CHANGES IN SOIL ORGANIC CARBON UNDER CONTINUOUS FARMING

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Cultivating a land without proper crop management may lead to diminished organic carbon. Thus, this study assesses the effects of long-term farming (2014 to 2018) on soil OC. This study was conducted in Share Farm II, Universiti Putra Malaysia Bintulu Sarawak Campus on a selected area that practiced crop rotation. Soil samples have been collected according to grid sampling techniques by beds row and inter-row, and are analysed for soil pH, OM, TOC, and total N. The results show a trend in the alleviation of soil acidity with 2018 > 2016 > 2014, however, there is a diminished of TOC as the year of cultivation increases from 3.42% to 1.87%. The results show insufficient crop residue that returns to the soil system which has been subjected to flash flood and poultry manure application. In return, C retention ability was reduced, which further limit OM capability to supply nutrients upon decomposition. The correlation analysis has revealed that different types of crop residue such as grass clippings that have been applied in 2016 may be another reason for the insufficient N availability (0.44%). Therefore, the quantity and quality of residues may affect the decomposition rate and provide a lower C/N ratio, which significantly affects the soil pH, total N, and other nutrients that are essential for crop uptake.

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INTRODUCTION

The cultivation of a land for agricultural activities has a major impact on soil organic carbon (OC). Literally, a forest system will retain the most source of C followed by grassland, whereby the lowest may be found in cropland (Xu et al., 2019; Evrendilek et al., 2004). According to Evrendilek et al. (2004), a decrease of OC content of up to 43% occurred when grassland was converted into cropland on a 12 year period, led by land disturbance of particular area that had facilitated organic matter (OM) decomposition. This had also been supported by Jiao et al. (2009), who agreed that the conversion of grasslands into forest or croplands induced OC loss on topsoil, which was irrelevant with the conversion years. Although intensive soil conservation practices have been implemented among farmers, however, other factors such as land topography and even texture may reflect the availability of OC. Among several factors affecting OC availability is the texture, where soil with large clay particle can store and maintain OC level, depending on the environmental factors (Zhong et al., 2018). In a humid tropical country, the increase of C content may be discoverable as crop litter or so called as OM that undergoes decomposition and C storage. Moreover, the formation of soil aggregation through the presence of polysaccharide in OC will tightly bind clay and make soil resistant towards C loss. This has also been confirmed by Razafimbelo et al. (2013) and Plante et al. (2006) who have concluded that the presence of clay and silt may stabilise C contents in soil as they are associated with micro aggregation. An increase in moisture in the presence of clay particles improve the OC content regardless of different climatic regions such as humid, sub-humid, and semi-arid, this has been further confirmed by Zhong et al. (2018).

Different vegetation types play major roles in controlling the availability of OC, for example, cultivating graminoid instead of Dicranopteris sp. provides high C contents by providing higher root and litter quality (Pan et al., 2018). High plant diversity promotes OC accumulation by decreasing the C/N ratio and promoting the decomposition process (Zhou et al., 2019), and is the main reason for increasing OC retention in the forest compared to agricultural lands (Fissore et al., 2017; Wang et al., 2012). Crop rotation will delay breakdown reaction on residuals, thus nutrients will be supplied slowly for plants uptake (Robačer et al., 2016). Using a plastic film has also given positive impacts in the cultivation of Zea mays where it is found that this technique has increased the decomposition rate naturally by trapping the heat and moisture within (Ma et al., 2020). As decomposition takes place, a high amount of N is released but this is dependent on the lignin content. Zuber et al. (2018) have concluded that high lignin has high C/N ratio due to the slower decomposition process. Practising zero-till management provides a remarkable effect by increasing OM that acts as a C sink and has been confirmed by Haruna and Nkongolo (2019), zero-till practices continue from 2011 to 2013, and have risen OM by 4% compared to conventional tillage. Thus, studies on the effects of continual agricultural activities in tropical countries with minimum land and crop management should be investigated in order to observe the OC/OM content. Therefore, the objectives of this study were to assess the effects of long-term farming on soil organic carbon in a specific year.

MATERIALS AND METHODS

Study location

This study has been conducted in Share Farm II, Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB) in 2014, 2016, and 2018. The area is administrated by the University Agriculture Park (TPU) and a few plots are used by undergraduate students for teaching purposes. Around less than 4 hectares of this area have been opened to vegetables cultivation since 2007, cultivating various short-term crops using a mixed and rotational practice. Identification on soil series for the area consists of the Bekenu soil series which has been developed over mixed sedimentary rocks.

In 2014, the study area was cultivated with Cucurbita moschata by practising the organic fertilisation technique. The crop was grown from August to December 2014 (four months) and rotated after the end of the crop’s season commonly with chilli, cucumber, and brinjal, which were harvested and sold at the university’s sales centre. About six beds were established with a planting distance of 0.5 m with four seedlings per holes. The crop was amended with poultry manure at 400 g/crop/month. While in 2016, the study area was cultivated with two types of vegetable, namely Amaranthus sp. and Brassica juncea. There are more than 50 beds that

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have been established along this area with different age of vegetables, however, the crop which has initially been supplied by poultry manure and lime has later been amended with inorganic and foliar fertiliser. The amount of fertiliser is expected to be around 300 g to 500 g/beds, which varies according to deficiencies symptoms that are present during the growing periods. In 2018, the area was cultivated with *Zea mays* from July to September 2018. The fertilisation practice in this area is similar to 2016, which has depended on the symptoms that have been present at the particular time, which consist of 36 beds.

**Soil sampling and statistical analysis**

The soil samples were augured using grid sampling according to beds row and inter-row and brought to the laboratory for the drying process. The dried soil was analysed for soil pH using ratio 1:2 with one part of the soil and two parts of distilled water, as mentioned by Tan (2010). While the percentage of OM and TOC were obtained from loss-on-ignition procedure describe by Sutherland (1998) and the amount of TOC was calculated by 58% over 100% of OM. The total N was determined using the AutoAnalyzer 3, and the solution was extracted using acid digestion as mentioned by Hach et al. (1985).

Data analysis was performed using the analysis of variance (ANOVA) procedure of Statistical Analysis System (SAS Version 9.4) with Tukey’s Studentized Range (HSD) test at p=0.05 to examine the effects of cultivation duration on the availability of selected soil parameters. Correlation of soil parameters on its strength was calculated using XLSTAT Version 2018 by Addinsoft™ using principal component analysis.

**RESULTS AND DISCUSSION**

**Effects of years cultivation on C/N ratios**

Continuous cultivation of crops in the Bekenu soil series showed a different trend on the availability of OM, TOC, and the total of N, which affects C/N ratios regardless of the years of cultivation (Table 2). It showed an increasing trend of soil pH from 2014 > 2016 > 2018 and a decreasing trend of OM and TOC from 2018 < 2016 < 2014. However, the availability of the total N was observed to had fluctuated with time and affecting the C/N ratios, with 2016 exhibiting the highest ratio among the others.

**Year 2014**

The increasing years of cultivation in this area has surprisingly lessened the soil acidity from 4.58 to 5.82. Every year, GML and poultry manure were amended two to three weeks before sowing activities which resulted in an increasing soil pH. This finding was also supported by other researchers who were applying lime and poultry manure to increase pH progressively (Chandra Shaha et al., 2012; Duruigbo et al., 2007). The increased availability of OM and TOC was also observed from this study, which was closely attributed to H+ exchange between crop litter, poultry manure, and soil. The highest OM (5.90%) in 2014 primarily originated from the poultry manure fertiliser (400 g/crop/month) onto *Cucurbita moschata*, which was enriched with C content. Application of composted poultry manure on maize crop at the rate 10 mg ha⁻¹ has strongly improved OM retention in sandy clay loam up to 4.35% and soil C/N ratio (Adeyemo et al., 2019; Bakayoko et al., 2009).

In this study, the total N has recorded both 2014 (4.27%) and 2018 (4.81%), and has exhibited a comparable value that is derived from poultry manure containing 360 mg kg⁻¹ of N. The comparable value of C (3.42%) and N (4.27%) has yielded a lower C/N ratio and may help soil microbial activities.

**Year 2016**

The area has been cultivated with *Amaranthus* sp. and *Brassica juncea* by practising similar farm establishment and is supplied with inorganic fertiliser and foliar fertiliser when necessary. These two leafy vegetables are known to be incapable of producing massive of litter since they only yielded 3.47% OM. Lessened TOC (2.01%) has also been measured which is mainly caused by the lack of OM and materials loss due to heavy rainfall. Flash flood has easily transported OM to the nearest drain due to its characteristics of low density and the less roughness of soil surface (Souza et al., 2019; Saint-Laurent et al., 2016). Saint-Laurent et al. (2016) had demonstrated that the TOC percentage during flash flood varied among flood zones between 1.74% to 3.3.4%. However, N availability for 2016 has recorded the lowest value (0.44%) compared to 2014 and 2018. This proportion of C and N has a remarkable effect on the C/N ratio with 4.57, which has
indicated 5 to 11 folds lower than 2014 and 2018, respectively. Lessened N availability (0.44%) was probably caused by immobilisation and apparently had indicated a N deficit. Although, the area was amended by grass clipping or leaves to protect the soil from excessive evapotranspiration and heat. Thus, as the grass decomposed slowly, it may contribute to the source of C to the soil. Moreover, lessened lignin and waxiness in grass may fasten decomposition and reflect the low value of C/N (Zhou et al., 2019; Xue and An, 2018). Rapid decomposition reaction enables the occurrence of N immobilisation and affect vegetables growth subsequent to the N shortage (Wells et al., 2013).

Table 1. Background of cultivated crops with an estimated size of the area during study period

| Years     | Crops                              | Size (ha) |
|-----------|------------------------------------|-----------|
| 2018**    | Zea mays                           | 0.21      |
| 2016*     | Amaranthus sp.; Brassica juncea    | 0.64      |
| 2014*     | Cucurbita moschata                 | 0.03      |

*Poultry manure and NPK, **Poultry manure only

Table 2. Impact of cultivation years on pH, OM, and TOC

| Years | pH         | OM           | TOC           | N            | C/N          |
|-------|------------|--------------|---------------|--------------|--------------|
| 2018  | 5.82 ± 0.09| 3.22 ± 0.12  | 1.87 ± 0.07   | 4.81 ± 0.42  | 0.39         |
| 2016  | 5.72 ± 0.15| 3.47 ± 0.11  | 2.01 ± 0.06   | 0.44 ± 0.45  | 4.57         |
| 2014  | 4.58 ± 0.05| 5.90 ± 0.16  | 3.42 ± 0.09   | 4.27 ± 0.39  | 0.82         |

*Means with different alphabet was significantly different at p=0.05 and ± symbol was standard error

Year 2018

It is explained that the possibility of OM reduction before 2018 has resulted from the series of vegetables cultivation. However, the measurement on soil OM in 2018 had indicated a recovery with a value of up to 3.22% as well as an improvement on C/N ratio but this was considered as an initial stage observation. The slightly lessened OM in 2018 compared to previous years (2016 and 2014) of cultivation may occur due to earlier samples analysis which was conducted in initial crop cultivation after three weeks of transplanting Zea mays. During this initial stage establishment, the area only depends on poultry manure and lime effects instead of inorganic fertiliser which evidently has been the lowest OM contents among all the years. Subsequent to late fertilisation, this area has indicated a comparable total N when compared with 2014. Such findings are similar to Xu et al. (2019) and Kushwah et al. (2014) which have obtained a lower C/N ratio in the initial stages of crop development, however these will be elevated slowly afterward. However, it has indicated a decline of C/N ratio when the converted crop cultivation area, for example, forest to cultivation trend from forest > grassland > cropland (Xu et al., 2019).

Correlation of between cultivation years

The first principal component, F1, was accounted for 57.95% of the variation with the positive axis represented by the total of N, OM, and TOC, while the negative axis was represented by soil pH and C/N ratio (Figure 1). Whereas the positive F2 axis was accounted for 20.31% and was represented by the pH and negative axis on OM, TOC, and C/N ratio. The analysis had exhibited three cultivation groups that were formed as effected by the cultivation year; G1 was 2014, G2 was 2016, and G3 was 2018. It was clearly shown that each group indicated a strong correlation on its parameters.
In G1, high OM and TOC have indicated that the soil is in a good fertility status. However, the soil was relatively acidic with a lowered C/N ratio, which could have arisen from insufficient poultry manure application that led to the increases in OM availability. The main reasons for this condition had resulted from the insufficient ion-exchange reactions, however, these were replaced by organic anion upon decomposed once they were applied to the soil (Duruigbo et al., 2007). Moreover, a decrease of soil pH has also been reported by Biratu et al. (2019) when applying organic manure to their soil that has been cultivated with cassava, which highlights that 12 months after planting is more acidic than 8 and 4 months after planting. Because of the higher C content in the poultry manure, it has benefited from the availability of TOC and increased total of N in the soil compared to soil acidity.

While in G2, which is represented by the year 2016 has provided a high C/N ratio among all the groups. Higher C/N ratio eventually have improved soil pH, OM, and TOC regardless of whether it may be considered as insufficient compared to 2014. The use of grass clipping as soil amendment not only increases the OM but has also improved other soil bases when the grass decomposed. It has been reported that by increasing grass residue on farming area may improve TOC and indirectly gives a promising effect on an increasing yield (Sadeghi and Bahrami, 2009). Correspondingly, G3 (2018) has shown a high soil pH compared to 2014 and 2016. Although high pH value has been recorded, it is found that OM and TOC have lessened when compared to N availability. This may be attributed to the early land establishment where the release of OM and TOC remains gradual and takes time upon decomposition.

CONCLUSION

Availability of TOC in three different years showed a decreasing trend by 2018 < 2016 < 2014 that were subjected to a longer year of cultivation although rotational practices were done. Insufficient poultry manure and crop residue returning to the soil was evident through the lessened OM and TOC with the increase in cultivation years that affected the C/N ratio. Thus, it would be recommended for farmers to consistently apply substantial amounts of treated animal manure and to leave crop residue that literally will enhance the soil’s fertility in the long term.
COMPETING INTEREST

The authors declare that they have no competing interests.

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