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Impacts of Tree Plantation Harvesting on Soil Density and Porosity in CARAGA Region, Mindanao, Philippines

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ABSTRACT

Tree farming is a common livelihood for people in the CARAGA region. About 2.5 million Filipinos are employed in the tree plantation industry. Harvesting is normally seen in the region on a daily basis, where its impacts are unaccounted for. This research was conducted to study the effects of harvesting on soil bulk density and porosity at the CARAGA region.

An experiment following a Randomized Complete Block Design (RCBD) with three treatments: control, landing site, skid trail, and three replications were set-up. Thirty soil samples were gathered from each replicate and processed in the laboratory.

Results showed that mean bulk density was1.29±0.08g cm^{-3} for the no harvesting site, 1.41±0.10g cm^{-3} for the landing site and 1.54±0.11 g cm^{-3} for the skid trail. There was a 19% increase in bulk density for the skid trail as compared to the control site. These values exceed the growth limiting value of 1.45-1.5 g cm^{-3}. Mean porosity values were 51±3% for the no harvesting site, 47±4% for the landing site and 42±4% for the skid trail. A significant decrease of 22% in porosity for the skid trail compared to the control was observed.

It is recommended that tillage be practiced to enhance aeration and decrease compaction in the site. The use of slash treatments to minimize the adverse effects of felling and skidding is also suggested.

Keywords: plantation harvesting, soil bulk density

INTRODUCTION

The CARAGA region is called The Timber Corridor of the Philippines, constituting 1.3 M ha of forest lands. It is also the only region where logging is allowed and where industrial tree plantations proliferate and are continually being developed (Caliguid 2012). The province of Agusan del Sur is one of the major providers of logs in the country. Sixty to eighty truckloads of logs are being transported per day in Bayugan City alone. Out of its total area of 8,966 km^2, 6,814 km^2 or 76% are forested areas. There are numerous Falcata (*Paraserianthes falcataria)* and Gmelina (*Gmelina arborea)* plantations all over the province along with other plantations such as rubber (*Hevea brasiliensis)* and rattan (*Daemonorops sp.* and *Calamus sp.)* (Agusan del Sur 2014). Tree farming is a common livelihood for people in the CARAGA region. About 2.5 million Filipinos are employed in tree plantation industries. Most of these are small backyard tree farmers. Income for these people come mostly or solely from these small tree plantation operations. Industrial tree plantations became popular in the Philippines, specifically in Mindanao (PCAARRD 2014).

Tree plantation harvesting and other ground-based operations (*e.g*. site preparation, hauling, skidding) have certain adverse effects to soil. These include increased bulk density and compaction, reduction in pore spaces, hydraulic conductivity and infiltration, among other things (Northern Research Station 2013). These constitute the physical properties of the soil which are important in determining crop suitability and forest production as well as their susceptibility to runoff and erosion (Heinrich and Arzberger 2004).

The harvesting of timber has been known to have certain effects on the area from which these logs are obtained. One of these effects is on the soil bulk density, which is the focus of this study. The increase in bulk density or compaction usually occurs from the passing of heavy machinery used to fell and transport logs. It also occurs in the landing site from which the logs are felled and from roads or skid trails used to transport these logs. Aside from the loss of vegetation, soil is greatly affected by harvesting not only in the area where the timber was cut but also in the actual transport of the logs (Wolkowski and Lowery 2008).

The trafficking of machinery affects not only bulk density but also soil porosity and water retention. An increase in bulk density was observed after the trafficking of a forwarder on a Piedmont soil. A decrease in air-filled porosity was also seen, because soil macropores were converted to micropores as a result of the compaction. Given this, there was also an increase in the water retention of the said Piedmont soil (Carter and McDonald 1997).

The texture of the soil impacted by harvesting also contributes to the variation of the effect on bulk density. Fine textured soils are highly susceptible to compaction in the deeper depths of 20-30 cm. In the study of Page-Dumroese *et al.* (2006), bulk density increased by 47% where moderate compaction occurred and 58% in severe compaction. Coarse textured soils did not

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have a significant increase in the 20-30 cm depth. The values of bulk density reached the root limiting value for the fine textured soil.

During the conduct of the study, some farmers have been complaining about decreased productivity from the trees they harvest. Thus, the importance of this study is to be able to know if the harvesting practices applied in the area do affect soil bulk density and porosity. Understanding this would greatly help in addressing issues concerning soil compaction. Formal and thorough assessment of such effects of timber harvesting has not yet been done in the region. Other than its effects on productivity, soil disturbance and conservation are also issues that need to be considered. Erosion and rutting may also be consequences of such activities, which may in turn lead to greater negative outcomes that may be harmful to society. In this regard, it is important to understand these effects so that problems caused by the issues on soil density can be identified and addressed.

MATERIALS AND METHODS

Location and Description of the Study Site

The study was conducted in Bayugan City and Sibagat, Agusan del Sur, Mindanao, Philippines. Three replicates were done. The first two replicates were in Bayugan City in Barangays Calaitan and Maygatasan while the third replicate was done in the municipality of Sibagat.

Heavy machinery such as tractors, crawlers, forwaders, and skidders were not used in any of the study sites. Logs were felled manually with the use of chainsaws and ropes. These logs are then transported, either carried individually by a farmer or hauled by carabao two to four logs at a time.

Experimental Design

A randomized complete block design (RCBD) was used for the set-up involving three treatments: no harvesting, landing site and skid trail. Three replications were established as represented by the three sites selected. Two criteria were used in the selection of the sampling sites. First, an area is selected if there is an on-going harvesting operation. Second, it was also chosen if a control or reference site can be established in the area, one that is close to the harvested site but is not impacted by the on-going harvesting operation. Considering these criteria, two sites were selected at the city of Bayugan and one at the Municipality of Sibagat (Table 1).

Sample Collection

The collection of samples were conducted in summer 2013. Soil samples were collected from April 29 to May 2, 2013. Thirty soil samples were obtained from each selected site. Ten samples were gathered from the landing site of logs. Another ten were gathered from the skid trail, and the last ten from an adjacent area from the site where no harvesting is done. The samples were obtained using a core sampler. Core samples are 15 cm in depth and 19.63 cm^2 in area. Each sample has a volume of 294.52 cm^3 (15cm x 19.63cm^2) based on the dimensions of the cylinder used.

Table 1. Description of the study site

Location	Site 1 Brgy. Calaitan, Bayugan City	Site 2 Brgy. Maygatasan, Bayugan City	Site 3 Sibagat
Total Area (m^2)	831	1,363	1,430
Area of Harvesting Site (m^2)	453	769	698
Area of Adjacent No Harvesting Site (m^2)	378	594	732
Length of Skid Trail (m)	196	315	251
Species	Falcata	Falcata	Falcata
Soil Type	Camansa Clay Loam	Camansa Clay Loam	Malalag Silt Loam

All samples were brought to the Soils Laboratory of the Institute of Renewable Natural Resources, College of Forestry and Natural Resources, University of the Philippines Los Baños. The soil samples were oven-dried for 24 hours at 105 ^oC and then weighed. From the oven-dry weight of the soil and the calculated volume, the bulk density of the soil was determined. For percent porosity determination, a value of 2.65 g cm^{-3} particle density was assumed for all samples (Flint and Flint 2002). The following formula from Buckman and Brady (1969) were used to compute for bulk density and percent porosity:

$$Bulk\ Density = \frac{ovendry\ weight\ of\ soil\ (g)}{volume\ of\ cylinder\ (cm^3)}$$

$$\%\ Porosity = 100\% - \left(\frac{bulk\ density}{particle\ density} \times 100\%\right)$$

Data Analysis

The analysis of variance (ANOVA) for RCBD at 5% level of significance was used to analyze the data. When ANOVA indicated significant differences, treatment mean comparison was done using the Least Significant Difference (LSD) method also at 5% level of significance.

RESULTS AND DISCUSSION

Impacts of Harvesting on Bulk Density

The harvesting of timber affected soil bulk density. For the landing site, there was increase in the bulk density values by nine percent compared to the area with no harvesting. From 1.29 g cm^{-3} the bulk density increased to 1.41 g cm^{-3}. Likewise, there was also significant increase in bulk density in the skid trail. The bulk density values in the skid trail were found to be 19% greater than that of the densities in the no harvesting site. From 1.29 g cm^{-3} in the control, bulk density increased to 1.54 g cm^{-3} in the skid trail (Table 2.)

Table 2. Effects of harvesting to bulk density and porosity

Treatment	Bulk Density (g cm^{-3}) Mean ± SE	Porosity (%) Mean ± SE
No Harvesting	1.29 ± 0.08	51 ± 3
Landing Site	1.41 ± 0.10	47 ± 4
Skid Trail	1.54 ± 0.11	42 ± 4

There was also a 9% increase in the skid trail compared to the mean bulk density from the landing site. The significant increase in bulk density resulting from skidding and log storage is due to the dragging and hauling of the logs on the ground. Other than the weight of the logs exerted on the soil, the actual dragging scrapes the soil. Another factor could be the trampling effect of the hooves of the carabaos that dug into the soil. Lastly, the frequency of trips of the carabaos dragging the logs could have exacerbated the previous factor mentioned.

Similar to other previous studies, the results support that harvesting practices such as felling and skidding cause a significant increase in bulk density, although the magnitude of the increase in bulk density was lesser than that observed in previous studies. Akay *et al*. (2007) reported a 61% increase, and Page-Dumroese *et al*. (2006) observed a 58% increase in their respective studies on harvesting impacts on soil compaction. These are much greater compared to the 19% observed in this study. The differences are probably due to different harvesting systems in terms of felling and transporting of logs. In the two cited studies, tractors, crawlers and skidders were used while no heavy machinery was used in the areas of this study. Logs were either carried by a tree farmer individually or hauled by a carabao, two to four logs at a time. Another reason is that the trees logged in the area were relatively small, only 20-30 cm in diameter at breast height (dbh). Since these logs are relatively small it can be said that their mass is lesser, hence, the impact upon landing on the soil is also lesser.

This study agrees with what Froehlich (1979) has observed in his study on soil compaction wherein he reported that cattle grazing caused an increase in bulk density. The use of carabaos for skidding in this study also caused an increase in bulk density, although it is more of the load it carries rather than the animal traffic. Increase in bulk density affects plant growth. Although the magnitude of increase observed in this study was less than that of previous studies, it is seen that the growth limiting bulk density, which is 1.5 g cm^{-3} for clay loam and 1.45 g cm^{-3} for silt loam is reached and exceeded. This is evident in both sites since the maximum bulk density reported for the landing site was 1.61 g cm^{-3}, and the maximum for the skid trail was 1.79 g cm^{-3} with a mean of 1.54 g cm^{-3}. This is limiting to growth because at this bulk density for this soil type, root elongation could be lessened or impeded. This then leads to decreased respiration and inefficient production of carbohydrates (Coder 1998). However, the mean values for the landing site did not exceed this critical value.

Although both the landing site and the skid trail are significantly affected by harvesting practices, the skid trails exhibited the most compaction, since it is the area with the highest bulk density among the three treatments. Bulk density increased by 19% as compared to the no harvesting site. Mean and maximum bulk densities exceeded the growth limiting value. Indications of rutting were also seen in the skid trails caused by the logs and carabao hooves. Bare soil was also observed in the path, as compared to its adjacent areas where grasses and other vegetation are present. The skid trail is greatly affected because most, if not all, of the logs harvested in these areas pass through the trail. The weight of the load and the frequency of traffic also contribute to these differences. Precaution must be taken so as not to deteriorate the soil further, especially during the wet season when the soil is more susceptible to compaction and rutting.

Impacts of Harvesting on Porosity

Significant differences in the amount of pore spaces are present in the three areas. The mean percent pore space for the no harvesting site was 51±3%. A decrease can be observed for the landing site having a mean percent pore spaces of 47±4%. Evidently, a decrease can also be seen for the skid trail, having 42±4% pore spaces which is 9% lesser compared to the no harvesting site. The landing site and skid trail also exhibited a 5% decrease in pore spaces. The study by Lin *et al*. (2014) showed a similar result where there was a 4% decrease in porosity for the primary trails. A decrease in soil porosity was also observed in a Piedmont soil resulting from the increase of bulk density in the study by Carter and McDonald (1997).

As explained by Daddow and Warrington (1983), the amount and sizes of pores affect root growth since roots mainly grow through the macropores. Since the sizes of pores are reduced in the process of compaction, it is possible that the sizes of these pores are smaller than that of the roots, thus, making it difficult for the roots to elongate and acquire the nutrients, water and air they require. Moreover, since the bulk density is increased and soil strength is also essentially increased, the roots lack the capacity to penetrate the soil and move the particles of the strengthened soil. Unfortunately, this study did not quantify whether it was the macropores or the micropores that were reduced in volume.

CONCLUSION

This study reports that bulk density is significantly greater in the landing site and skid trail, and that percent porosity is significantly lesser in the areas affected by harvesting. The transport and harvesting of logs increase the compaction of the soil. Increase in bulk density affects plant growth. If bulk density would continue to increase in the areas as a result of harvesting, eventually this would reflect in the productivity of the trees. Similarly, the decrease in the macropores will make it difficult for tree root penetration and decrease the aeration of the soil, thereby leading to a reduction of tree growth in the area.

Both landing site and skid trail are affected by harvesting and this is seen in the effects on bulk density and porosity. However, the effects are more pronounced in the skid trail, having higher percentages of difference for both parameters. Evidence of rutting can also be seen on the skid trail.

Currently, soil degradation is one of the major problems of the country that needs to be addressed. The study on soils is very important so as to understand and solve the issues and problems originating from this. It is suggested that the farmers in the area consider improving the tillage of the soil to enhance soil aeration and decrease the compaction of the soil in the landing site where they will most likely establish their new plantation. The use of slash treatments such as wood chips and saw dust and laying them out on the trail may also be helpful in minimizing the effects of harvesting to bulk density and porosity.

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