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Small - Scale Surface Mining in Tarkwa - Nsuaem Municipality in Western Ghana and its Effect on Soil Physical Properties

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Abstract
Small - scale surface mining in Tarkwa - Nsuaem municipality in western Ghana and its effect on soil physical properties is presented in this study. The rising rate of land degradation by the small - scale surface miners in the study area has created a situation in which farmlands are becoming scarce and farmers are left with no choice than to use mined - out lands. The study set out to measure the physical properties of soil from mined - out lands to determine their suitability for use for agricultural purposes. One set of samples comprising soil from mined and unmined sites were randomly collected using a cylindrical metal core of known volume. After recording their wet weights, the samples were then oven dried at 105°C for 24 hours after which their dry weights were also recorded. The bulk density, porosity, solid space, mass wetness and void ratio were then calculated. The procedure was repeated for three other sites in the study area. The results showed that the mined soil, in its current state, was unsuitable for use by farmers for agricultural purposes because it was compacted, less porous, susceptible to erosion, dry and could barely support plant life. It was recommended that practices that maintain or increase soil organic matter which leads to high pore space and low bulk density be adopted to restore the mined - out lands to their natural state.
Keywords: Bulk density, Porosity, Pore space, Mass wetness, Void ratio

1. Introduction

Soil is important for the survival of the human race, plant and animal life and so it is crucial that its structure and strength, the distribution of nutrients, the extent of compression and its relationship with water and plants, among others is sustained as long as possible. But this expectation may become short - lived if activities which degrade the soil are allowed to be carried out without putting the necessary measures in place to restore it to its natural state. One of such activities is small - scale surface mining which is currently gaining grounds in Ghana due to the involvement of the unemployed unskilled youth who hitherto would have engaged themselves in income generating activities such as farming, fishing, petty trading and artisanal ventures among others.

Being poverty driven, small - scale mining in the country involves manual use of rudimentary tools and machinery in removing the soil for the extraction of naturally occurring minerals sometimes at great risk to the lives of the miners. With more than one million people directly involved across the country (Ghana News Agency, 2011), it serves as a readily available source of employment for the unskilled youth and the rural folk (Bawa, 2008; Tom - Dery *et al*, 2012). It also contributes some foreign exchange to the country's economy (Adu - Gyamfi, 2011) as well as the production of gold and diamond (Bawa, 2008). In 2011, both legal and illegal small - scale mining produced 800,000 ounces of gold which was 23% of the country's total gold production (Ghana News Agency, 2011).

In Ghana, small - scale mining was legalized in 1989 as part of the minerals sector restructuring and the government established the Precious Minerals Marketing Corporation which became the sole governmental agency for the purchase of the produce of small-scale miners but this was later opened up to private licensed buyers(Akabzaa & Darimani, 2001). In 2011, about 300 small - scale mining groups were registered(Adu - Gyamfi, 2011) and many more including foreigners remained unregistered and therefore operated illegally and unregulated (McTernan, 2013). The small-scale mining activities are located mostly in rural settlements of the country such as the greenstone belts and alluvial areas especially along the Offin, Pra, Ankobra and Tano rivers and their tributaries (Bawa, 2008).

These unskilled miners mainly practice surface mining which includes open - pit or strip mining and according to Tom - Dery *et al* (2012) it involves the removal of underlying vegetation cover, top soil, rocks and other strata, leaving in its wake devastating environmental problems such as pollution of rivers and streams nearby that serve as sources of drinking water for communities downstream (Adu - Gyamfi, 2011), deforestation, significant air pollution and soil erosion and farmland degradation.

Tarkwa - Nsuaem is in the western region of Ghana and lies in the heart of the tropical rain forest whose

vegetation is largely characterized by a rich variety of flora and fauna. The main economic activity of the people in the town and its surrounding communities is subsistence and commercial farming but according to Akabzaa & Darimani, (2001) the area has the highest concentration of mining companies in the country and so mining has overtaken farming as the single largest economic activity. Farmlands are frequently destroyed without adequate compensation paid to the affected farmers. Therefore, there is tremendous pressure on farmlands and farmers are in a way forced to use mined - out lands for their farming activities.

It is against this background that this study was conducted to examine the physical properties of the mined - out soil which is available to the farmers in the study area and its surrounding communities. Specifically, this research seeks to measure and compare the bulk density, porosity, solid space, mass wetness and void ratio of the mined - out soil with the unmined soil in the same area. Since these parameters altogether give an indication of the quality of the soil, it is expected that the results would create more awareness about state of the mined - out lands in the study area and their suitability for use for farming purposes. This would enable relevant authorities to streamline the activities of the miners to ensure compliance to rules and regulations governing small scale mining in the country. Also, efforts to reclaim vegetation cover could be intensified to restore the mined - out lands to their natural state to make more land available to farmers.

2. Materials and Methods

2.1 Study area

Tarkwa Nsuaem is in the Wassa West Municipal in western Ghana and lies between latitudes 4° N and 5°40" N and longitudes 1°45"W and 2°10" W with a total population of 90, 477 according to 2010 population and housing census (Ghana Statistical Service, 2012), and covers a total area of 2354 km^2. The southern portion of the municipal falls in the south western equatorial climatic region while the northern part has a wet semi-equatorial climate with both portions experiencing two distinct rainy periods. The municipal has a mean annual rainfall ranging between 1500mm and 1933mm with most of the rains occurring from April - June and October - November. Relative humidity for the area ranges from 70% to 90%. The daily temperature ranges are between 20° C and 40° C while the mean monthly temperature ranges are from 24° C to 30°C (Akabzaa & Darimani, 2001). The soil type is generally sandy loam. The area has a heavy concentration of both large - scale mining companies and registered small - scale ones. However, there are also several unregistered small - scale mining groups operating illegally in the area. All these companies employ the open-pit (surface mining) method in their mining operations.

2.2 Sampling procedure

2.2.1 Mined sites

Four mined - out sites were randomly selected from the study area. At each site, an area was randomly demarcated and the surface smoothened and roots removed. Using the method described by Thien and Graveel (2003), a cylindrical metal core of known volume was hammered into the soil, by means of a wooden mallet, until it got completely buried. It was then excavated and any excess soil at both ends trimmed off in such a way that the retained soil aligned with the both rims of the cylindrical metal core. The soil was then extracted from the metal core into a bag and labeled. The procedure was then repeated for three other mined - out sites.

2.2.2 Unmined sites

For each mined - out site randomly selected, soil from its neighboring unmined portion was sampled. The procedure for the extraction was the same as that described for the mined soil.

2.3 Measurements and data analysis

After recording their wet weights, all the labeled soil samples were then oven dried at 105°C for 24 hours after which their dry weights were also subsequently recorded. The formulae used for calculating bulk density, porosity, solid space and mass wetness are as outlined in Thien and Graveel (2003) while that for void ratio is as stated in Hillel (1982).

(i) Bulk density (g/cm^3)

$$\frac{Sample\ dried\ weight}{Sample\ volume}$$

(ii) Porosity (%)

$$100 - \left(\frac{\text{Bulk density}}{\text{Particle density}} \times 100 \right)$$

Where the particle density = 2.65g/cm^3

(iii) Solid space (%)

$$\left(\frac{\text{Bulk density}}{\text{Particle density}} \times 100 \right)$$

(iv) Mass wetness (%)

$$\frac{\text{Wet weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

(v) Void ratio

$$\frac{\text{Volume of solids and pores} - \frac{\text{Oven dry weight}}{\text{Particle density}}}{\frac{\text{Oven dry weight}}{\text{Particle density}}}$$

The data obtained were subjected to analysis of variance using GenStat version 11.1 to compare mean values between the mined and unmined samples at 5% significance level.

3. Results

The results, as shown in Table 1, indicate that bulk density and solid space values for soil from the mined sites were higher than that from the unmined sites at the four sites surveyed. However, the values for porosity, mass wetness and void ratio were lower in the soil from the mined sites than that from the unmined sites.

Table 1. Soil physical properties calculated for soil sampled from the mined and unmined sites

Site	Bulk density(g/cm^3)		Porosity(%)		Solid space(%)		Mass wetness (%)		Void ratio	
	Mined	Unmined	Mined	Unmined	Mined	Unmined	Mined	Unmined	Mined	Unmined
1	1.3	0.8	51	68	49	32	10	34	1.0	2.2
2	1.4	0.9	48	67	52	33	3	33	0.9	2.0
3	1.4	0.8	48	70	53	30	5	23	0.9	2.3
4	1.1	0.8	59	69	42	31	17	25	1.4	2.3

From Table 2 below, it is clear that there are marked significant differences between soil sampled from the mined sites and the unmined sites in relation to the aforementioned soil physical properties.

Table 2. Effect of small - scale surface mining on the mean values of soil physical properties

Sample	Mean bulk density(/cm^3)	Mean solid space(%)	Mean porosity(%)	Mean mass wetness	Mean void ratio
Mined soil	1.30	49.0	51.5	8.8	1.05
Unmined soil	0.83	31.5	68.5	28.8	2.2
LSD(0.05)	0.20	6.9	8.1	14.9	0.33
CV(%)	8.4	8.8	6.0	35.4	9.1

Fig. 1(a) and (b) show pictures of mined fields with less vegetation cover and signs of erosion. This is actually the manner in which farmlands, as shown in (c), are abandoned following the activities of small - scale miners.

(a) (b)

(c)

Fig. 1. (a) and (b) Mined sites with less vegetation and showing signs of erosion
(c) Unmined site showing full vegetation cover

4. Discussion

The results give a clear indication about the overwhelming state that farmlands are left after the activities of small - scale surface mining in the study area. In comparison with the samples from the unmined soil, all the samples from the mined fields exhibited marked significant differences in the parameters measured. This gives an indication that the mining activities have caused changes in the soil physical properties in the study area.

Bulk density reflects the soil's ability to function for structural support, water and solution movement and soil aeration. Due to the rudimentary nature of the small - scale surface mining operations, much of the soil gets compacted in the process. The evidence for compaction is in the significantly lower void ratio values of the samples from the mined sites as shown in Table 2. According to Lal (2006), soil compaction is often indicated by increases in bulk density and it can affect plant rooting and growth (Chesworth, 2008) and also lead to reduced infiltration causing increased flooding, runoff and erosion. Therefore the significantly higher bulk

density in the mined soil over the unmined soil has manifested in the former's poor state as shown in Fig. 1(a) and (b). Any land in such a state is unsuitable for farming and therefore the prolonged desecration of land by these miners is gradually making farmlands scarce in the study area.

The total volume of spaces not occupied by solid phase is termed porosity and is important to the ability of soils to support plant, animal and microbial life (Rowell, 2014). As evident from the results, porosity in the mined soil was significantly lower than the unmined soil. This was actually expected because as explained by Lal (2006), an increase in bulk density leads to a decrease in porosity which is consistent with the corresponding increase in solid space as shown in Table 1. Therefore the mined soil has significantly less spaces to hold water, allow drainage, allow entry of oxygen and removal of carbon dioxide. The less spaces to hold water is evident in the significantly low mass wetness values calculated for the mined soil samples as shown in Tables 1 and 2. A relatively dry soil heats up more quickly than wet soil (Wild, 1993) and this therefore affects plant development particularly poor growth and penetration of roots (Lai, 1985) and is a reason for the state of the lands shown in Fig 1 (a) and(b).

5. Conclusion

The effect of small - scale surface mining on soil physical properties using Tarkwa - Nsuaem municipality in western Ghana as a case study has been presented. Farmlands used by farmers are gradually becoming scarce due to the activities of the small - scale miners, both legal and illegal. Farmers are therefore compelled to turn to already mined and abandoned lands to farm. However, the results show that the mined soil, in its current state, is unsuitable for use by farmers for agricultural purposes. The soil is compacted, less porous, susceptible to erosion, dry and can barely support plant life.

6. Recommendation

Based on the findings of this study, it is recommended that the activities of the small - scale miners be monitored and efforts to restore mined lands to states suitable for farming initiated. This should include practices that maintain or increase soil organic matter which leads to high pore space and low bulk density. This may start with deep tillage of the mined sites to loosen the soil which is heavily compacted followed by cover cropping and crop rotation among others.

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