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# Utilization of bottom ash for degraded soil improvement for sustainable technology

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**Abstract.** Bottom ash is one of the main products from coal combustion in coal-fired power plants. It has been applied in many applications such as landfill, cement industry or raw feed for clinker, concrete, etc. Furthermore, it can be used in agriculture to improve soil quality. However, the utilization rate of bottom ash in agriculture is still very low only 0.1% of bottom ash. The properties of bottom ash can adjust the pH in soil and provide some nutrients to improve soil quality. Moreover, the soil degradation is a major problem in agricultural countries. The soil degradation is the decline in soil quality due to the improper land use, agriculture with misuse or excess use of fertilizers and so on. In Thailand, the soil degradation is a serious problem in agriculture in the northern mountainous areas. The mainly causes of soil degradation are from human activities such as overuse of pesticide, herbicide, and fertilizer, deforestation, expansion of cultivated areas. Therefore, the objective of this research is to apply the bottom ash from Mae-Moh power plant to improve soil quality of degraded soil in Nan province, Thailand and to investigate the effects of amount of bottom ash from 0-30% by weight on some parameters such as pH, electrical conductivity (EC), bulk density and soil texture. From the result, it is clear that with higher amount of bottom ash, the quality of degraded soil has been improved especially pH and soil texture. The pH can increase from 5.664 up to 7.408. Soil texture can change from clay to loam or sandy loam. The bulk density of soil decreases at all rates of bottom ash which is favorable for plant growth. This research can be applied for soil amendment and is expected to improve the yield for plant growing. Furthermore, the practical combinations of 10% and 20% of bottom ash are considered to apply in the real field to evaluate the improvement on soil properties in the future.

## 1. Introduction

Nowadays, an economic growth and a rising world population are leading to an increase in the global energy consumption. The coal-fired power plants still play the important roles to supply the global energy. Furthermore, a large amount of waste like bottom ash is generated from coal-fired power plants and becomes the major environmental problems. However, it is used in many applications like cement industry, concrete and landfill. In agriculture, the bottom ash utilization rate is only 0.1% [1]. Due to its properties, the bottom ash can replace lime to increase pH value of soil [2]. Also, it can be applied to improve soil texture, enhance water holding capacity and air content as well as supply some necessary mineral ingredients of most soil types; thus increasing quantity and quality of peanut [3]. The bottom ash also can be used as soil amendment in heavy clay soil, that can help increase soil workability and



porosity, improve crop yield as well as has less impact on environment [4]. Since bottom ash is lightweight material, it can mix with soil to provide lightweight media for plants of the green roofs [4]. It can be seen that the potential use of the bottom ash in agriculture is very high. However, in the most of previous researches, bottom ash is applied in normal soil to estimate the change in soil properties. On the other hand, properties of bottom ash greatly depend on coal sources as well as technology that used in coal-fired power plant. If the utilization rate in agriculture of bottom ash can increase, that can help to reduce the environmental problems and the operation cost of coal-fired power plants in developing countries as well as agriculture countries.

In addition, another huge problem in agriculture is the soil degradation defined as a change in the soil health status resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries [5]. Soil degradation involves in salinity, loss of organic matter, fertilize decline, soil acidic or alkalinity etc. The main causes of soil degradation are human activities such as overuse of pesticide, herbicide, and fertilizer, deforestation, expansion of cultivated areas. Soil degradation decreases soil quality, as well as reduces yield and quality of crops. In Thailand, soil degradation is a serious problem in agriculture in the northern mountainous areas, including Nan province due to human activities such as clearing land for agricultural practices, deforestation by people, exploitation of marginal soils under inadequate soil management practice [6], expansion of cultivated areas, landslide, flooding and agrochemicals [7].

Therefore, the objectives of this study are to apply and evaluate the bottom ash from Mae-Moh power plant to improve the quality of degraded soil in Nan province and to determine the optimum ratio of bottom ash-soil combinations as well as to estimate potential use in agriculture of bottom ash from Mae-Moh power plant for degraded soil in Nan. This study is expected that bottom ash can be applied in agriculture to improve soil quality, reduce environmental impacts, and improve profitability of bottom ash; thus contributing to the economic and social development of Thailand as well as developing countries in the region. In addition, the cost of fertilizer consumption and waste-management can be decreased. Furthermore, effective land use and friendly environment of waste reduction as well as deforestation can be lower.

## **2. Experimental**

### *2.1. Material*

Bottom ash is obtained from the Mae-Moh power plant, Lampang province and degraded soil is provided from Nan province, Thailand. Bottom ash will be mixed with degraded soil at certain ratio from 0-30% by weight of bottom ash.

### *2.2. Soil texture measurement*

To determine the soil texture, the percentage of clay, silt and sand in soil and combinations are measured by wet sieve and hydrometer experiment, following the American Society for Testing and Materials (ASTM- D422-63) standard [8]. Based on ASTM standard, 100 grams of sample is putted in 500 ml cylinder. At the same time, place 125 ml of 40g/l sodium hexametaphosphate solution into the cylinder that contains the sample, then stir the sample until it is thoroughly wetted and soak it at least 16 hours. After 16 hours, place the solution into sedimentation cylinder and add distilled water until total volume is 1000 mL and cover the end of cylinder, turn it upside down and back for 1 minute. Read from hydrometer and measure temperature of solution at the following intervals of time from 0 to 1440 mins. After 24 hours, transfer solution to the set sieve No.40 to 200 and wash with water until cylinder is clear. After that, dry the particles retained on sieve No.40 to No.200 in the oven for 24 hours, then weigh of each portion.

### *2.3. pH and EC measurement*

The pH and EC value of all samples are measured by using Benchtop pH/Water Quality Analyzer LAQUA F-74. To prepare solution the measurement, 10 grams of sample is dissolved with 10 ml of distilled water for pH measurement. Also, for EC measurement, 15 grams of sample is dissolved in 15 ml of distilled water. The solution is shaken for about 2-3 minutes, then leave it to settle for 2 minutes.

The pH/Water Quality Analyzer is used to measure pH and EC value of the samples. The procedure is repeated for three times to get the average value of pH and EC.

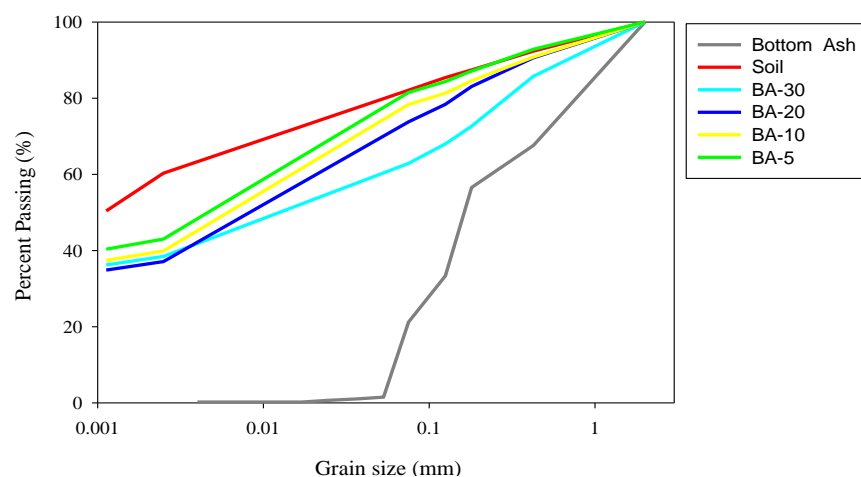
#### 2.4. Bulk density measurement.

From Tan [9], the equipment used to measure the bulk density of samples is scale, oven and 100 mL graduated cylinder. The procedure is that the sample is added into the cylinder and compacts the samples by tapping the bottom of the cylinder. Keep tapping and filling the sample until 100 mL of cylinder is filled. Weigh and record it of the cylinder contain sample. Repeat all procedure for three times to get the average value of the bulk density.

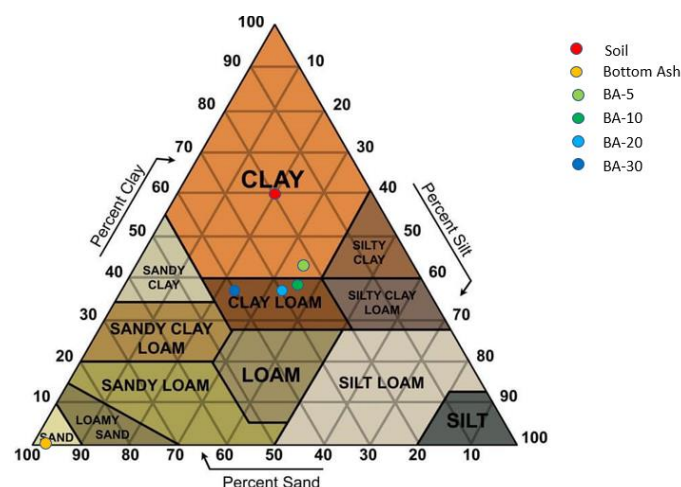
### 3. Results and Discussion

#### 3.1 Effect of bottom ash on soil texture

Soil texture is one of the most important soil properties. It affects other soil properties such as water holding capacity, soil structure, soil compaction; thus influencing plant growing. Each type of plant will be suitable with different soil texture. However, loam is considered as an ideal soil for sufficient vegetative growth, root development [10]. From this study, the effects of amount of bottom ash on soil texture are presented in Figure 1 and Figure 2.



**Figure 1.** Particle size distribution curve of soil, bottom ash and combinations.

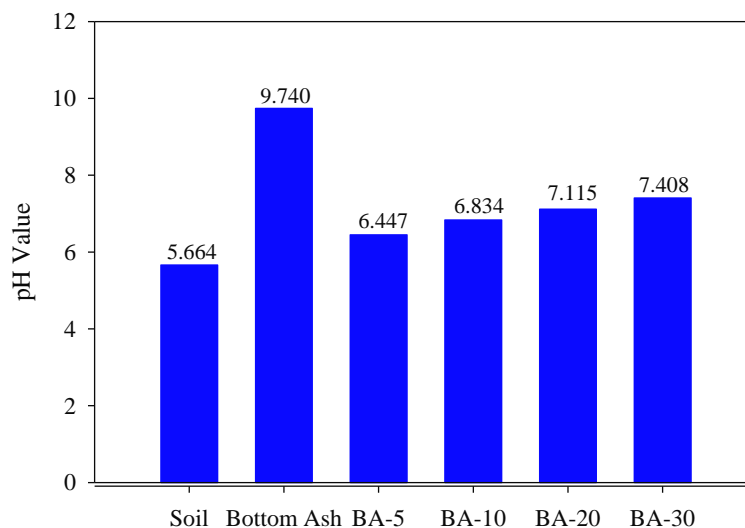


**Figure 2.** Results of hydrometer experiment are plotted on soil texture triangle.

Figure 1 presents the particle size distribution curve to determine percentage of sand, silt and clay in soil, bottom ash and combinations. Also, soil texture of combinations are classified by plotting percentage of sand, silt and clay on soil texture triangle graph as shown on Figure 2. From Figure 2, the degraded soil in Nan is classified as clay, which contains 60% of clay, 20% of silt and 20% of sand. Bottom ash from Mae-Moh power plant is sand, which contains 98.5% of sand and 1.5% of silt. The results show that bottom ash can reduce the clay content in the soil and increase the sand content. By the increasing percentage of bottom ash in the combinations, the soil texture has the tendency to be sand. Therefore, changing the texture of soil from clay to clay loam, with most ratios of bottom ash are applied, except combination of 5% bottom ash and 95% of soil. Consequently, bottom ash is considered to be helpful for soil texture improvement.

### 3.2 Effect of bottom ash on pH

pH is the chemical characteristics of the soil that affects the availability of plant nutrients and plant growth. Most plants can grow best in soil with a slightly acid reaction [9]. Soil in Nan is acidic with pH=5.664 and bottom ash from Mae-Moh power plant is strongly alkaline with pH=9.740. According to the results, bottom ash can increase soil pH as shown in Figure 3. The mixtures of bottom ash from 5% to 25% are considered the appropriate ratios for the pH improvement of soil, which increase the soil pH from 5.664 to 7.115. At the 30% bottom ash, soil becomes relatively alkaline and it is not good for plant growth.



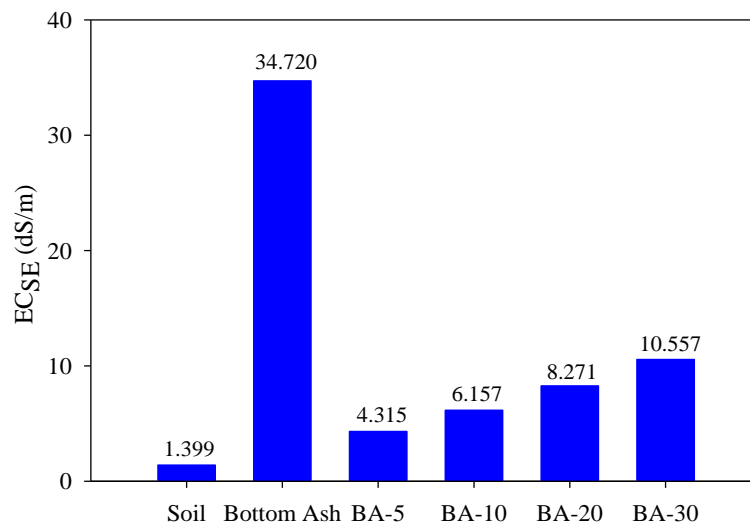
**Figure 3.** pH measurement of soil, bottom ash and combinations.

### 3.3 Effect of bottom ash on Electrical Conductivity (EC)

The electrical conductivity (EC) is also the important soil property. It is an indirect measure of the total salt concentration in soil, or salinity. It influences crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms. Practically, it is difficult to measure directly EC value of soil. Therefore EC (1:5) is considered as an alternative method to measure the EC value of the soil. However, to predict the plant response, EC (1:5) must be converted to the EC of a saturated extract ( $EC_{SE}$ ) by the equation as shown below [11]. According to the classification of crop tolerance to salinity of Maas and Hoffman [12], most plants cannot grow with  $EC_{SE}$  higher than 32 dS/m. From the results, bottom ash increases  $EC_{SE}$  value of soil at all ratios as shown in Figure 4. Although,  $EC_{SE}$  value of bottom ash is very high (34.72 dS/m),  $EC_{SE}$  value is still suitable for plant grow when bottom ash is mixed with soil.

$$EC_{SE} \text{ (dS/m)} = EC \text{ (1:5) (dS/m)} \times \text{Conversion Factor}$$

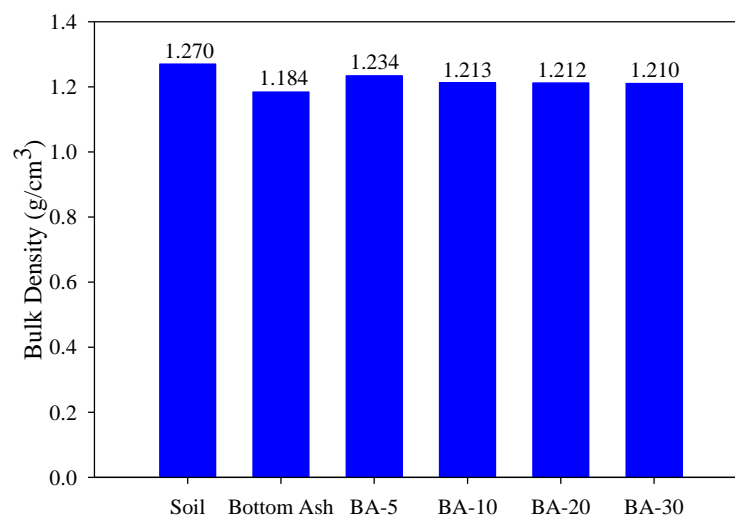
Where the Conversion Factor is derived from clay content.



**Figure 4.** Electrical conductivity of saturated extract value of soil, bottom ash and combinations.

### 3.4 Effect of bottom ash on bulk density

Bulk density is an important physical characteristic of soil because it affects the root growth. Bulk density is measured to evaluate the compaction of soil. The soil with high bulk density can limit root growth, associated plant nutrient and water uptake. Like soil texture, each soil will have a different ideal bulk density for plant growth and threshold of bulk density value that restricts root growth. In this study, the soil sample is clay. According to United States Department of Agriculture (USDA), the ideal bulk density for root growth in clay or clay loam soil is lower than  $1.10 \text{ g/cm}^3$  and the threshold bulk density is higher than  $1.47 \text{ g/cm}^3$  for clay and  $1.5 \text{ g/cm}^3$  for clay loam, respectively [13]. From the experimental results, the application of bottom ash can decrease bulk density of soil as shown in Figure 4, bottom ash with  $1.184 \text{ g/cm}^3$  bulk density can reduce bulk density of soil from  $1.270 \text{ g/cm}^3$  to  $1.210 \text{ g/cm}^3$ . Although, bulk density of all mixtures higher than ideal bulk density for plant growth, it is still lower than that to restrict root growth.



**Figure 5.** Bulk density experiment result of soil, bottom ash and combinations.

From the results of this study, it can be used in the real application because the bottom ash is intended to improve the quality degraded soil in Nan province, Thailand for corn growing and to determine the optimum ratio of bottom ash and soil combinations as well as the conditions that fit well with corn growth. Moreover, the properties of soil after applying the bottom ash can be used for various types of crops in that province.

#### 4. Conclusion

From this study, the effects of bottom ash on soil properties are investigated in various mixing ratios from 0% to 30% by weight. The results present that the application of bottom ash can improve soil texture from clay to clay loam at ratio from 10% to 30% by weight, adjust the pH value of soil to fit well for soil amendment and decrease the bulk density of soil at all ratios to have more space for air in soil. For the electrical conductivity (EC), the bottom ash cannot improve EC of soil, but EC value after bottom ash applied are still in the range that is suitable for plant growth at all ratios. In addition, the application of bottom ash can improve qualities of degraded soil such as soil texture, bulk density, pH value that help soil function fit well with various crops. It is also helpful for environment on waste management and cost reduction on waste disposal and effective land use. Furthermore, the application of the bottom ash at 10% and 20% by weight is considered as optimum ratio bottom ash-soil combinations and can be applied in the real field for further study of soil property improvement.

#### Acknowledgments

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