Soil Quality Monitoring and Evaluation Under Conventional Plow-based and Conservation Agriculture Production Systems in Southern Philippines

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Abstract

Soil quality under conventional plow-based agriculture production systems has been known to degrade over time owing to greater exposure of soil organic matter to microbial attack. This study was conducted to monitor and evaluate soil quality under conventional plow-based and conservation agriculture production systems (CAPS) in southern Philippines. Six CAPS treatments in the form of cropping patterns with different cover crops under two fertility levels including plow-based system were established and laid out in a randomized complete block design in a typical upland agricultural producing area in Claveria, Misamis Oriental, Philippines. Soil sampling was performed at three depths (0-5 cm, 5-10 cm and 15-30 cm) at the experimental site in July 2010, December 2010, April 2011 and September 2011. The soil samples collected were brought to University of the Philippines Los Baños for physical and chemical analysis. The observed values of bulk density, soil organic matter, soil nitrogen, soil phosphorus and soil pH at various CAPS treatments were consequently analyzed. The residual soil moisture content was also measured at the various plots of the CAPS treatments at the site using time domain reflectometry (TDR). Results showed that differences in soil quality parameter values were observed over time and at various depths for the various CAPS treatments, although the observed differences over time did not appear to be substantial after one year of cropping. The soil organic matter at the uppermost soil layer (0-5 cm) did not exhibit a well-defined pattern of temporal variation although the organic matter under conventional plow-based system appeared to decline slightly over time. Both soil nitrogen and phosphorus concentrations in all CAPS treatments were generally higher in the upper soil layers (0-15 cm) than in the deeper soil layers (15 to 30 cm) under the two fertility levels. The soil bulk density remained practically the same as the baseline conditions for all soil layers. Analysis of variance of the residual moisture during the dry month of April 2011 showed that the plots under conservation agriculture have significantly higher residual moisture content than under conventional plow-based system with maize+Stylosanthes guianensis- Stylosanthes guianensis- fallow CAPS treatment exhibiting the highest residual moisture content level. Additional soil quality monitoring is necessary to generate empirical evidence on the effect of conservation agriculture on soil quality improvement. All these findings could then serve as basis for future assessment of the impacts of conservation agriculture and conventional plow-based systems on soil quality.

Keywords: soil quality, conservation agriculture, cover crops, soil organic matter, biological engineering

1. Introduction

Soil degradation continues to be a serious problem in the Philippines. One of the major causes of the deterioration of the quality of this important natural resource is the continued practice of conventional plow-based agriculture that leads to significant soil disturbances. This consequently results not only to excessive soil erosion but loss of soil organic matter as well. Soil quality under conventional plow-based agriculture production systems has been known to degrade over time owing to greater exposure of soil organic matter to microbial attack. From the economic standpoint, this traditional plow-based system also leads to increase in the cost of agricultural crop production due to increased fertilizer inputs, soil amendments and other inputs to compensate for the loss of soil fertility and the degradation of soil quality. From the environmental protection standpoint, this traditional agricultural practice leads to sedimentation of natural streams, reduction in channel capacities and flooding. This adverse impact has become even more pronounced in the recent years with the occurrence of extreme rainfall events presumably due to climate change and climate variability.

One of the most promising new technologies that can be used to address soil degradation problems is a biological engineering technology called “conservation agriculture”. Conservation agriculture is a relatively new concept essentially based on the principles of minimum soil disturbance, continuous mulch cover and diversified crop rotations (Erenstein et al., 2008). It has been widely adopted in countries like the United States, Canada, Brazil, Argentina, Australia, Paraguay and on the Indo Gangetic Plains, on about 95.8 million hectares (Derpsch, 2008), as a sustainable agriculture and soil conservation practice.

In Southeast Asia, the application of conservation agriculture is still essentially at the research stage. One of the most notable of these is in Cambodia, where conservation agriculture has been tested in numerous farms. Presently it is the subject of continuing research (Boulakia et al., 2009). In Laos, Tivet et al. (2008) demonstrated that soil aggregation, water holding capacity and biological activity were enhanced under conservation agriculture production systems. In Vietnam, conservation agriculture on sloping lands was found to reduce soil erosion by up to 96% and at the same time increased crop yield by over 200% (Doanh and Tuan, 2008). Other than the aforementioned, no other published literature is available pointing towards significant advances in conservation agriculture research in Southeast Asia.

In the Philippines, no research exists on the soil quality impacts of conservation agriculture, in its strictest sense. Hence, this study was conducted to monitor and evaluate soil quality under conventional plow-based and conservation agriculture production systems (CAPS) in a typical upland crop production area in southern Philippines.

2. Methodology

This study was implemented at the Sustainable Agriculture and Natural Resources Management (SANREM) research site in Claveria, Misamis Oriental in the island of Mindanao in southern Philippines. Six CAPS treatments in the form of cropping patterns with different cover crops under two fertility levels including plow-based system were established and laid out in a randomized complete block design in a typical upland agricultural producing area in the said site. The six treatments, including the conventional plow-based system serving as the control, were replicated four times and were laid out in a randomized complete block design. Subplots in

each treatment were also established to represent two fertility levels. A summary of the modified experimental treatments is given in Tables 1 and 2.

Soil sampling was performed at three depths (0-5 cm, 5-10 cm and 15-30 cm) at the experimental site in July 2010, December 2010, April 2011 and September 2011. The soil samples collected were brought to University of the Philippines Los Baños for physical and chemical analysis. The observed values of bulk density, soil organic matter, soil nitrogen, soil phosphorus and soil pH at various CAPS treatments were consequently analyzed. The residual soil moisture content was also measured at the various plots of the CAPS treatments at the site using time domain reflectometry (TDR).

TABLE 1. Summary of the CAPS treatments

	Cropping pattern
T1	Arachis Pintoi + Maize- Arachis pintoi + Maize
T2	Maize + Stylo - Stylo fallow
T3	Maize+cowpea - Upland rice +cowpea
T4	Maize+Rice bean-Maize+Rice bean
T5	Cassava + Stylo
T6	Maize-maize (conventional plow-based) (control)

TABLE 2. Summary of subplots

	Fertility Level
Fo	0-30-0 for N, P_2O_5, K_2O
F1	60-30-30 for N, P_2O_5, K_2O

3. Results and Discussion

Results of the physico-chemical analysis of the soil samples obtained from the various CAPS treatments at the research site are shown graphically in Figures 1 to 3. For the December 2010 soil sampling (Fig. 1), i.e. five months after crop establishment of the first cropping at the site, the mean soil bulk density ranged from 1.06 to 1.16 g/cc for all treatments regardless of fertility level and soil depth. For the 0-5 cm soil layer, however, the bulk density ranged from 1.04 to 1.18 g/cc for all treatments and fertility levels. The bulk density values were practically the same for all layers with a mean value of 1.11, 1.10 and 1.14 g/cc, for the 0-5, 5-15 and 15-30 cm soil layers, respectively for both fertility levels. The mean organic matter ranged from 4.27 to 5.21 % under fertility level Fo and from 4.47 to 5.12% under fertility level F1 for all treatments and for all soil layers. For the 0-5 cm soil layer, the mean organic matter ranged from 5.52 to 6.09% and from 5.53 to 6.45% under Fo and F1 fertility levels, respectively. In general, the soil organic matter at the upper soil layer exhibited higher values than the deeper layer averaging 5.83, 5.35 and 3.24% for the 0-5, 5-15 and 15-30 cm layers, respectively under Fo fertility level and 5.85, 5.24 and 3.40% for the same soil layer sequence under F1 level. All treatments, both conventional plow-based and conservation agriculture production systems, did not exhibit substantial differences in terms of soil organic matter for all layers and fertility levels at this stage of cropping. The other nutrients nitrogen and phosphorus ranged from 0.17 to 0.21 % and from 2.2 to 3.2 ppm, respectively for all treatments, soil layers and fertility levels on the average. However, both soil nitrogen and phosphorus concentrations were generally higher in the upper soil layers (0-15 cm) than the deeper soil layers (15 to 30 cm). The soil proved to remain acidic

with the mean soil pH ranging from 4.5 to 4.77 for all treatments, soil layers and fertility levels. However, the mean soil pH at 0-5 cm layer proved to be slightly higher than the baseline level. This may be attributed to lime application during cropping.

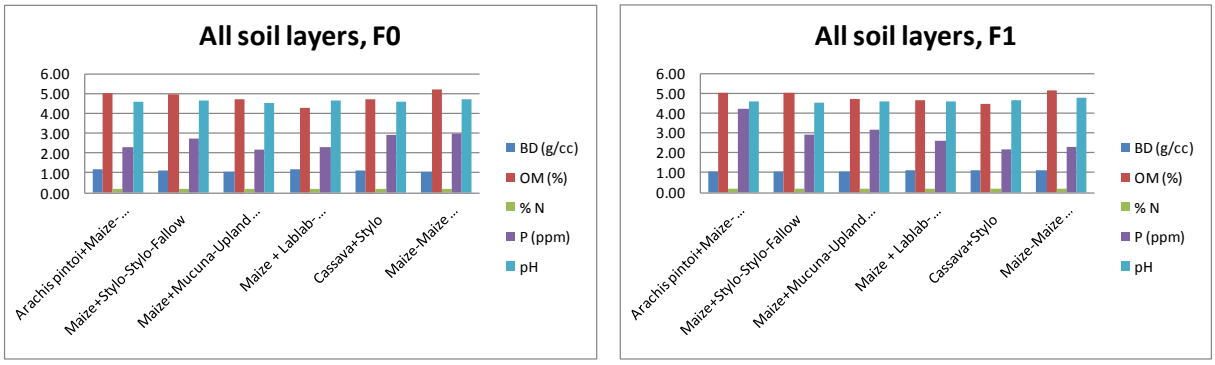

Figure 1. Soil physico-chemical properties at various CAPS treatments averaged for all layers at fertility levels, F0 and F1 in December 2010.

For the April 2011 soil sampling (Fig. 2), i.e. nine months after the start of the field experiments, most of the soil quality parameters remained practically similar to the December 2010 levels, as to be expected. The soil bulk density ranged from 0.92 to 1.04 g/cc for all treatments, soil layers and fertility levels. Although slightly lower than the December 2010 values, the soil bulk density practically remained the same for all layers with a mean value of 0.94, 0.99 and 1.04 g/cc, for the 0-5, 5-15 and 15-30 cm soil layers, respectively for both fertility levels. The mean soil organic matter ranged from 4.33 to 5.33 % under fertility level Fo and from 4.64 to 5.38% for F1. For the 0-5 cm soil layer, the mean organic matter ranged from 5.34 to 6.52% under Fo and from 5.37 to 7.39% under F1. Similar to the December 2010 sampling, the soil organic matter at the upper soil layer generally exhibited higher values than the deeper layer averaging 5.91, 5.00 and 3.51% for the 0-5, 5-15 and 15-30 cm layers, respectively under Fo fertility level and 6.31, 5.02 and 3.69% under F1 level. Although the variations are still minimal as to be expected with less than a year of cropping, the treatments under conservation agriculture production systems exhibited slightly higher organic matter content at the upper soil layer than the conventional plow-based system. Under fertility level F1, the organic matter content at 0-5 cm averaged 6.01 and 6.49% for fertility levels Fo and F1 respectively, while that under conventional plow-based system averaged 5.91 and 6.31% for Fo and F1, respectively. The other nutrients nitrogen and phosphorus showed practically similar values as in the December 2010 levels with mean soil nitrogen concentration ranging from 0.19 to 0.23 % and soil phosphorus concentration ranging from 1.55 to 3.10 ppm for all treatments, soil layers and fertility levels. However, both soil nitrogen and phosphorus concentrations were generally higher in the upper soil layers (0-15 cm) than the deeper soil layers (15 to 30 cm). The soil remained acidic after nine months with mean soil pH ranging from 4.27 to 4.8. However, the upper soil layer exhibited slightly higher soil pH compared to the baseline conditions again due to lime application during cropping.

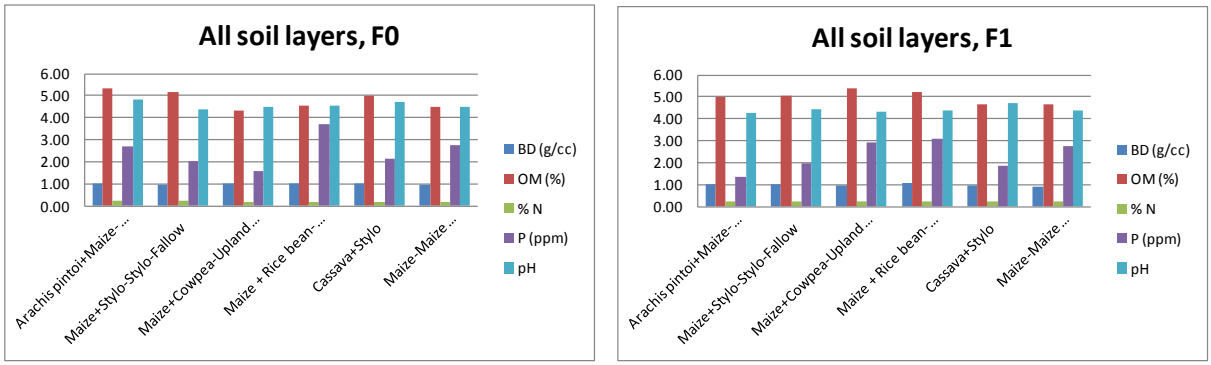

Figure 2. Soil physico-chemical properties at various CAPS treatments averaged for all layers at fertility levels F0 and F1, in April 2011.

The results of the soil quality analysis of the samples obtained at the site in September 2011, fourteen months after the first cropping, are depicted in Figure 3. Results of the analysis showed that regardless of fertility level, the soil organic matter content is generally higher under conservation agriculture production systems than under conventional plow-based system. For the 0 to 5 cm soil layer alone, the organic matter ranged from 5.4% to 6.94% and from 6.05% to 6.45% for F0 and F1 fertility levels, respectively, with treatment 5 (Cassava+stylo) and treatment 2 (Maize+stylo-stylo-fallow) exhibiting the highest observed soil organic matter for F0 and F1, respectively. Treatment 1 (Arachis pintoi+Maize-Arachis pintoi) also exhibited a relatively high organic matter content at 6.46% and 6.26% at F0 and F1 levels, respectively. On the other hand, the soil organic matter content under conventional plow-based system for the same soil layer only reached 4.96% and 5.24% for F0 and F1 fertility levels, respectively. This is to be expected as substantial soil disturbance is incurred under plow-based systems leading to greater exposure to microbial attack and the subsequent reduction in organic matter content. On the other hand, results of the analysis for soil nitrogen, phosphorus and pH did not exhibit distinct difference between CAPS and conventional plow-based system.

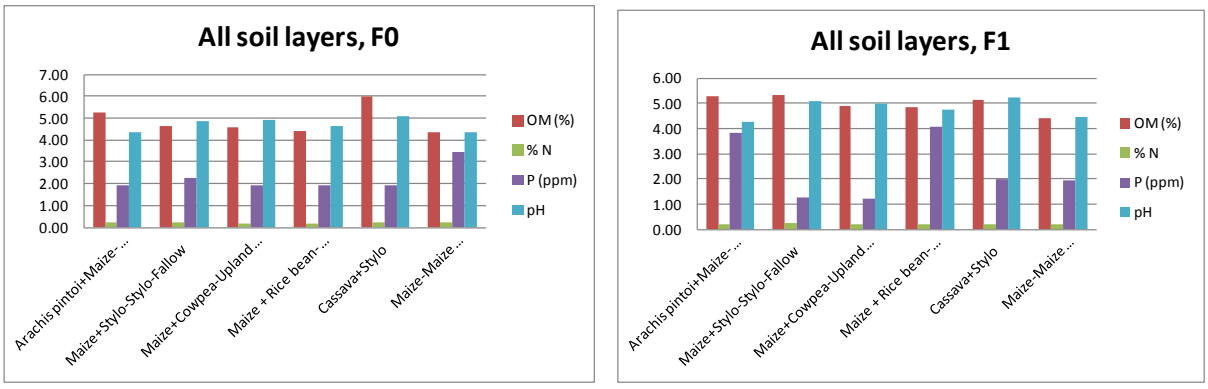

Figure 3. Soil physico-chemical properties at various CAPS treatments averaged for all layers at fertility level F0 and F1 in September 2011

To obtain a gauge on the effects of conservation agriculture on soil quality over time, the temporal trends of soil organic matter content, the primary soil quality index, was evaluated. Plots of the temporal variation of soil organic matter at the upper soil layer of 0 to 5 cm for various CAPS treatments and fertility levels from the first soil sampling in July 2010 until the September 2011 sampling are shown in Figure 4. It is apparent that the soil organic matter content at the upper soil layer under conservation agriculture production systems (Treatments 1 to 5) generally increased over the period considered. On the other hand, the soil organic matter content under conventional plow-based system (Treatment 6) appears to steadily decline for the same period. Nevertheless, further soil quality monitoring and analysis need to be carried out to generate a more adequate basis for assessing these temporal effects.

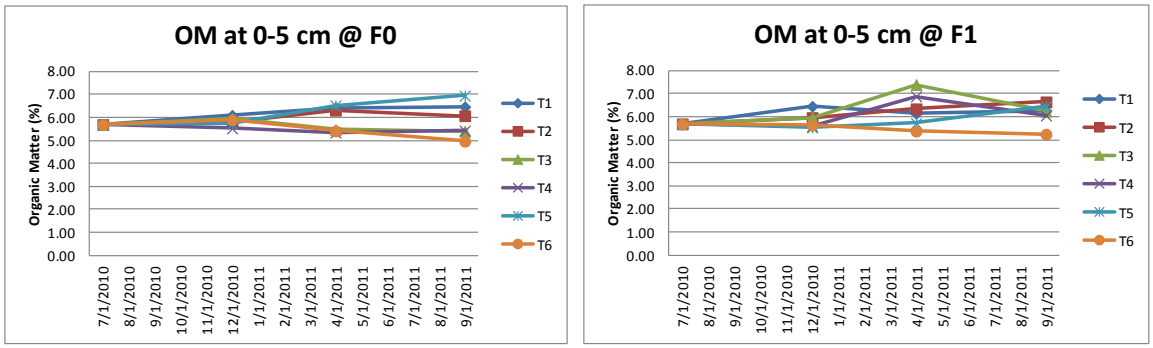

Figure 4. Temporal variation of soil organic matter at upper soil layer under various CAPS treatments at fertility level F0 and F1

In addition to the aforementioned soil quality parameters, the residual soil moisture content was also measured at each of the four replicates of the six CAPS treatments under fertility level F1 at the site using time domain reflectometry (TDR) during the dry month of April in 2011. The residual moisture content at the upper 12 cm soil layer ranged from 30.6 to 39% on a volume basis for CAPS treatments 1 to 5 and from 24.7 to 31.1 % for the conventional plow-based system. The mean residual moisture content under each of the CAPS treatments 1 to 6 is significantly different from that under the conventional plow-based system based on Tukey's HSD and Dunnett's tests. Results also showed that treatment 2 (maize+stylo-stylo fallow) yielded the highest residual moisture content followed by treatments 5, 1, 4 and 3.

4. Summary and Conclusion

This study was conducted to monitor and evaluate soil quality under conventional plow-based and conservation agriculture production systems (CAPS) in southern Philippines. Six CAPS treatments in the form of cropping patterns with different cover crops under two fertility levels including plow-based system were established and laid out in a randomized complete block design in an upland agricultural area in Claveria, Misamis Oriental, in southern Philippines. Soil sampling and analysis were performed at the various CAPS treatments, at different depths and times of the year.

Results showed that changes in soil quality parameter values were observed over time and at various depths for the various CAPS treatments, although the observed differences over time did not appear to be substantial after one year of cropping. The soil organic matter at the uppermost soil layer (0-5 cm) did not exhibit a well-defined pattern of temporal variation

although the organic matter under conventional plow-based system appeared to decline slightly over time. Both soil nitrogen and phosphorus concentrations in all CAPS treatments were generally higher in the upper soil layers (0-15 cm) than in the deeper soil layers (15 to 30 cm) under the two fertility levels. The soil bulk density remained practically the same as the baseline conditions for all soil layers. Analysis of variance of the residual moisture during the dry month of April 2011 showed that the plots under conservation agriculture have significantly higher residual moisture content than under conventional plow-based system with maize+Stylosanthes guianensis- Stylosanthes guianensis- fallow CAPS treatment exhibiting the highest residual moisture content level.

In order to generate more empirical evidence on the impact of conservation agriculture on soil quality, continuous soil quality monitoring is necessary. Ultimately, all these findings could serve as basis for policy formulation and possible technology upscaling in other upland areas in the Philippines.

5. Acknowledgement

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