The interaction of peat and sulphidic material as substratum in wetland: ash content and electrical conductivity dynamic

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Abstract. A part of peatlands in Indonesia developed above sulfidic material. They spread around the tidal swamps area. Vertical tide movement will certainly bring consequences to the behaviour of both materials, such as ash content and electrical conductivity properties. The research was conducted to study ash content and electrical conductivity of peatland with several thickness and acid sulphate soil under some hydrological conditions. The results showed that ash content and electrical conductivity decreased with increasing of peat thickness, especially in upper layer of peatland. Decrease and disappear of peat layer has increased the ash content and electrical conductivity in the peat layer and in the sulfidic layer. Declining of ground water level increased electrical conductivity of soil.

1. Introduction
About 206.000 km² peatlands are found in Indonesia [1]. They formed in low altitude coastal and sub-coastal situations, in which 10,52 million ha of them influenced by tidal force [2]. Based on geographical condition of peat formation, the sulfidic material is often found under peat layer, and almost of peatland are associated with acid sulphate soils.

Peat is origin from organic matter, it contains large amount of carbon (C). Peat defined as material that contain C less than 18 % if the mineral fraction contains ≥ 60 % clay, or < 12 % if the mineral fraction contains no clay; or < 12 % if the mineral fraction contains < 60 % clay [3]. The correlation of C content and other minerals (stated as ash content) of soil is a negative correlation. The relationship between C and ash content is a reflection of relationship of peat thickness and ash content in the field. In which, ash content is increase with decreasing peat thickness. According to [4] ash content of tropical peatland is range < 1 % to > 65 %. In the term of soil fertility, ash content may used as an indicator of peat soil fertility, topogenous peat stated more fertile than ombrogenous peat, this fact relate with higher ash content in topogenous peat than ombrogenous peat. The ash content of peat often correlated with the quantity of mineral particles from fields and other bare soils [5].

In addition to ash content, other soil property that describe the presence of nutrients in the soil is electrical conductivity (EC). Soil EC is an important indicator of soil health. It affects to crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms. Although EC does not provide a direct measurement of specific ions, it has been correlated to concentrations of many soil nutrients such as nitrates, potassium, sodium, sulfate, and ammonia. For certain non-saline soils, determining EC can be a simple method to estimate the amount of available nitrogen (N) for plant growth. [6] stated EC of inland peat ranges 40 - 100 mS cm⁻¹ and 140–320 mS cm⁻¹ for coastal peat [7]. The value of EC indirectly indicates the amount of water and water-soluble nutrients available for plant uptake, it means the value of soil EC is influence by soil water content.
Based on those conditions, therefore a better understanding of the interaction of peat and sulphidic material on ash content and electrical conductivity dynamic in wetland for a better management of peatland. The research was conducted to study the role of groundwater level fluctuations on P concentration at peatland with sulphidic material substratum.

2. Materials and Methods

2.1. Site Description
The research was conducted on three conditions of ombrogen peatlands, i.e. deep, moderate and shallow peat with sulphidic material as the substratum mineral and the peaty acid sulphate soil. Each study site is spread in one area and each of them are separated by tertiary channels. The study site was located at Pangkoh IX, Pulang Pisau District, Central Kalimantan. This research is part of a research series conducted for two years, and especially for peaty acid sulphate soil site, the data discussed in this paper derived only from second year observation.

2.2. Soil Sampling Points
Soil sample was collected with using peat borer according to interlayer (the border layer of peat and mineral layer) and soil horizon status. The sampling depth were (in cm) 25, 50, 75, 95, 115 and 135 for shallow peat; 50, 100, 120, 135 and 155 for moderate peat; 50, 150, 200, 225, 245 and 265 for deep peat, and 25, 50 and 75 for peaty acid sulphate soil, respectively (Figure 1). In each study site, sampling points were replicated three times. ash content (determined with ignition method) and electrical conductivity (measured with a conductivity cell by measuring the electrical resistance of a 1:5 soil:water suspension) were observed in June of 2010 (transition from wet to dry season), September of 2010 (peak of dry season) and January of 2011 (peak of wet season).

![Figure 1. Soil profile and sampling points in peaty acid sulphate soil, shallow peat, moderate peat and deep peat.](image)

3. Results

3.1. Ash content
The presence of peat layer above on sulphidic material layer decreased ash content in sulphidic material layer. Contrasely, the presence of sulphidic material layer underneath of peat layer increased ash content in peat layer. Ash content ranges 0.32 to 8.70 % in peat layer and 16.48 to 43.54 % in sulphidic material layer (Figure 2, 3 and 4).

Figure 2. Ash content in shallow, moderate and deep peatland that observed on wet season (MH).
**Figure 3.** Ash content in shallow, moderate and deep peatland that observed on transition from wet season to dry season (T).

**Figure 4.** Ash content in shallow, moderate and deep peatland that observed on dry season (MK).

3.2. **Electrical conductivity.**

The influence of sulphidic material on EC in peat layer was reflected on the fluctuation value of EC in sulphidic material (0,030 - 0,142 mS cm$^{-1}$) which higher than peat layer (0,023 -1,400 mS cm$^{-1}$) (Figure 8). Its pattern indicated that sulphidic material become source of dissolved ion in peatland with sulphidic material as substratum.
Figure 5. Electrical conductivity in shallow, moderate and deep peatland that observed on wet season (WS).

Figure 6. Electrical conductivity in shallow, moderate and deep peatland that observed on transition from wet season to dry season (T).
Figure 7. Electrical conductivity in shallow, moderate and deep peatland that observed on dry season (DS).

Figure 8. Electrical conductivity fluctuation in shallow (a), moderate (b) and deep (c) peatland that observed on wet season (MH), transition from wet season to dry season (T) and dry season (MK) for two years observation.

4. Discussion
The highest ash content was found in sulphidic material layer, but ash content in peat layer was gradually decrease with increasing distance from peat layer to sulphidic material layer. The distribution of ash content indicates that sulphidic material layer is main source of mineral in peatland. They move with water movement in soil profile. Based on peat thickness, ash content in uppermost layer of deep peatland was lower than shallow and moderate peatland (Figure 2, 3 and 4). This condition may related with ; 1) The relation of ash content with groundwater movement which influenced by distance between sulphidic material layer as source mineral and peat layer as precipitation point, amount of precipitated mineral decreased with increasing distance from sulphidic
material layer. 2) Peat layer in deep peatland has lower stage of decomposition than moderate and shallow peatland. According to [8] mineral content in peat material decrease with decreasing peat decomposition stage.

Likewise with ash content in sulphidic material layer in deep peatland that lower than moderate and shallow peatland (Figure 2, 3 and 4). Organic matter movement to the lower layer increased organic matter content in sulphidic material layer. According to [9] sulphidic material have a high potential for the concentration and accumulation of organic materials. Based on those figures, ash content in sulphidic material layer decreased with increasing peat thickness, this condition may relate with amount of organic matter that leached and precipitated, which linearly increased with increasing peat thickness. Those fact indicated that peat thickness has important role on ash content in sulphidic material layer.

Ash content in acid sulphate soil layer was higher than peat soil, especialy in surface layer. This fact means that peat layer depletion leads ash content increased. In addition, the movement of dissolved organic compounds from the peat layer to the mineral layer was also influence to the ash content in the sulfidic material layer. Precipitation of organic carbon compounds in the sulfidic material layer decreased the ash content in the mineral layer (weight based). This phenomenon can be observed from the low ash content of sulfidic material layer in peaty soils compared to acid sulfate soils which has 60 % of ash content (data not shown in figure). This fact strengthens the evidence that the presence of peat layer above on the sulfidic material also contributes to the increased of mineral content in the peat layer and the sulfidic material layer.

Electrical conductivity (EC) was influenced by interaction between peat layer and sulphidic material layer. This interaction strongly related with role of groundwater as media for ion movement in peat layer. [10]. concluded important role of vertically water movement on magnitude concentration and distribution of ions in peatland. According to [11] low EC in peat natural forest (0,056 mS cm$^{-1}$) compared peatland for agriculture (0,085 mS cm$^{-1}$) is an indicator that the changes of EC value of peatland was more influenced by mineral suply from external peatland than internal peat decomposition. In addition, interaction of peat layer and sulphidic material layer on EC value was influenced by land hydrological condition. This condition was reflected in EC fluctuation value, the highest EC value (1,400 mS cm$^{-1}$) was occured when GWL is at its in the lowest point (DS on first year observation) (Figure 8). As stated previously that EC is function from the comparison of soil water content and amount of dissolved mineral in soil, the higher water content accordingly decresed EC value.

The higher EC value was occured on DS of first year observation (Figure 7). This condition related with groundwater level, in which lowest groundwater level was occured on DS of first year, whereas groundwater level at MK, MH and T in second year observation wasn’t different, as a results EC value were not different. [12] stated that conductivity of peat dependence on water content.

Although sulphidic material layer has important role as suplier of mineral for peat layer, the presence of peat layer above sulphidic material layer directly influenced on soil EC value of peatland with sulphidic material as substratum. This fact may seen from a tendency of the higher EC value in the upper layer of peat than the lower layer (Figure 5, 6 and 7). The peat material role was on intensively mineralization process in upper layer and complex formation ability of humic substances which contained inside. Low EC value in peat layer may related with ions adsorption process by peat material as consequences for its large cation exchange capacity, uptake by plant and leaching process. [13] stated that the changes of cations concentration was influenced by active moitities in peat material, which able to adsorb ion in huge quantities.

Results in this research shown that interaction between peat material and sulphidic material influenced to soil EC, sulphidic material act as source of ions in peatland with sulphidic material substratum, they move simultaneously with water in soil matrix. Increasing EC value due to declining groundwater level may govern toxicity of certain elements such as Na to the plants. Therefore all efforts in the framework of peatland management and utilization of peatland for agriculture should be
based on peat layer conservation and maintain groundwater level in order to keep of peatland sustainability.

Peat material and sulphidic material interacts to influence ash content in peatland with sulphidic material substratum. The presence of peat layer above on sulphidic material layer decreased ash content in sulphidic material layer, and vice versa in which the presence of sulphidic material layer underneath of peat layer increased ash content in peat layer. The distribution pattern of ash content indicates that sulphidic material layer is main source of mineral in peatland. It moves with water movement in soil matrix.

Interaction between peat material and sulphidic material influenced to soil EC. Interaction of peat layer and sulphidic material layer on EC value was influenced by land hydrological condition. Electrical conductivity value was fluctuate, the highest EC value was occured when groundwater level in the lowest point. Sulphidic material act as source of ions in peatland with sulphidic material substratum, they move simultaneously with water in soil matrix.

5. Conclusion
The results showed that ash content and electrical conductivity decreased with increasing of peat thickness, especially in upper layer of peatland. Decrease and disappear of peat layer has increased the ash content and electrical conductivity in the peat layer and in the sulfidic layer. Declining of groundwater level increased electrical conductivity of soil.

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