Magnetic properties of soils from landslide potential area
(Case study: Pasir Ipis-Lembang, West Bandung)

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Abstract. In this study we have analized magnetic properties of soils from landslide potential area. Top soil and four soil cores from Pasir Ipis as study area were taken as samples. All samples measured by rock magnetism method, magnetic susceptibility, to describe the characteristic of the physical property of samples. Magnetic susceptibility values of top soil samples are ranging from $193 \times 10^{-8}$ m$^3$/kg to $545 \times 10^{-8}$ m$^3$/kg, whereas for soil cores the magnetic susceptibility values range from $245 \times 10^{-8}$ m$^3$/kg to $674 \times 10^{-8}$ m$^3$/kg. It implies that the soil samples are dominated by ferrimagnetic minerals. Relative difference of magnetic susceptibility values measured at two frequencies or $\chi_{fd}(\%)$ for all samples range from 2 to 10 $\%$, indicating that the samples contain a mixture of ultrafine superparamagnetic grains and non superparamagnetic grains.

1. Introduction
In West Java, landslides are natural hazards that commonly occur. According to Center for Volcanology and Geological Hazard Mitigation (PVMBG) since at least 2011 to 2013 there were 87 incidences and 323 landslide prone areas in West Java [1]. There are increasing number of occurrence, especially in the rainy season, that needs special attention in prevention and mapping landslide potential areas. There are number of studies have been carried out to evaluate landslide areas using geophysical methods. Deniyanto (2011) [2] used radar method to identify the landslide slip zone, whereas Bartha et al. (2005) [3] have analyzed water content and mineralization process at Sudety mountains with resistivity measurement. Rock magnetic method have been used by Kosaka (2000) [4] to evaluate landslide deposits in Tsurukawa fault zone in Japan. In this study we have analyzed the magnetic properties of soils from Pasir Ipis, West Java. Pasir Ipis is categorized as red zone area which is an area that susceptible to landslide due to climate change conditions which also influences to magnetic susceptibility [5,6]. The magnetic properties analysis was carried out based on magnetic susceptibility values of soil samples taken in the study area. The aim of this study is to provide information about magnetic properties of soil from landslide potential area.

2. Site Description and Method
The soil samples were obtained from Pasir Ipis which has geographic coordinate S 06°49′15″ E 107°37′48″ and elevation of 1580 masl. This area lies in the slope of Mt. Tangkubanperahu. We have...
collected topsoil samples from 17 sampling points. The soil samples were also obtained from surface to a certain depth in the form of four soil cores.

All soil samples were subjected to volume magnetic susceptibility, \( \kappa \), measurement using Bartington MS2 Susceptibility Meter with a sensor of type B (MS2B). Bartington MS2B performed on dual frequencies, which are 470 Hz as a low frequency and 4700 Hz as high frequency. The volume magnetic susceptibility values were then converted into mass-specific magnetic susceptibility to have mass magnetic susceptibility in low and high frequencies (\( \chi_{LF} \) and \( \chi_{HF} \), respectively). The relative difference of \( \chi_{LF} \) and \( \chi_{HF} \) produces a parameter known as frequency-dependent susceptibility (\( \chi_{fd} \)). The frequency-dependent susceptibility can be expressed in the form of a percentage or \( \chi_{fd}(\%) \), defined as \( 100 \% \times (\chi_{LF} - \chi_{HF})/\chi_{LF} \). The \( \chi_{fd}(\%) \) value indicates the presence of ultrafine magnetic grains or superparamagnetic grains in the sample.

3. Result and Discussion

Magnetic susceptibility measurements showed that the soil samples have magnetic susceptibility values in the range of \( 193 \times 10^{-8} \) m\(^3\)/kg - \( 674 \times 10^{-8} \) m\(^3\)/kg. Based on Dearing [7], the samples are controlled by ferrimagnetic minerals. Topsoil samples has magnetic susceptibility value ranging from \( 193 \times 10^{-8} \) m\(^3\)/kg to \( 545 \times 10^{-8} \) m\(^3\)/kg. The mapping of the magnetic susceptibility values is shown in Figure 1.

![Figure 1. Distribution of magnetic susceptibility values of topsoil samples.](image)

We have four soil cores samples, namely core 1, core 2, core 3, and core 4. The four soil cores have different penetration of depth. The elevation, penetration of depth and magnetic susceptibility values for each core are shown in Table 1. Plot of variation of magnetic susceptibility values with depth is shown in Figure 2.
Table 1. Elevation, depth and magnetic susceptibility of soil cores samples

| No | Elevation (m) | Depth (cm) | Range of magnetic susceptibility ($\times 10^{-8} \text{ m}^3/\text{kg}$) |
|----|--------------|------------|----------------------------------------------------------|
| 1  | 1511         | 165        | 292 – 459                                                |
| 2  | 1526         | 285        | 246 – 430                                                |
| 3  | 1526         | 130        | 558 – 673.88                                             |
| 4  | 1655         | 140        | 265 – 425                                                |

Every core has different magnetic susceptibility values due to differences of geomorphology area. There are decreasing magnetic susceptibility values each 5 cm penetration of depth that indicated by differences of water content [8] which influences to magnetic susceptibility values due to water has diamagnetic susceptibility (negative and low magnetic susceptibility) [7]. Plot of variation of magnetic susceptibility values with depth is shown in Figure 2.

Figure 2. Plot of magnetic susceptibility values of soil core samples with depth

The $\chi_d$ (%) values of topsoil samples soil cores samples are in the range of 1.24% - 9.33%. Most of soil samples were found to have $\chi_d$ (%) value in a range of 2% - 10%, indicating that the soil samples contain...
a mixture of ultrafine superparamagnetic grains and non-superparamagnetic grains. Superparamagnetic grains have magnetic grain size less than 0.03 μm. This conclusion was supported by plot of $\chi_{LF}$ with respect to $\chi_{fd}$ (%), as shown in Figure 3, for soil cores samples. A reference plot taken from Dearing (1999).

Figure 3 show superparamagnetic chart [7], indicating that $\chi_{fd}$ (%) values of four soil cores has range 2 - 10%, indicating that the soil samples contain a mixture of ultrafine superparamagnetic grains and non-superparamagnetic grains. The $\chi_{fd}$ (%) has the smallest value at a depth of 110 cm which indicates the absence of superparamagnetic grain and has the highest values at a depth of 50 cm in coring two.

4. Conclusion
From rock magnetic studies of soils from landslide potential area, the following conclusions could be drawn. First, the soil samples from Pasir Ipis has magnetic susceptibility values are in the range of $193 \times 10^{-8}$ m$^3$/kg to $673.88 \times 10^{-8}$ m$^3$/kg which indicates the dominated of ferrimagnetic mineral. Second, the $\chi_{fd}$ (%) values are within the range between 2-10% shows that the composition of magnetic minerals in the sample is a combination of ultrafine superparamagnetic grains and non-superparamagnetic grains. The existence of ultrafine grains may have correlations with the susceptibility landslide.

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