AGROFORESTRY INFLUENCES ON SOIL AGGREGATE STABILITY AND ENZYME ACTIVITY

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INTRODUCTION:

The percentage of water stable aggregates (WSA) is a measure of resistance to breakdown by water and mechanical activities. Water stable aggregates improve soil water and air movement. Macro-aggregates (diam. > 250 μm) are considered as a secondary soil structure associated with pores, microbial habitat, and physical protection of organic matter (Christensen, 2001; Carter, 2004). Aggregates provide spatially differentiated habitats for microorganisms and are important for biogeochemical soil processes (Park and Smucker, 2005).

Enzyme assays provide quantitative information on microbial diversity, soil chemical processes, mineralization rates, and organic matter accumulation. Enzyme assays among different management practices may also indicate short-term differences in soil quality improvement, microbial diversity, rapid responses to changes in management, and sensitivity to environmental stresses (Dick, 1997). Studies show that enzyme activity and microbial diversity are different in agroforestry alley cropping practices due to differences in litter quality and quantity, and root exudates (Gomez et al., 2000; Myers et al., 2001; and Mungai et al., 2005).

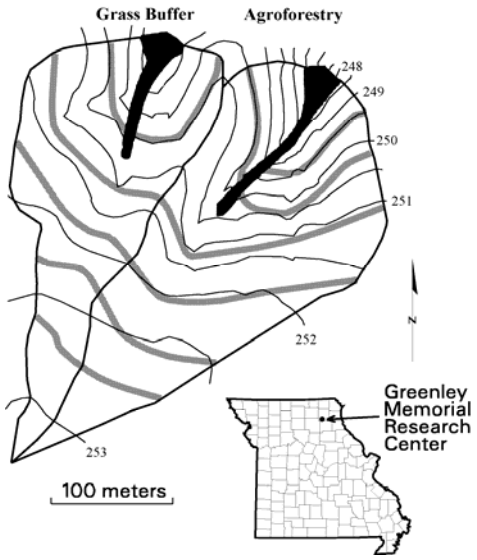

Figure 1. Topographic map of the grass buffer and the agroforestry watersheds with 0.5 m elevation interval contour lines (black), grass (grass only), agroforestry (grass+trees) buffers (gray), and grass waterways (wide black). The inset map shows the location of watershed in Knox County, MO.

Although several environmental benefits of agroforestry practices are reported in the literature, Lovell and Sullivan (2006) stated that more research is needed for a comprehensive understanding of buffer effects on overall environmental quality. The objective of this study was to compare differences in water stable aggregates, soil carbon, soil nitrogen, and enzyme activities in crop, grass buffer, agroforestry buffer, and grass waterway areas at three landscape positions in agroforestry and grass buffer alley cropping watersheds.

MATERIALS AND METHODS:
Soils from the row crop (CS), grass buffer (GB), agroforestry buffer (AG), and grass waterway (GWW) treatments were sampled in two transects extending from the summit to the lower backslope landscape positions in September 2006. GB and AG soils were sampled from buffers 1, 3 and 5 (counting from the south; Fig. 1) representing upper, middle, and lower landscape positions, respectively. Soil samples for the GB were taken from the center of the buffer. Soil for the AG treatment was sampled about 40 cm from the base of the tree trunk. For the CS treatment, soils were collected about 5 m south of the tree sample in the crop area. For the GWW treatment, soils were collected from three locations (south, middle, and north). Surface 0-10 cm soils were collected with a soil auger and soils were placed in a labeled ziplock bag. Sealed bags were transported to the laboratory in a cooler and stored at 4°C prior to measurements being conducted.

Water stable aggregates were determined using a 10 g soil sample according to the wet-sieving method on aggregates >250µm diameter (Kemper and Rosenau, 1986). Total organic carbon and nitrogen concentrations were determined by combustion analysis at 950°C using a LECO TruSpec CN Analyzer.

The hydrolysis of FDA was colorimetrically quantified at 490 nm (Dick et al., 1996). β-glucosidase enzyme activity was determined according to Dick et al. (1996). The concentration of *p*-nitrophenol was colorimetrically (410 nm) expressed in µg *p*-nitrophenol released g^{-1} dry soil h^{-1}. Glucosaminadase enzyme activity was determined as described by Parham and Deng (2000). Soil was incubated with the *p*-nitrophenyl-N-acetyl-β-D-glucosaminide substrate for one hour at 37°C. The concentration of *p*-nitrophenol was measured colorimetrically (405 nm) and the enzymatic activity was expressed in mg *p*-nitrophenol released kg^{-1} soil h^{-1}. Soil was incubated with 2,3,5-triphenyltetrazolium chloride substrate at 37°C for 24 hours to determine dehydrogenase enzyme activity (Pepper et al., 1995). The concentration of the triphenyl formazan (TPF) product was colorimetrically (485 nm) measured and the enzymatic activity was expressed in µg TPF released g^{-1} dry soil h^{-1}.

Analysis of variance was conducted with SAS using the GLM procedure to test differences between treatments and differences were declared significant at the $\alpha = 0.05$ level (SAS Institute, 1999).

RESULTS:
The percentage of WSA was significantly different between the buffer area and crop area soils (Fig. 2A). Among the four treatments, GWW had the highest percentage of WSA (19.97±1.75) and it was significantly different from the other three treatments. The GB and AG areas had almost two times more (1.94) stable aggregates as compared to crop areas (7.68±1.24). The percentage of WSA's was significantly different among all three landscape positions (Fig. 2B). The lower (17.3%±1.53%) and middle (13.03%±1.53%) positions contained higher percentages of WSA as compared to the upper landscape position (8.76%±1.54%).

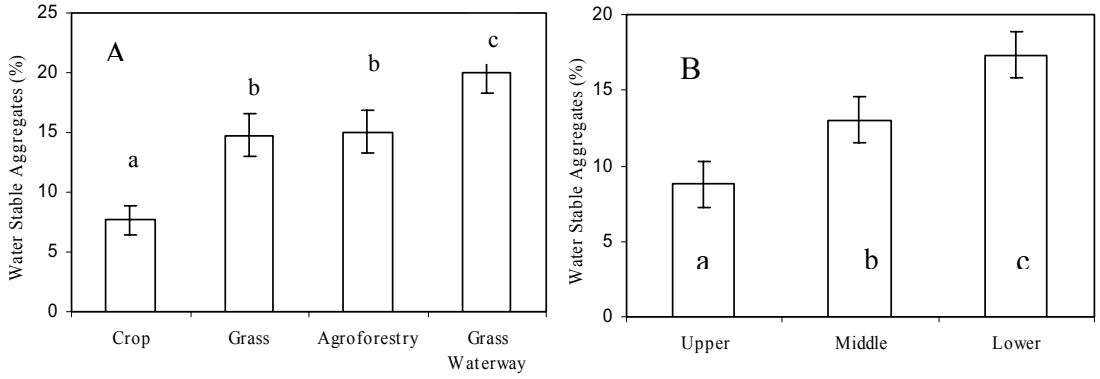

Figure 2. Water stable aggregates by treatment (A) and landscape position (B). Bars with the same lower case letters were not significant at $p < 0.05$.

Soil carbon concentrations in the surface soil were significantly higher for GB, AG, and GWW treatments compared with CS (Fig. 3A). The carbon percentage in the CS soil was less than 2% while the average percentage for the other three treatments was greater than 2.25%. Among the four treatments, the GWW had the highest carbon concentration. The difference was not significant among the permanent vegetative practices. Nitrogen distribution also followed a trend similar to carbon. The CS treatments were lowest in nitrogen content, which was significantly different from the other three treatments. The landscape position effect on carbon concentration was significant for the CS treatment (Fig. 3B); however, the landscape effect was not significant for the GB treatment. Among the three landscape positions sampled, the lower position within the AG system had the highest carbon content.

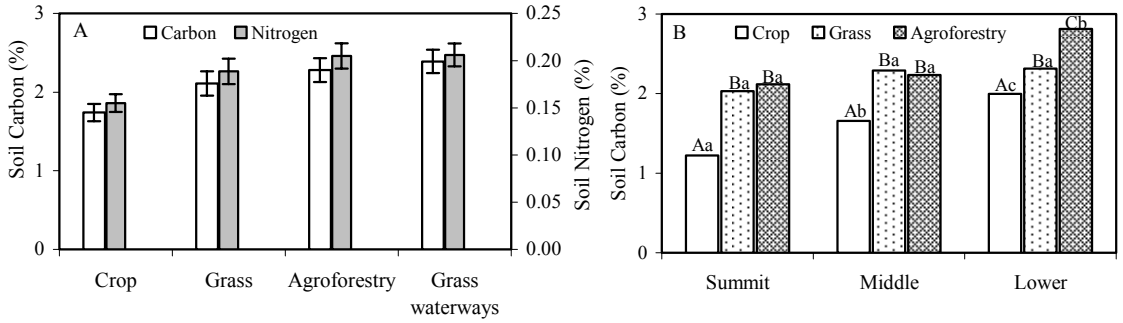

Figure 3. Total soil carbon and nitrogen by treatment (A) and landscape position for row crop, grass buffer, and agroforestry buffer treatments (B). Bars with upper- and lower-case letters denote significant differences within a landscape position among treatments and among landscape positions within a treatment, respectively, at $p < 0.05$.

The FDA activity was significantly different between CS areas and the remaining three treatment areas (Fig. 4A). It was the lowest in CS area (8±0.61 μg fluorescein g^{-1} dry soil h^{-1}) and the highest in the GB area (13±0.86 μg fluorescein g^{-1} dry soil h^{-1}) under assay conditions. The AG and GWW treatments contained similar amounts of enzyme activity releasing an average of 11±0.86 and 10±0.86 μg fluorescein g^{-1} dry soil h^{-1}, respectively.

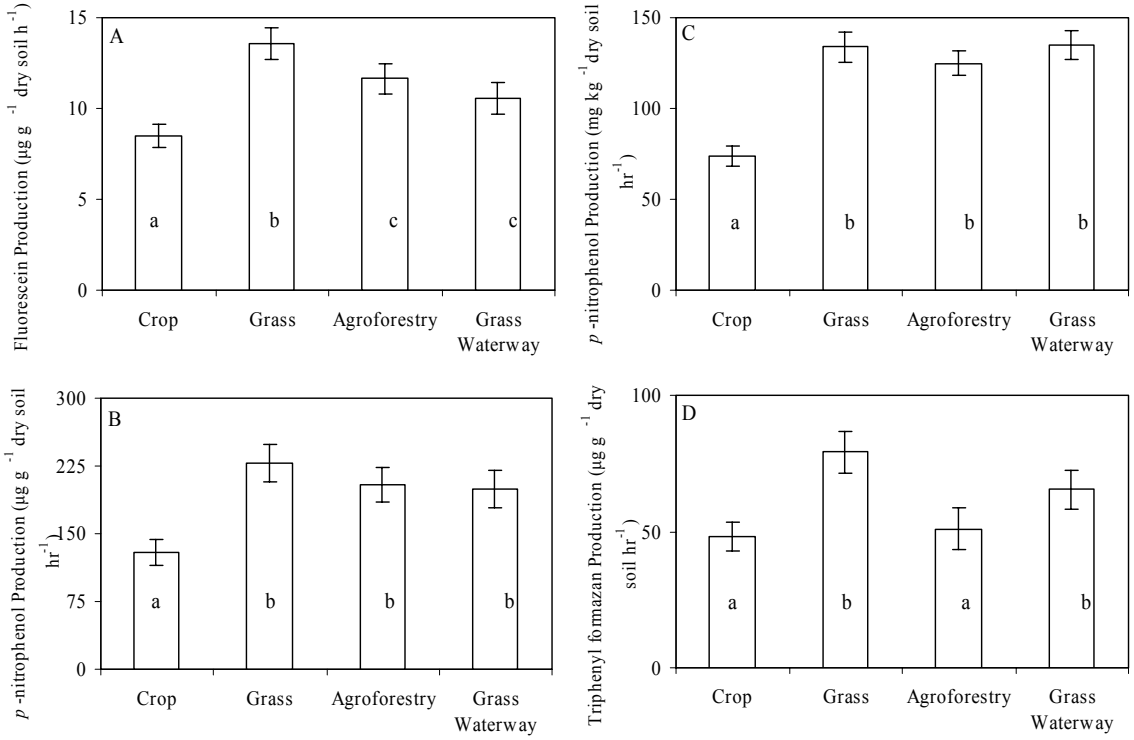

Figure 4. FDA enzyme activity (µg fluorescein released g^{-1} dry soil h^{-1}; A), β-glucosidase enzyme activity (µg *p*-nitrophenol released g^{-1} dry soil h^{-1}; B), glucosaminadase enzyme activity (mg *p*-nitrophenol released kg^{-1} soil h^{-1}; C), and dehydrogenase enzyme activity (µg triphenyl formazan g^{-1} dry soil h^{-1}; D) for the four treatments. Bars with the same letter were not significant at $p < 0.05$.

Similar to FDA hydrolase, β-glucosidase activity (129±14.82 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}) was significantly lower in the CS are compared to GB, AG, and GWW treatment areas (Fig. 4B). The GB area had the highest level of enzyme activity with 228±20.59 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}. With only slight differences, the AG and GWW treatments contained 204±19.26 and 199±20.59 µg *p*-nitrophenol released g^{-1} dry soil h^{-1}, respectively.

Analysis of glucosaminadase activity revealed significant differences between CS areas (73±5.12 mg *p*-nitrophenol released kg^{-1} dry soil h^{-1}) and the remaining treatment areas (Fig. 4C). Grass areas (GB and GWW) contained the highest levels of glucosaminidase activity with GWW and GB yielding 135±7.80 and 133±8.34 mg *p*-nitrophenol released kg^{-1} dry soil h^{-1}, respectively. Dehydrogenase activity was higher in grassed areas as compared to crop treatments (Fig. 4D). Grass buffers and grassed waterways exhibited an average production of 79±7.52 and 65±7.23 µg TPF g^{-1} dry soil h^{-1}, respectively. The lower levels of dehydrogenase activity within cropped areas were discovered to differ slightly between AG and CS treatments which contained an average TPF production of 50±7.52 and 48±5.21 µg TPF g^{-1} dry soil h^{-1}, respectively. However, the difference was not significant.

CONCLUSIONS:

Based on measured properties, it is obvious that continuous disturbance has significantly reduced soil quality in the crop areas. The study showed that establishment of agroforestry buffers on previously cultivated agricultural areas has a significant effect on the measured soil quality indicators. The buffers were established in 1997 and therefore, the changes reported here occurred in less than 10 years. The extent of the improvement is partially determined by the vegetation type. These improved properties and other associated changes due to establishment of buffers may help to reduce NPSP from row crop agricultural lands.

Further studies are needed to understand the temporal variations and to quantify the influence of buffer age on these parameters. This will help to determine how long it would take to reach a steady state under these management systems. Additional research is also needed to understand substrate composition and its chemical quality on soil enzyme activity and microbial diversity in relation to agroforestry and grass buffer conservation management practices.

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