Research in
AGRICULTURE, LIVESTOCK and FISHERIES
ISSN : P-2409-0603, E-2409-9325
An Open Access Peer-Reviewed International Journal

Article Code: 0276/2020/RALF
Article Type: Research Article

Res. Agric. Livest. Fish.
Vol. 7, No. 2, August 2020: 175-181.

CHANGES IN SOIL ORGANIC CARBON UNDER CONTINUOUS FARMING

Izzah Abd Hamid[1], Wan Asrina Wan Yahaya[1]* and Norziana Zin Zawawi[2]

[1]Department of Crop Science, Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, 97008 Bintulu, Sarawak, Malaysia; [2]Soil Science, Water, and Fertilizer Research Centre, MARDI, 43400 Serdang, Selangor, Malaysia.

***Corresponding author:** Wan Asrina Wan Yahaya; E-mail: asrina@upm.edu.my

ARTICLE INFO

Received
08 July, 2020

Revised
13 August, 2020

Accepted
17 August, 2020

Online
31 August, 2020

Key words:
Organic carbon
Soil texture
C/N ratio
Manure
Continuous cultivation

A B S T R A C T

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.

To cite this article: Izzah A. H., W. Y. Wan Asrina and Z. Z. Norziana, 2020. Changes in Soil Organic Carbon Under Long Term Continuous Farming**.** Res. Agric. Livest. Fish., 7 (2): 175-181.

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 identified as sandy clay loam textures with the argillic horizon (Paramananthan, 2000). Moreover, this soil is 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

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	$5.82^{a} \pm 0.09$	$3.22^{b} \pm 0.12$	$1.87^{b} \pm 0.07$	$4.81^{a} \pm 0.42$	0.39
2016	$5.72^{a} \pm 0.15$	$3.47^{b} \pm 0.11$	$2.01^{b} \pm 0.06$	$0.44^{b} \pm 0.45$	4.57
2014	$4.58^{b} \pm 0.05$	$5.90^{a} \pm 0.16$	$3.42^{a} \pm 0.09$	$4.27^{a} \pm 0.39$	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.

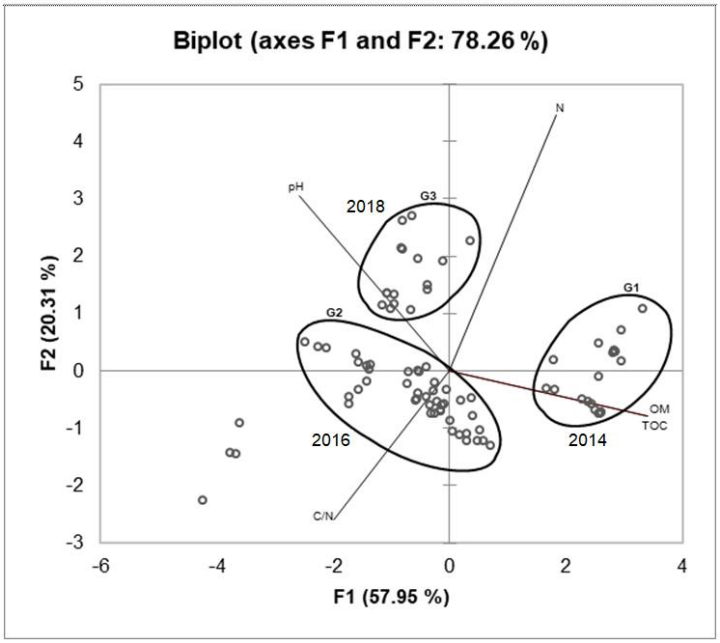

Figure 1. Distribution of soil samples in three different cultivation years accounted for 78.26%. G1 is 2014, G2 is 2016, and G3 is 2018

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 Bahrani, 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.

REFERENCES

1. Adeyemo AJ, OO Akingbola and SO Ojeniyi, 2019. Effects of poultry manure on soil infiltration, organic matter contents and maize performance on two contrasting degraded alfisols in southwestern Nigeria. International Journal of Recycling of Organic Waste in Agriculture, 1-8.
2. Bakayoko S, D Soro, C Nindjin, D Dao, A Tschannen, O Girardin and A Assa, 2009. Effects of cattle and poultry manures on organic matter content and adsorption complex of a sandy soil under cassava cultivation (*Manihot esculenta*, Crantz). African Journal of Environmental Science and Technology, 3: 190-197.
3. Biratu GK, E Elias and P Ntawuruhunga, 2019. Soil fertility status of cassava fields treated by integrated application of manure and NPK fertilizer in Zambia. Environmental Systems Research, 8: 1-13.
4. Chandra Shaha S, MA Kashem and KT Osman, 2012. Effect of lime and farmyard manure on the concentration of cadmium in water spinach (*Ipomoea aquatica*). ISRN Agronomy, 2012: 1-7.
5. Duruigbo CI, JC Obiefuna and EU Onweremadu, 2007. Effect of poultry manure rates on the soil acidity in an Ultisol. International Journal of Soil Science, 2: 154-158.
6. Evrendilek F, I Celik and S Kilic, 2004. Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey. Journal of Arid Environments, 59: 743-752.
7. Fissore C, BJ Dalzell, AA Berhe, M Voegtle, M Evans and A Wu, 2017. Influence of topography on soil organic carbon dynamics in a Southern California grassland. CATENA, 149: 140-149.
8. Hach CC, SV Brayton and AB Kopelove, 1985. A powerful Kjeldahl nitrogen method using peroxymonosulfuric acid. Agricultural and Food Chemistry, 33: 1117-1123.
9. Haruna SI and NV Nkongolo, 2019. Tillage, cover crop and crop rotation effects on selected soil chemical properties. Sustainability, 11: 1-11.
10. Jiao Y, Z Xu and J Zhao, 2009. Effects of grassland conversion to cropland and forest on soil organic carbon and dissolved organic carbon in the farming-pastoral ecotone of Inner Mongolia. Acta Ecologica Sinica, 29: 150-154.
11. Kushwah SK, ML Dotaniya, AK Upadhyay, S Rajendiran, MV Coumar, S Kundu and AS Rao, 2014. Assessing carbon and nitrogen partition in *Kharif* crops for their carbon sequestration potential. National Academy Science Letters, 37: 213-217.
12. Ma QJ, Q Zhang, J Niu and XG Li, 2020. Plastic-film mulch cropping increases mineral-associated organic carbon accumulation in maize cropped soils as revealed by natural 13C/12C ratio signature. Geoderma, 370: 1-9.
13. Pan P, F Zhao, J Ning, L Zhang, X Ouyang and H Zang, 2018. Impact of understory vegetation on soil carbon and nitrogen dynamic in aerially seeded Pinus massoniana plantations. PloS One, 13: 1-13.
14. Paramananthan S, 2000. Soils of Malaysia: Their Characteristics and Identification. Academy of Sciences, Kuala Lumpur, Malaysia.
15. Plante AF, RT Conant, CE Stewart, K Paustian and J Six, 2006. Impact of soil texture on the distribution of soil organic matter in physical and chemical fractions. Soil Science Society of America Journal, 70: 287-296.
16. Razafimbelo T, T Chevallier, A Albrecht, L Chapuis-Lardy, FN Rakotondrasolo, R Michellon, L Rabeharisoa and M Bernoux, 2013. Texture and organic carbon contents do not impact amount of carbon protected in Malagasy soils. Scientia Agricola, 70: 204-208.
17. Robačer M, S Canali, HL Kristensen, F Bavec, SG Mlakar, M Jakop and M Bavec, 2016. Cover crops in organic field vegetable production. Scientia Horticulturae, 208: 104-110.

18. Sadeghi H and MJ Bahrani, 2009. Effects of crop residue and nitrogen rates on yield and yield components of two dryland wheat (*Triticum aestivum* L.) cultivars. Plant Production Science, 12: 497-502.
19. Saint-Laurent D, R Paradis, A Drouin and V Gervais-Beaulac, 2016. Impacts of floods on organic carbon concentrations in alluvial soils along hydrological gradients using a digital elevation model (DEM). Water, 8: 1-17.
20. Souza FGD, VF Melo, WF Araújo and THDC Araújo, 2019. Losses of soil, water, organic carbon and nutrients caused by water erosion in different crops and natural savannah in the Northern Amazon. Revista Ambiente and Água, 14: 1-16.
21. Sutherland RA, 1998. Loss-on-ignition estimates of organic matter and relationships to organic carbon in fluvial bed sediments. Hydrobiologia, 389: 153-167.
22. Tan KH, 2010. Principles of Soil Chemistry. Taylor & Francis, Boca Raton, Florida.
23. Wang S, X Wang and Z Ouyang, 2012. Effects of land use, climate, topography and soil properties on regional soil organic carbon and total nitrogen in the Upstream Watershed of Miyun Reservoir, North China. Journal of Environmental Sciences, 24: 387-395.
24. Wells MS, SC Reberg-Horton, AN Smith and JM Grossman, 2013. The reduction of plant-available nitrogen by cover crop mulches and subsequent effects on soybean performance and weed interference. Agronomy Journal, 105: 539-545.
25. Xu E, H Zhang and Y Xu, 2019. Effect of large-scale cultivated land expansion on the balance of soil carbon and nitrogen in the Tarim Basin. Agronomy, 9: 1-18.
26. Xue Z and S An, 2018. Changes in soil organic carbon and total nitrogen at a small watershed scale as the result of land use conversion on the Loess Plateau. Sustainability, 10: 1-14.
27. Zhong Z, Z Chen, Y Xu, C Ren, G Yang, X Han, G Ren and Y Feng, 2018. Relationship between soil organic carbon stocks and clay content under different climatic conditions in Central China. Forests, 9: 1-14.
28. Zhou G, S Xu, P Ciais, S Manzoni, J Fang, G Yu, X Tang, P Zhou, W Wang and J Yan, 2019. Climate and litter C/N ratio constrain soil organic carbon accumulation. National Science Review, 6: 746-757.
29. Zuber S, G Behnke, E Nafziger and M Villamil, 2018. Carbon and nitrogen content of soil organic matter and microbial biomass under long-term crop rotation and tillage in Illinois, USA. Agriculture, 8: 1-12.