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Magnetic properties and magnetic minerals morphology of orchards soils Batu Malang

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Abstract. Apples Plantation is one of the national agricultural assets, especially fruits commodities. This study examined magnetic properties, especially magnetic susceptibility and morphology of magnetic minerals in orchards soils Batu Malang. The magnetic susceptibility test was conducted using Bartington MS2B and magnetic minerals morphology performed by SEM-EDX test. The results showed that the orchards soils magnetic susceptibility has a range of $2.58 - 8.26 \times 10^{-6} \text{m}^3 \text{kg}^{-1}$. The results of SEM-EDX test, indicate that magnetic minerals of orchards soils Batu Malang has octahedral shape, that may this magnetic mineral comes from pedogenic processes with various size is $40.64 - 143.07 \mu\text{m}$. Some magnetic minerals are spherules that indicate the magnetic minerals come from anthropogenic processes with various size is $34.38 - 67.02 \mu\text{m}$.

1. Introduction

Batu is a city in East Java Province located at $112^\circ 17'10.90''$ - $122^\circ 57'11''$ E and $7^\circ 44'55.11''$ - $8^\circ 26'35.45''$ S. Batu is one of the cities in East Java which is very potential for developing agriculture. One agricultural production that has valuable commodity in Batu is apple plantation. Apple is an annual fruit plant that grows well in the highlands [1]. Some excellent Apple varieties include Rome Beauty, Manalagi, Anna, Noble and Wangli or Lali [2].

In an effort to improve the growth and production of apple, it is necessary to examine the physical properties of soil by understanding the magnetic properties of minerals contained in apple plantation soil and the processes that may affect the formation of these magnetic minerals. From the magnetic properties can be obtained information about the properties of magnetic minerals, the content of elements contained in the soil, morphology of magnetic minerals and sources of magnetic mineral [3–5]. As the main carrier of magnetic properties in sediments, soils, or other natural samples, magnetic minerals can contribute as specific environmental background throughout its growth [6].

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Magnetic susceptibility has proven to be one of the most reliable, economical and fast methods for tracking the state of the soil environment [7]. Magnetic susceptibility can be used to investigate mineral concentration and grain size distributions of different Fe-oxides in soil or sediment [8]. This technique also proved to be a useful indicator in assessing soil properties in various environmental conditions [9]. Magnetic soil susceptibility has also been shown to be affected by parent materials, climate change and anthropogenic contribution such as industrial pollution, fossil fuel combustion, transportation and agro-chemicals.

Another parameter used to assess soil physical properties is the morphology of magnetic minerals. The morphology of magnetic minerals provides information about the source of magnetic minerals originating from pedogenic, anthropogenic or lithogenic [4], and the shape of magnetic minerals. On the other hand, the magnetic grain size information is adjusted to the domain type whether included in single-domain (SD), multi-domain (MD), or pseudo-single domain (PSD) [10]. Efforts to find out the environmental conditions of magnetic minerals are very important, not to mention the soil of the Apple Plantation. This is because of identification obtained some information about pollution, fertility, and magnetic properties of the soil.

2. Experimental Method

The research begins with sampling in the field, then preparations and samples test are carried out in the laboratory. The sampling stage was carried out at the Coban Talun Apple Plantation located between 112°17'10.90" - 122°57'11" E and 7°44'55.11" - 8°26'35.45 S. Sampling was carried out in 4 randomly determined gardens, and in each garden was divided into 5 points. 140 samples were taken from 5 points in each garden. In each point was taken 10 and spaced 10cm depth. The small portion of samples were inserted into the plastic clip and prepared to holder sample for magnetic measurement in Central Laboratory of FMIPA UM using the MS2B (Bartington Susceptibility Meter). Subsequently, the samples that has the lowest and highest susceptibility, named A.2.1.4 and C.5.1.3 were conducted for SEM-EDX test to obtain the morphology of magnetic minerals.

The analysis was conducted on the magnetic susceptibility value of κ (kappa) then converted to the of mass magnetic susceptibility χ . From the acquisition of low and high frequency magnetic susceptibility, then the magnetic susceptibility frequency dependent can be calculated. To find the magnetic domain distribution, the value of magnetic susceptibility of low frequency and magnetic susceptibility frequency dependent show in plot of graph. Furthermore, data analysis of SEM-EDX test results to find the magnetic mineral morphology of samples.

3. Results and Discussion

3.1 Magnetic Susceptibility

The magnetic susceptibility average of apple plantation soils which includes the magnetic susceptibility low frequency (χ_{lf}), the magnetic susceptibility high frequency (χ_{hf}) and frequency-dependent magnetic susceptibility (χ_{fd}) of each sampling location are shown in Table 1.

Table 1. Range of Susptibility Results with Dependent Frequency

Plantation Location	Range of Susceptibility			Average of Susceptibility		
	χ_{lf} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	χ_{hf} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	χ_{fd} (%)	χ_{lf} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	χ_{hf} ($10^{-6} \text{ m}^3 \text{ kg}^{-1}$)	χ_{fd} (%)
A	2.58 – 7.64	2.43 - 7.50	1.7 – 5.8	5.41	5.23	3.5
B	4.52 – 7.48	4.36 - 7.37	1.3 – 4.9	6.26	6.08	2.9

C	4.67 – 8.26	4.46 - 7.95	2.3 – 4.8	6.45	6.23	3.4
D	3.99 – 8.16	4.35 - 7.97	2.3 – 5.4	6.22	5.99	3.8

The results of the analysis show the magnetic susceptibility range of $2.577 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ to $8.258 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ and the average susceptibility value of $6.0862 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. The highest average susceptibility value is found in Location C that is χ_{lf} of $6.4498 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$, χ_{hf} of $6.2342 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ and the smallest is in Location A is χ_{lf} of $5.4094 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ whereas χ_{hf} is $5.2311 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$.

The magnetic susceptibility value of each Location shows almost the same result, this is because the sampling location is located in one area and has similar environmental conditions. In the Location A has a range χ_{lf} of $2.577 - 7.639 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ with an average value of χ_{lf} of $5.4094 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. Location B has a range χ_{lf} $4.521 - 7.481 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ with an average value of χ_{lf} $6.2597 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. Location C has a range χ_{lf} $4.673 - 8.258 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ with an average value of χ_{lf} $6.4498 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. Whereas Location D has a range χ_{lf} $3.994 - 8.156 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$ with mean value χ_{lf} $6.2221 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$.

The analysis result shows magnetic susceptibility value of $2.577-8.258 \times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. Judging from the average value of susceptibility low frequency (χ_{lf}) the magnetic properties of the Batu City apple plantations are classified by paramagnetic properties because their magnetic susceptibility is positive and low [11]. The relationship between the magnetic susceptibility with the dependent frequency shown in Figure 1 is the greater the magnetic susceptibility value, the smaller the dependent frequency value.

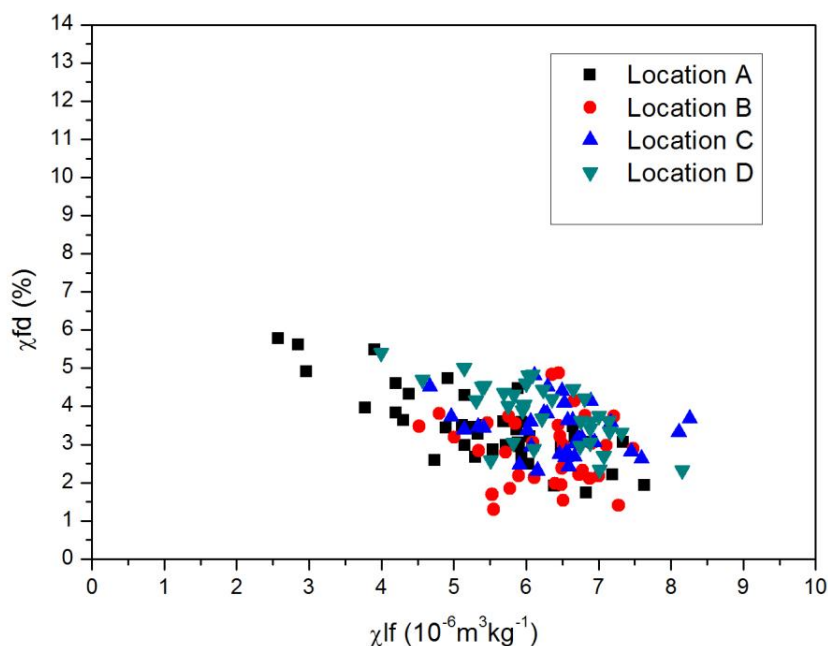


Figure 1. Graph of Relation between Low Frequency Magnetic Susceptibility with Dependent Frequency

Figure 1 shows that some samples have a range of $\chi_{fd}\%$ between 0-2% indicating that the sample is a Multidomain grain (MD) that has no SP grain at all. Most of the samples have a range of χ_{fd} between 2-10% indicating that the sample is a blend of superparamagnetic grain and non-superparamagnetic coarse grain, or SP grain with size $<0.005\mu\text{m}$ [11].

One of the factors influencing magnetic susceptibility value is grain size and shape. Based on the value of χ_{fd} in Table 2, it is known that the Batu City apple plantation has a value of χ_{fd} 0 - 2% indicating that the sample is a Multidomain grain (MD) which has no SP grain at all. Most of the samples have a range of χ_{fd} between 2-10% indicating that the sample is a blend of superparamagnetic grain and non-superparamagnetic coarse grain, or SP grain with size $<0.005\mu\text{m}$ [11].

3.2 Morphology of Magnetic Minerals

3.2.1 Morphology of Magnetic Minerals Sample A.2.1.4

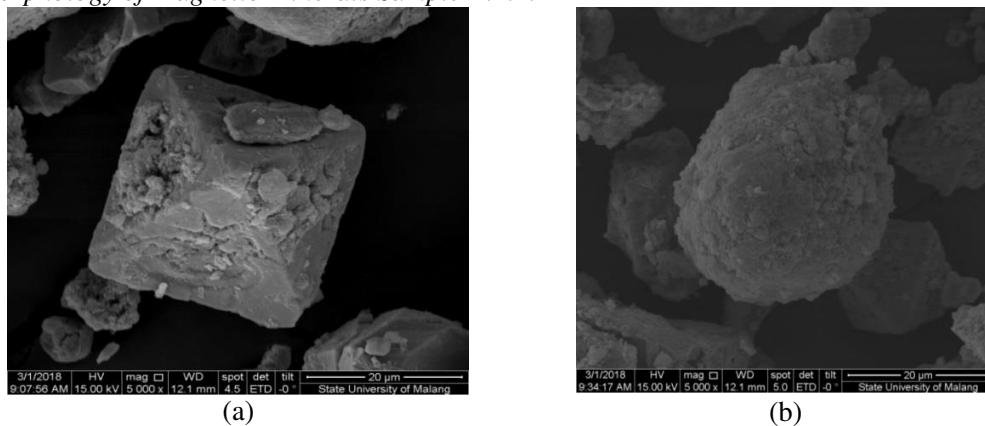


Figure 2. Morphology of Magnetic Minerals extracted from sample A.2.1.4 (a) magnification 2000x, (b) magnification 5000x.

Table 2. EDX data of Magnetic Minerals

Element	Wt%	At%	Element	Wt%	At%
OK	19.81	32.88	OK	29.59	36.41
MgK	02.43	02.66	MgK	00.72	00.62
AlK	03.47	03.42	AlK	00.34	00.27
SiK	00.72	00.68	SiK	19.01	13.87
TiK	05.20	02.88	TiK	17.17	12.03
FeK	53.97	25.66	FeK	13.66	04.82
Matrix	Correction	ZAF	Matrix	Correction	ZAF

Figure 2 shows SEM images with magnification of 2000x and 5000x which have octahedral shapes indicate that these magnetic minerals are derived from the pedogenic process [4] and some are spherules, rounded magnetic minerals indicating the magnetic minerals are derived of anthropogenic processes [12].

The EDX analysis provides information on the chemical composition of the magnetic mineral. From the characterization results it is known that in Figure 2 (a) the highest element concentration is Fe equal to 53.97 Wt%, followed by element O equal to 19.81% and Ti equal to 5.2 Wt%. It is therefore assumed that the samples contained a mineral type of titanomagnetite which is an association of magnetite (Fe_3O_4) with ulvospinel (FeTiO_3) [12,13]. It is also supported based on the morphology of magnetic mineral grains, octahedral or angular shaped grains (Angular Shape) is typical of titanomagnetite fragments [4]. When considered as a whole it is possible to form compounds such as Hematite (Fe_2O_3), Rutile (TiO_2), Ilmenite (FeTiO_3), Quartz (SiO_2) and some elements such as Aluminum (Al) and Magnesium (Mg). While in Figure 2 (b) visually the surface is rough, brightly colored and hollow. The bright color of this magnetic mineral is influenced by the Si element which has a high concentration of 19.01 Wt% and element O

which has a concentration of 29.59 Wt% which causes many cavities and is an impurity [14]. The grain size of these minerals is 40.941 μm and 34.380 μm .

3.2.2 Morphology of Magnetic Minerals Sample A.2.1.4

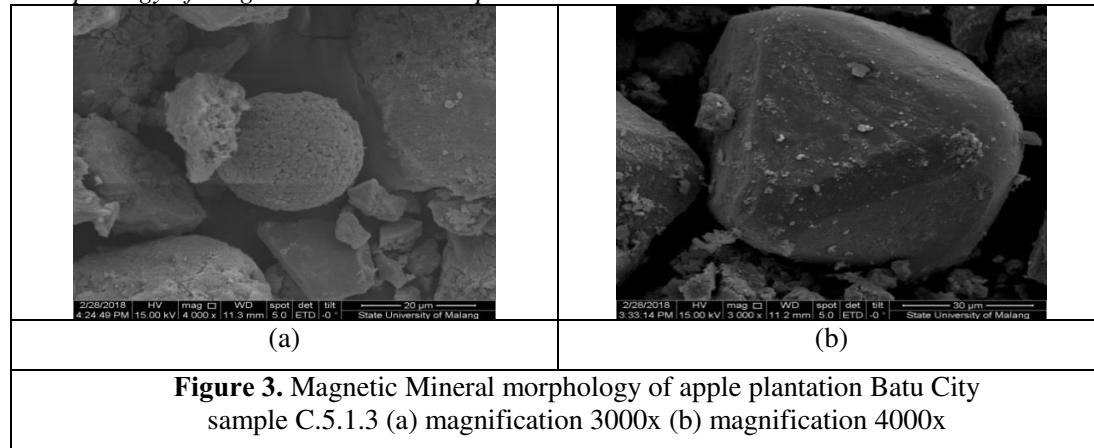


Figure 3. Magnetic Mineral morphology of apple plantation Batu City sample C.5.1.3 (a) magnification 3000x (b) magnification 4000x

Table 3. Results of Magnetic Mineral EDX

Element	Wt%	At%	Element	Wt%	At%
OK	11.10	23.08	OK	16.46	31.24
MgK	02.23	03.05	MgK	02.27	02.83
AlK	03.13	03.86	AlK	04.20	04.73
SiK	00.90	01.07	SiK	02.73	02.95
TiK	05.53	03.84	TiK	08.97	05.69
FeK	68.29	40.69	FeK	56.78	30.87
<i>Matrix</i>	<i>Correction</i>	<i>ZAF</i>	<i>Matrix</i>	<i>Correction</i>	<i>ZAF</i>

Figure 3. The SEM images with magnification 3000 \times and 4000 \times that have octahedral shapes indicating that these magnetic minerals are derived from the pedogenic process and some are rounded magnetic minerals indicating that the minerals are derived from anthropogenic processes.

Based on the EDX characterization, the magnetic grain of Fig. 3 (a) has a smooth and non-hollow surface, which is because the magnetic grain has a high Fe concentration of 68.29 Wt% and then followed by element O which has a concentration of 11.10 Wt%. When considered as a whole it is possible to form compounds such as Hematite (Fe_2O_3), Rutile (TiO_2), Ilmenite (FeTiO_3), Quartz (SiO_2) and some elements such as Aluminum (Al) and Magnesium (Mg) [10]. While in Figure 3 (b) visually the surface is rough, and hollow. The rough and hollow surface of this magnetic mineral is influenced by the element O which has a concentration of 16.46 Wt%. The grain size of these minerals is 89.003 μm and 27.225 μm .

4. Conclusion

The magnetic susceptibility analysis show that apple plantation soils in Batu has a range of 2.58 – 8.26 $\times 10^{-6} \text{ m}^3 \text{ kg}^{-1}$. Analysis of domain distribution from magnetic susceptibility of low frequency and dependent frequency magnetic susceptibility shows that the overall sample obtained has an average grain spread of a mixture of superparamagnetic and non-superparamagnetic grains <0.005 μm . While the image of SEM-EDX characterization shows that magnetic minerals extracted from of Batu apple plantation soils have rounded and octahedral shape. The octahedral could be derived from a pedogenic process, whereas the spherical form is derived from an anthropogenic process.

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