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SOIL QUALITY PARAMETERS FOR ROW-CROP SYSTEMS AND GRAZED PASTURES WITH AGROFORESTYRY BUFFERS

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Abstract: Incorporation of trees and establishment of buffer are believed to enhance soil quality. Soil enzyme activities and water stable aggregates have been identified as good indices for assessing soil quality to evaluate early responses to changes in soil management. However, studies comparing these parameters for grazing pastures and row crop systems are limited. The objective of this study is to examine the activities of selected enzymes (fluorescein diacetate (FDA) hydrolase, dehydrogenase, αglucosidase and αglucosaminidase), the percentage of water stable aggregates (WSA), and soil organic carbon and nitrogen as soil quality parameters for grazed pasture and row-crop systems. The study consisted of four management treatments: grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB) and row-crop (RC). Soil organic carbon (SOC), total nitrogen (TN) contents and soil bulk density were also determined. Two soil depths (0-10 and 10-20 cm) were analyzed for all treatments for two consecutive years, 2009 and 2010. The row-crop treatment showed significantly lower αglucosidase and αglucosaminidase activity and significantly lower WSA compared to all other treatments. The FDA hydrolase activities were not significant in 2009 but were significant in 2010. There were numerical variations of parameters in two years but the pattern was consistent. Surface soil revealed higher enzyme activities and higher WSA than the sub-surface soil. The treatment by depth interactions were significant for αglucosidase and αglucosaminidase enzymes in 2009 but the interactions were significant for dehydrogenase and αglucosaminidase enzymes in 2010. Implications can be made that permanent vegetation will improve soil quality by enhancing organic matter accumulation in the soil and increasing microbial activity with minimum soil disturbance which will have a positive effect on the ecosystems.

Keywords: ecosystem, microbial activity, perennial vegetation, soil enzymes, soil organic carbon.

INTRODUCTION

The interactions between soil biological parameters and management practices and consequential effects on environmental quality are of great agricultural and ecological significance (Watt et al., 2006). Despite the important roles of the soil microbiota in agroecosystem functions (Verhoef and Brussaard, 1990), very little is known of their activities, composition, and abundance under grazing pasture systems.

According to Doran and Parkin (1994), soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health. Periodic assessments of soil quality with known indicators and thresholds help to assess the capacity of land for a particular function. Selection of soil quality indicators depend on soil characteristics, land use and management goals, and environmental protection (Stott et al., 2010).

Enzyme activities have been identified as possible indicators of the quality of soil because of their relatively rapid responses to changes in soil management (Dick, 1994; Bandick and Dick, 1999). Soil enzymes play key biochemical functions in the overall process of organic matter decomposition in the soil system (Burns, 1983; Sinsabaugh et al., 1991). While these studies have typically dealt with differences in soil enzyme activities, it is also possible with these assays to develop specific measures of functional diversity.

Silvopasture is a type of agroforestry management system that is believed to provide environmental, economical and social benefits. In silvopasture systems, grazing and stocking rates affect animals, affect utilization of nutrients by soil plant systems, and enhance soil microbial activities and thereby soil ecology of pasture soils (Haynes and William, 1993; Sigua, 2003). Thus, incorporation of agroforestry into pastures is believed to improve soil quality.

Information on grazing systems with agroforestry and grass buffer interactions within the temperate agroforestry zone on soil quality and conservation is limited; therefore research designed to explore new species and management combinations is needed to optimize production and sustainability of these systems (Jose et al., 2004). The objectives of this study were to evaluate the effects of agroforestry and grass buffers on soil parameters in grazed pasture and row-crop systems and compare temporal variations of parameters. We hypothesized that there is an effect of grazed pasture with buffers and row-crop management on soil quality parameters and that parameter values vary annually due to variation in soil characteristics.

MATERIALS AND METHODS

Study Area

The study was carried out at the Horticulture and Agroforestry Research Center (HARC) of the University of Missouri in New Franklin, MO (92°74´ W and 37°2´ N; 195 m above sea level). Four small watersheds under grazed pasture (GP) were used for the study, which include replicate wa-

tersheds with agroforestry buffers (AgB) (tree-grass buffers) and grass buffers (GB). The size of each watershed with buffers is about 0.8 ha. The grazed pasture area was divided into six paddocks. The cattle were introduced in 2005 and were rotationally grazed (Kumar et al., 2008). The land was under tall fescue grass (*Festuca arundinacea* Schreb.) without grazing before the establishment of watersheds. The GB buffer areas were reseeded with tall fescue (*Festuca arundinacea*; Kentucky 31) in 2000. Pastures were seeded with red clover (*Trifolium pratense* L.) and lespedeza (*Kummerowia stipulacea* L.) in 2003. The AgB buffers consisted of eastern cottonwood trees (*Populus deltoides* Bortr. ex Marsh.). Soils for the row-crop (RC) treatment were sampled from an adjacent field on the north side of the pasture areas. The crop was corn in 2009 and it was soybean in 2010. Soils at the study site were classified as Menfro silt loam (fine-silty, mixed, superactive, mesic Typic Hapludalfs).

Experimental design and sampling

The management treatments were GP, AgB, GB, and RC. The AgB and GB treatments were in the buffer areas of the small watersheds with respective buffer type and the GP treatment was in the rotationally grazed area in the watersheds. The experimental design was completely randomized with a split plot for soil depths (0-10 and 10-20 cm). There were two replicates for treatments and three sampling locations per treatment plot.

Soil sampling was conducted during June of two consecutive years, 2009 and 2010. There were three sampling positions per treatment plot and two replications. For GP and RC treatments, samples were taken from middle landscape positions only. The soil samples for the GB buffer treatment were taken from the center of the buffer. Samples for the AgB buffer treatment were sampled about 40 cm from the base of a tree trunk. Hence, treatments consisted of six sample locations (three sub-samples and two replications). Soils were collected from two depths (0-10 and 10-20 cm). The sampling bags were sealed and transported to the laboratory in a cooler. All samples were maintained at field moist condition and were stored at 4℃ until analyzed.

Laboratory Analyses

Water stable aggregates were determined from a 10-g air-dried soil sample using the wet-sieving method on aggregates > 250 μm diameter (Angers and Mehuys, 1993). All enzymes were colorimetrically quantified in laboratory assays following the standard procedure (Table 1). Soil organic carbon (SOC) and total nitrogen (TN) contents were determined by dry combustion analysis at 950°C using LECO TruSpec CN analyzer as described by Nelson and Sommers (1996). The water stable aggregates (WSA) and enzyme activities were analyzed in duplicate for each sample.

Statistical Analyses

The data were analyzed as a completely randomized design with a split plot for soil depth using

Proc GLM in Statistical Software Package SAS version 9.2 (SAS, 2008). Data collected in each of two years were analyzed separately to determine the treatment effects and the interactions with depth. The parameters measured were analyzed taking into account the four management treatments and two depths. The main effects consisted of treatment effects (management) and the split plot consisted of depth effects. The least significant difference tests (Duncan's LSD) were used for pair-wise comparisons of treatment means. Differences were declared significant at the five percent level of significance ($p \leq 0.05$).

RESULTS

Water stable aggregates

Water stable aggregate (WSA) percentages ranged from 24.8% to 68% among the study treatments. The RC treatment had the lowest WSA level and it was significantly lower than all other treatments (Table 2). The GB treatment had the highest WSA percentage in both years. Variation in WSA levels within perennial vegetation treatments for two years was not significant. There were significant depth effects in both years (Table 3; Fig. 1).

Soil bulk density

The differences in bulk density among treatments were not significant but the row crop treatment had the highest value (1.42 g cm^{-3}) and AgB had the lowest value (1.31 g cm^{-3}; Table 2). The bulk density values decreased in the order RC>GP>GB>AgB. Although there were no significant differences, values were in expected range; differences did not exist possibly due to the low number of replications (two).

Soil Carbon and Nitrogen

Soil organic carbon (SOC) and total nitrogen (TN) contents varied slightly between the two years. The SOC content ranged 1.26% in RC treatment 1.92% in AgB treatment. Similarly TN content ranged between 0.16 to 0.22%, lowest in RC treatment and the highest in AgB treatment (Table 2). The variation among treatments was not significant possibly due to low number of replications. There were significant depth effects in SOC and TN (Fig. 2). The perennial vegetation treatments showed a greater decrease in SOC and TN contents from surface to sub-surface compared to row crop agriculture.

Enzyme activities

βglucosidase and βglucosaminidase enzyme activities.

Analysis of αglucosidase and αglucosaminidase activity revealed significant differences between the RC treatment and all other treatments in both years (Table 2). The αglucosidase activities were consistent in two years in the perennial vegetation treatments. However, the year to year variation

in αglucosidase activity in the RC treatment was greater. There were comparatively higher activities of αglucosaminidase enzyme in the second year than first year for all treatments. Among all treatments and years, the RC treatment had the significantly lower activities. The treatment by depth interaction was significant for αglucosaminidase enzyme (Fig. 3.).

Flurorescein diacetate(FDA) hydrolase activity.

The FDA activities were slightly decreased in all treatments except the GB treatment in 2010 compared to 2009. The RC treatment was not significantly different as compared to the GP and AgB treatments but was significantly lower compared to the GB treatment in 2010 (Table 2). The differences in activities among the perennial vegetation treatments were not significant.

Dehydrogenase enzyme activity.

Dehydrogenase activities differed significantly among treatments (Table 2). All perennial vegetation treatments showed significantly higher activity than the RC treatment. The activities were relatively higher in 2010 compared to 2009 for all treatments.

The depth effect was significant for all enzyme activities in both years (Table 3). There were no significant treatment by depth interactions in 2009; however, these interactions were significant in 2010 (Fig. 4). The difference in activities between the surface and sub-surface soil was significant for both years.

DISCUSSION

The results showed that WSA percentages within soils under RC management were significantly lower as compared to the GP, AgB, and GB treatments which closely parallel previous findings. Studies demonstrate that water stable aggregates in natural grassland, agroforestry, prairies, and managed natural vegetation were found to be significantly higher compared to cultivated areas with row crop management (Kremer and Li, 2003; Mungai et al., 2005; Udawatta et al., 2008; 2009; Guo et al., 2010; Kremer and Kussman, 2011).

Water stable aggregates are highly dependent on soil organic matter and biological activity in soil. In the RC treatment, physical disturbance and tillage operations accelerate organic matter decomposition, and destroy fungal hyphae and soil aggregates (Frey et al., 2003; Green et al., 2005). In contrast, perennial vegetation systems improve soil aggregation and organic matter accumulation (Franzluebbers et al., 2000). Grass can act as a cover crop, improve particulate organic matter content, and aggregation by providing continuous grass and root residues (Franzluebbers and Stuedemann, 2005; Handayani et al., 2008).

The soil organic matter pools (C and N) were affected by management practices. The higher root activity, microbial decomposition and continuous vegetative cover might have contributed

to greater carbon and nitrogen accumulation compared to row crop where tillage and cultivation practices caused losses of carbon and nitrogen. Accumulation of soil organic matter within macroaggregates leads to greater water stable aggregates. The greater stability of aggregates protects soil carbon from faunal action and microbial consumption (Beare et al., 1994; Six et al., 2000). As organic matter increases, soil biological activity increases. This enhances the diversity of organisms and the ecosystem functions they perform.

Following the dynamics of WSA and organic matter, the study showed significant differences in selected enzyme activities. The αglucosidase and αglucosaminidase enzyme activities were most consistent between the two years. These activities were significantly higher in perennial vegetation treatments compared to row crop management in both years and these findings agree with results from related research (Acosta-Martinez et al., 2003; Dick et al., 1996; Kremer and Li, 2003; Mungai et al., 2005; Udawatta et al., 2008, 2009; Kremer and Kussman, 2011). In a study by Ekenler and Tabatabai (2003), significantly reduced enzyme activity, specifically αglucosaminidase has been attributed to soil disturbance and conventional tillage. The higher activities of these enzymes can also be attributed to the increased organic matter and greater activities of roots compared to conventionally cultivated crop areas (Myers et al., 2001; Kremer and Li, 2003; Mungai et al., 2005; Table 4).

CONCLUSIONS

The nature of enzyme activities observed in this study support the hypothesis that perennial vegetation provides favorable conditions for greater enzyme activities and microbial diversity compared with soils under row crop management. Results hold that permanent vegetation leads to carbon accumulation and consequently increases in selected soil quality parameters compared to row crop areas. Most soil quality indicators were significantly greater in perennial vegetation areas compared to row crop agriculture and the parameters were consistent during two measurement years. Based on water stable aggregates and enzyme activities, it is obvious that regular disturbance has significantly reduced soil quality in row crop agriculture. The study showed that establishment of agroforestry and grass buffers in grazed pasture areas has a significant effect on measured soil quality indicators and enhances soil quality and helps maintain ecosystem sustainability.

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Table 1. Standard methods of enzyme assays.

Enzymes	Weight	Substrate	Incubation /shaking	Spectrophotom-eter Wavelength	Unit	Reference
Dehydrogenase	6g	TTC	37°C, 24 h	485 nm	µg TPF g^{-1} dry soil	Tabatabai, 1994
β-glucosidase	1g	PNG	37°C, 1 h	410 nm	µg PNP g^{-1} dry soil	Dick et al., 1996
	1g	PNNG	37°C, 1h	405 nm	µg PNP g^{-1} dry soil	Parham and Deng, 2000
FDA	1g	FDA	Shaking, 105 min	490 nm	µg F g^{-1} dry soil	Dick et al., 1996

Abbreviations:
TTC: 2, 3, 5-triphenyltetrazolium chloride TPF: triphenyl formazan PNG: p-nitrophenyl-αD-glucoside
PNNG: p-nitrophenyl-N-acetyl-αD-glucosaminide PNP: p-nitrophenol FDA: Fluorescein diacetate F: fluorescein

Table 2. Water stable aggregates (WSA), bulk density (Db), soil organic carbon (SOC), Total Nitrogen (TN), αglucosaminidase (GS), αglucosidase (GC), dehydrogenase (DH) and Fluorescein Diacetate (FDA) hydrolase enzyme activities for grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB) and row crop (RC) treatments (year 2010, n=12).

Treatment	WSA	Db	SOC	TN	GS	GC	DH	FDA
	---%---	-g cm^{-3}-	----------%----------		----------µg g^{-1} dry soil----------			
GP	55.6b	1.38a	1.60a	0.18a	170.8a	240.7a	323.8a	759.7ab
AgB	59.2b	1.31a	1.92a	0.22a	166.5a	246.2a	310.2a	804.6ab
GB	65.5a	1.32a	1.88a	0.20a	177.0a	236.6a	337.9a	811.4a
RC	31.4c	1.42a	1.26a	0.16a	92.2b	165.3b	174.6b	705.4b

Data followed by the same letter within a column were not significantly different at p≤0.05

Table 3. Variation of water stable aggregates and enzymes activities with depth for agroforestry buffer (AgB), grass buffer (GB), grazed pasture (GP) and row crop (RC) treatments (year 2010).

Treatment	Depth	WSA	FDA	Dehydrogenase	β-glucosidase	β-glucosaminidase
	-cm-	--%--	----------µg g^{-1} soil----------			
GP	0-10	68.0a	935.1a	452.0a	324.3a	234.6a
	10-20	43.0b	584.4b	195.7b	157.2b	107.1b
AgB	0-10	71.4a	1006.1a	416.2a	342.1a	229.5a
	10-20	47.0b	603.0b	204.2b	150.2b	103.6b
GB	0-10	76.2a	1005.2a	471.8a	319.4a	247.2a
	10-20	55.0b	617.7b	204.1b	153.8b	106.8b
RC	0-10	40.0a	930.6a	213.0a	198.8a	106.7a
	10-20	23.0b	480.2b	136.3b	131.8b	77.6b

Data followed by different letters within a column within a treatment were significantly different at $p \leq 0.05$.

Table 4. Correlation coefficients (r) of αglucosidase, αglucosaminidase, dehydrogenase and FDA enzyme activities, with soil organic carbon and total nitrogen content in 2010.

Parameters	β-glucosidase	β-glucosaminidase	Dehydrogenase	FDA
Soil organic Carbon	0.86 ($p<0.0001$)	0.88 ($p<0.0001$)	0.89 ($p<0.0001$)	0.84 ($p<0.0001$)
Total Nitrogen	0.84 ($p<0.0001$)	0.84 ($p<0.0001$)	0.85 ($p<0.0001$)	0.82 ($p<0.0001$)

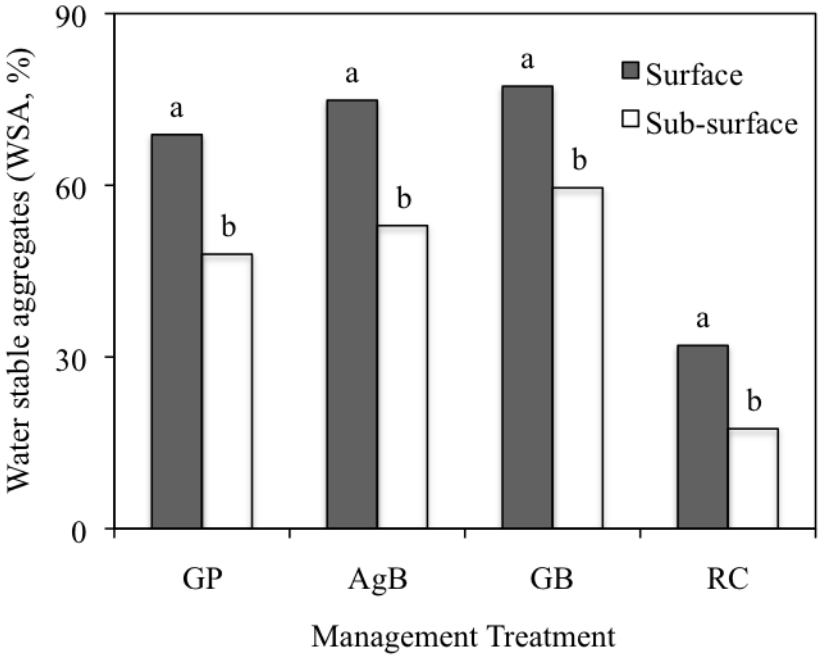
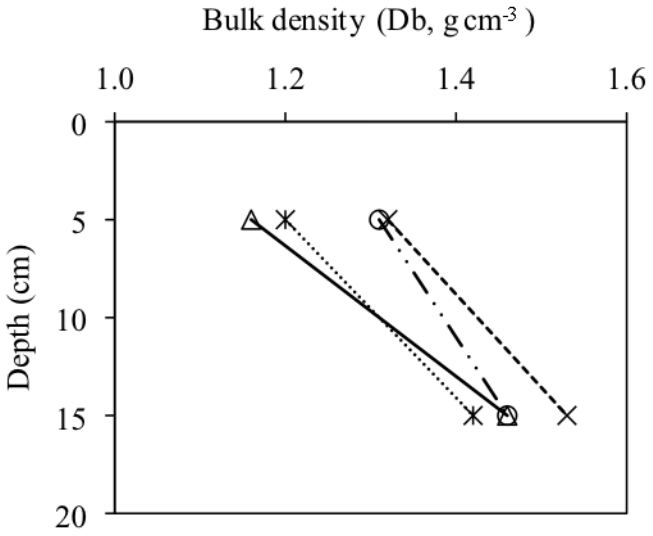
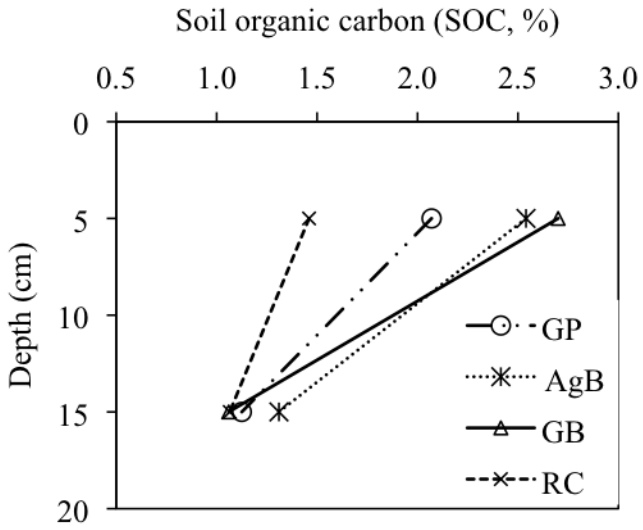


Figure 1. Water stable aggregate levels (WSA, %) for the grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB) and row crop (RC) management treatments. Samples were from the 0 to 20 cm soil depth and data presented were the average of sampling years, 2009 and 2010.



a.



b.

Figure 2. Soil bulk density (a.) and soil organic carbon (b.) as a function of depth for the four study treatments, grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB), and row crop (RC) for the year 2010. Samples were from the 0 to 10 and 10 to 20 cm soil depths.

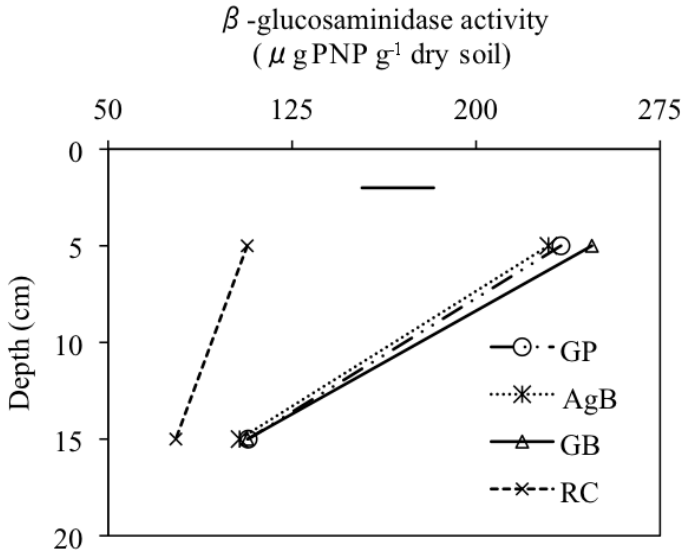


Figure 3. αglucosaminidase enzyme activity as a function of depth in 2010 for the four study treatments, grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB), and row crop (RC) for the year 2009. The bar indicates the LSD value (29.2).

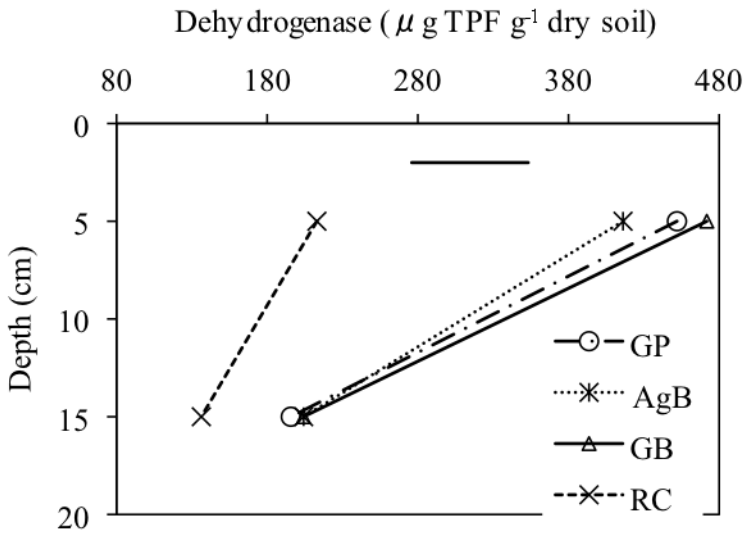


Figure 4. Dehydrogenase enzyme activity as a function of depth for the four study treatments, grazed pasture (GP), agroforestry buffer (AgB), grass buffer (GB), and row crop (RC) for the year 2010. The bar indicates the LSD value (77.3).