand       |
| P2        | Typic Dystrudepts/Kambisol Distrik     | Ap      | 0-18       | 10YR 3/2              | very dark grayish brown | sandy loam      |
|           |                                        | Bw2     | 40-90      | 10YR 5/6              | yellowish brown   | sandy loam       |
| P3        | Typic Hapludults/Podsolik Haplik        | Ap      | 0-25       | 10YR 3/2              | very dark grayish brown | sandy clay loam |
| P4        | Typic Haplohemists/Organosol Hemik      | Oe1     | 0-50       | 10YR 2/2              | very dark brown   | hemic            |
|           |                                        | Oe2     | 50-150     | 10YR 3/1              | very dark gray    | hemic            |
| P5        | Typic Haplosaprist/Organosol Saprik     | Oa1     | 0-60       | 7.5YR 2.5/1           | black             | sapric           |
| P6        | Typic Endoaquepts/Gleisol Distrik      | Ap      | 0-17       | 2.5Y 3/1              | very dark gray    | silty clay loam  |
|           |                                        | Bg1     | 17-40      | 2.5Y 4/2              | dark grayish brown | silty clay loam  |
|           |                                        | Bg2     | 40-67      | 2.5Y 5/1              | gray              | silty clay       |
| P7        | Typic Dystrudepts/Kambisol Distrik     | Ap      | 0-23       | 10YR 2/1              | black             | sandy loam       |
|           |                                        | Bw1     | 23-56      | 7.5YR 2.5/2           | very dark brown   | sand             |
|           |                                        | Bw2     | 56-120     | 7.5YR 3/2             | dark brown        | loamy sand       |
| P8        | Sulfic Endoaquepts/Gleisol Sulfik       | Ap      | 0-18       | 7.5YR 2.5/1           | black             | silty loam       |
|           |                                        | Bg1     | 18-44      | 2.5Y 5/2              | grayish brown     | sandy clay loam  |
|           |                                        | Bg2     | 44-120     | 2.5Y 5/1              | gray              | silty clay       |

3.2. Soil properties

There are two categories of parent materials in broad categories in Kundur Island: igneous rock (granite) and unconsolidated materials (peat, alluvium, marine). Soils from granite parent materials in intrusion plain landform were mostly found on the Kundur Island.

Table 3 presented information of mineral analysis of pedon. Sand mineralogy contents of soil derived from granite in Kundur Island were turbid quartz (52%), clear quartz (41%), and tourmaline (7%). Furthermore, there also found zircon, weathered mineral, and rock fragment sporadically. Granite as a highly siliceous parent material has moderate to high levels of quartz compared to other materials [6]. Clay mineralogy contents of the soil were predominant of kaolinite and rarely of vermiculite and gibbsite. General chemical properties of soils derived from granite parent material could be related to its mineralogy. There are three types of soil, namely Regosol, Kambisol, Podsolic. Soils derived from granite have low acidity. In P2 and P3, the pH increased with depth (table 4). This possibly due to the leaching of bases from topsoil to lower ones [13]. Granite parent material was characterized by low level of bases such as magnesium and calcium [6]. Soils in P1, P2, P3 showed lower levels of Ca and Mg compared to soil with other parent materials.

Regosol has pH of 4.4-4.9, slightly acidic compared to Kambisol and Podsolic (ranged from 4.6-4.8). Regosol has a higher organic carbon content and lower base saturation compared to Kambisol and Podsolic. The organic carbon content in Regosol ranged from 1.69 to 5.96%, while in Kambisol and Podsolik ranged from 0.69 to 2.35% and 0.53-1.91%, respectively. Base saturation in Regosol ranged from 15-19%, while in Kambisol and Podsolik ranged from 19-21%. Regosol in granite parent
material has a very acidic to acidic pH [14-15], high organic carbon content [14], and lower base saturation compared to Kambisol and Podsolic.

**Table 3.** Information of mineral analysis in soil from granite parent material and soil from clay deposits material.

|                | Sand mineralogy | Clay mineralogy |
|----------------|-----------------|-----------------|
|                | Turbid quartz   | Clear quartz    |
|                | Tourmaline      | Zircon          |
|                | Weathered mineral | Rock fragment |
|                | Kaolinite       | Vermiculite     |
|                | Gibbsite        | Illite          |
| Pgm            | 52              | 41              |
| Pcd            | 7               | sp              |
|                | sp              | sp              |
|                | ++++            | (+)             |
|                | (+)             | -               |
|                | +++             | -               |
| Remarks: Pgm= pedon in granite parent material, Pcd= pedon in clay deposits parent material, sp= sporadic, +++ = predominant, +++ = dominant, + = minor, (+) = trace/rarely, - = not detected.

Clay mineralogy contents of the soil derived from clay deposits in Kundur Island showed the existence of kaolinite (dominant) and illite (minor). The presence of these two minerals indicated the strong influence of the granite parent material on Kundur Island to the other soils. P6, P7, P8 as soil from material-deposited were included in the alluvial parent material. These soils have variable organic content and base content, but generally moderate or higher [6]. It can be seen in table 4 that organic carbon of P6, P7, P8 have high value, ranged from 5.12-5.74% in P6, 5.98-11.04% in P7, and 7.69-20.90% in P8.

P6 and P7 refer to alluvial plains. Agricultural lands in Kundur Island, such as the paddy field in P6, are widespread in alluvial plains, while P7 was rubber plantation. Soil CEC was low. The low soil CEC is the main obstacle to soil fertility [16]. Alluvial soils derived from clay deposits have better pH, the number of cations, and base saturation than alluvial soils derived from clay and sand deposits, presumably due to the influence of brackish water.

The soil in fluviomarine on Kundur Island is Sulfic Endoaquepts (P8). The nature of parent material influenced the exchangeable cations in the fluviomarine [17]. P8 with clay and organic deposits parent material has exchangeable cations decreased in the subsoil in the following order: Na>Mg>Ca>K. The dominant exchangeable Na was caused by the influence of the seawater [18]. This soil has very acid to acidic pH (3.2-4.2) and moderate to high Al saturation (13-22%). As the depth decreased, the pH value decreased and the Al saturation increased. This can be caused by the existence of drainage or canal that was connected to the sea. The existence of drainage can decrease pH value and increase Al content from pyrite oxidation [19]. The cation exchange capacity is related to the soil organic matter content [17]. In P8, Soil CEC decreased with soil depth. This was due to the decreasing organic carbon content. P8 showed very low P2O5 (1-14 mg 100g-1) and moderate K2O (25-32 mg 100g-1). The higher content of K can be caused by K fertilization in P8, where the land use was palm oil plantation.

Kundur Island’s peatland spread over in several areas adjacent to the sea, located around 415 to 6,700 meters from the coastline. Peat in Kundur Island is included in the great group of Haplohemists and Haplosaprists. P4 was Typic Haplohemists and P5 was Typic Haplosaprist. P4 and P5 as peat soils pedon have very acidic pH, ranged from 2.6-3.5. The pH value of peat soil tends to decrease with the depth of peat [12]. In P5, peat at 60-160 cm has lower pH than the upper peat at 0-60 cm. P4 and P5 have very high aluminum saturation, ranged from 62-81%. Peat soils have an acidic pH and high aluminum saturation content, probably due to mineral enrichment. The peat position in Kundur was probably the cause of mineral enrichment.
Table 4. Information of chemical analysis observed.

| Pedon | Depth (cm) | pH (H₂O) | C  | N  | P₂O₅ | K₂O | Cation exchange rate (NH₄Acet 1N, pH 7) | Effective Basesaturation | Base saturation | Al % |
|-------|------------|----------|----|----|-------|-----|----------------------------------------|--------------------------|----------------|------|
| P1    | 0-21       | 4.4      | 3.85 | 0.12 | 4 | 3 | 0.56 0.33 0.05 0.02 2.70 15 65 |            |                |      |
|       | 21-66      | 4.8      | 5.96 | 0.17 | 9 | 1 | 0.93 0.49 0.02 0.02 3.08 16 53 |            |                |      |
|       | 66-120     | 4.9      | 1.69 | 0.06 | 3 | 1 | 0.39 0.17 0.01 0.05 1.71 19 64 |            |                |      |
| P2    | 0-18       | 4.8      | 2.35 | 0.05 | 5 | 3 | 0.42 0.24 0.06 0.12 1.88 21 55 |            |                |      |
|       | 18-40      | 4.7      | 1.11 | 0.02 | 3 | 1 | 0.39 0.20 0.02 0.05 1.74 19 62 |            |                |      |
|       | 40-90      | 4.6      | 0.69 | 0.01 | 2 | 1 | 0.32 0.18 0.02 0.03 1.63 19 66 |            |                |      |
| P3    | 0-25       | 4.8      | 1.91 | 0.07 | 6 | 3 | 0.46 0.30 0.06 0.13 2.35 20 60 |            |                |      |
|       | 25-51      | 4.6      | 0.93 | 0.03 | 5 | 1 | 0.45 0.27 0.02 0.11 2.32 19 63 |            |                |      |
|       | 51-102     | 4.6      | 0.53 | 0.02 | 4 | 1 | 0.38 0.21 0.02 0.09 2.13 20 67 |            |                |      |
|       | 102-120    | 4.8      | 0.42 | 0.02 | 5 | 1 | 0.43 0.22 0.01 0.04 1.86 20 62 |            |                |      |
| P4    | 0-50       | 3.4      | 37.95| 1.38 | 7 | 4 | 2.76 1.08 0.07 0.41 16.63 5 74 |            |                |      |
|       | 50-150     | 3.3      | 33.39| 0.99 | 2 | 3 | 1.33 1.42 0.04 0.47 11.52 5 72 |            |                |      |
|       | 150-360    | 3.5      | 32.75| 0.84 | 1 | 3 | 2.89 0.96 0.03 0.50 11.67 9 62 |            |                |      |
| P5    | 0-60       | 3.3      | 51.91| 1.54 | 7 | 6 | 1.98 3.12 0.11 0.26 16.85 6 68 |            |                |      |
|       | 60-160     | 2.6      | 44.49| 1.27 | 4 | 5 | 1.82 2.04 0.09 0.32 22.19 5 81 |            |                |      |
| P6    | 0-17       | 4.8      | 5.74 | 0.17 | 17| 12| 1.98 3.62 0.18 1.33 9.95 60 29 |            |                |      |
|       | 17-40      | 4.9      | 5.33 | 0.15 | 10| 16| 1.80 4.56 0.26 1.99 11.40 75 24 |            |                |      |
|       | 40-67      | 4.8      | 5.12 | 0.13 | 7 | 22| 1.91 4.90 0.40 2.11 12.25 74 24 |            |                |      |
| P7    | 0-23       | 3.8      | 6.79 | 0.21 | 3 | 4 | 0.33 0.19 0.07 0.07 4.26 5 85 |            |                |      |
|       | 23-56      | 3.7      | 5.98 | 0.15 | 1 | 2 | 0.36 0.17 0.03 0.05 3.46 6 82 |            |                |      |
|       | 56-104     | 3.4      | 11.04| 0.27 | 8 | 2 | 0.38 0.18 0.02 0.02 9.58 4 94 |            |                |      |
| P8    | 0-18       | 4.2      | 20.90| 0.64 | 14| 32| 2.32 0.80 0.63 15.08 23.03 38 18 |            |                |      |
|       | 18-44      | 4.1      | 9.39 | 0.30 | 3 | 25| 2.13 9.64 0.47 12.90 28.88 >100 13 |            |                |      |
|       | 44-120     | 3.2      | 7.69 | 0.26 | 1 | 29| 2.49 13.39 0.55 18.00 44.16 >100 22 |            |                |      |

4. Conclusions

The parent material of the soils on Kundur Island were Udipsamments (Regosol) in P1, Dystrudepts (Kambisol) in P2, and Hapludults (Podsolik) in P3 lying in granite intrusion with granite parent material; Haploxemis in P4 and Haplosaprists in P5 (Organosol) lying in peat; Endoaquepts (Gleisols) in P6 and P7 lying in alluvial with clay deposits and clay and organic deposits; and Dystrudepts (Kambisol) in P8 lying in alluvial with clay and sand deposits.

Soils derived from granite parent material have higher sand content in comparison to other soils. These soils contain resistant sand minerals such as turbid quartz, clear quartz, and tourmaline while the clay mineralogy of the soils was kaolinite, vermiculite, and gibbsite. The pH of the soils was acidic and the levels of Ca and Mg were low. As a comparison, Regosol has very acidic to acidic pH, high organic carbon, and lower base saturation compared to Kambisol and Podsolik.

Soil derived from peat were hemic and sapric maturity. The pH of the peats was very acidic (2.6-3.5) and had high aluminum saturation (62-81%).
Soil derived from alluvium have higher clay content (P6 and P8), while P7 as soil from clay and sand deposits have higher sand content. The clay mineralogy of the soils was kaolinite and illite. This mineral presence indicated the influence of granite parent material to the other soils in Kundur Island.

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