AGROFORESTRY BUFFERS FOR NON POINT SOURCE POLLUTION REDUCTIONS FROM AGRICULTURAL WATERSHEDS

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ABSTRACT:
Despite increased attention and demand for the adoption of agroforestry practices throughout the world, rigorous long-term scientific studies confirming environmental benefits from the use of agroforestry practices are limited. The objective was to examine non point source pollution (NPSP) reduction as influenced by agroforestry buffers in watersheds under row crop management. The row crop study site consists of three watersheds in a paired watershed design in MLRA 113 Central Claypan Areas. Runoff water samples were analyzed for sediment, total nitrogen (TN) and total phosphorus (TP) for the 2004 to 2008 period. Results indicate that agroforestry and grass buffers under conditions of row crop management significantly reduce runoff, sediment, TN, and TP losses. Sediment loss for row crop management sites was 17.9 kg ha^{-1} yr^{-1}. On average, buffers reduced sediment, TN, and TP losses by 29, 12, and 24% compared to the control treatments. Results from this study can be used to design improved agroforestry practices for ecosystem services by minimizing the amount of land taken out of production while optimizing environmental benefits.

INTRODUCTION:
Three decades after the implementation of the Clean Water Act in the 1970s, nonpoint source pollution (NPSP) remains a major challenge in protecting and restoring water quality. Despite improvements in soil conservation practices, crop rotation and nutrient management programs, significant concerns still exist regarding soil erosion and nutrient runoff from agriculture (Udawatta et al., 2006). Agricultural practices of row cropping are often blamed for adverse effects on the quality of surface and ground waters. The U.S. Environmental Protection Agency (2009) noted that agriculture is the leading cause for water pollution which has impacted 44%, 64%, and 30% of evaluated river, lake, and estuary areas respectively. The most common pollutants to water bodies were: sediment, nutrients, pathogens, organic enrichments, mercury, and PCBs (Polychlorinated biphenyls).

Although many of our current agricultural practices negatively affect water and soil quality, improved management practices have the potential to reverse these negative effects. Establishment of permanent vegetation on agricultural watersheds as upland buffers and streamside riparian buffers has been shown to improve water quality parameters (Udawatta et al., 2002; 2010; Schultz et al., 2009). This is because incorporation of permanent vegetation on row crop and pastured watersheds improves soil physical and biological properties compared to row crop management alone (Mungai et al., 2005; Seobi et al., 2005; Kumar et al., 2008; Udawatta et al., 2008). Strategically positioned buffers would enhance environmental benefits by filtering nutrients and reducing sediment losses more effectively. This strategy might include conversion of sensitive areas such as variable source areas or areas with greater runoff potential to permanent vegetation or wetlands (Schmitt, 1999; Qui, 2003).

Landowners, state agencies and other regulatory authorities need scientifically proven, practical, and biologically acceptable buffer development guidelines for the protection of water resources. Although agroforestry practices are effective in protecting water and soil quality, studies comparing the effectiveness of these buffers within ecoregions or landuses are largely missing from the literature (Loveall and Sullivan, 2006). This paper examines the effects of agroforestry and grass buffers on discharge of water, sediment, and nutrients from a long-term study under row crop management.

MATERIALS AND METHODS:

The study watersheds located at the University of Missouri's Greenley Memorial Research Center in Knox County, Missouri, USA have been monitored since 1991 to evaluate the influence of "in-field" buffers on water quality in row crop watersheds (40° 01' N, 92°11' W; Fig. 1; Udawatta et al., 2002). This study used a paired watershed approach with three adjacent north-facing watersheds designated as "east", "center", and "west" with land areas of 1.65, 4.44, and 3.16 ha, respectively. Agroforestry (oak trees + grass) and grass (grass only) buffer treatments were established in 1997 on the center and west watersheds, respectively. The grass-legume combination planted throughout the buffer strips included redtop (*Agrostis gigantea* Roth), smooth bromegrass (*Bromus inermis* L.), and birdsfoot trefoil (*Lotus corniculatus* L.). Pin oak (*Quercus palustris* Muenchh.), bur oak (*Q. macrocarpa* Michx.), and swamp white oak (*Q. bicolor* Willd.) were alternately planted in the center of the buffer strips at a 3-m spacing to create agroforestry buffers on the center watershed. Grass waterways on the three watersheds consist of 'Kentucky 31' tall fescue.

The watersheds were instrumented with concrete approach sections, H-flumes, bubbler flow-measuring devices, and water sampling units (ISCO Inc., Lincoln, NE, USA). ISCO bubbler flow measuring devices record flow rate, water level, sampling time and ISCO water samplers collect water samples. Runoff samples were collected after each measurable runoff event. Water samples were transported from the field to the laboratory and composite samples were analyzed for sediment, total phosphorus (TP), and total nitrogen (TN) using standard procedures. Statistical analysis of data was performed using SAS (SAS Inst. 1999).

RESULTS:

Although annual discharge of water per area varied greatly among treatments and years, crop management sites showed significant reductions in runoff as influenced by buffers. Under row crop management, watersheds with agroforestry and grass buffers had significantly smaller runoff volumes than the control. The average runoff volumes during the study period were 145 and 112 m^3 ha^{-1} for the control and buffer treatments. The treatment watersheds yielded less runoff than the predicted volumes except for three runoff events. The difference, observed minus predicted, ranged from +5 to –73 m^3 ha^{-1} as compared to the predicted loss (Fig. 2). On average, the grass buffer and agroforestry buffered watersheds yielded reduced runoff volumes that were 23 and 15% less than the predicted volumes during the study.

Soil loss on watershed sites was significantly affected by buffer treatments. Soil loss in runoff water generally paralleled rainfall amounts. Agroforestry, grass buffer, and control treatments had sediment losses of 76, 82, and 110 kg ha^{-1} during the study period. On average, the control watershed lost 7.36 kg sediment ha^{-1} in each runoff event and 22 kg sediment ha^{-1} yr^{-1} for the study period. The average sediment losses were 5.04 and 5.46 kg ha^{-1} in each runoff event for watersheds with agroforestry and grass buffers, respectively. Agroforestry and grass buffer treatments reduced sediment losses by 30 and 28%, respectively, during the 2004 to 2008 period when analyzed using the paired watershed approach (Table 1). The average annual sediment loss for the row crop site with the three managements was 17.9 kg ha^{-1}.

Total nitrogen (TN) loss was significantly reduced by all buffer treatments (Table 1). TN loss was reduced by 11 and 13% by the agroforestry and grass buffer treatments compared with the predicted losses based on calibration equations. The agroforestry, grass buffer, and control treatments lost 14, 16.8, and 24.8 kg TN ha^{-1} respectively, during the treatment period. Annual losses were 2.8, 3.3, and 4.96 kg ha^{-1} yr^{-1} on the respective treatments.

Row crop management at the Greenley Center also showed a reduction in TP loss as influenced by buffers. The reductions in TP loss on the agroforestry and grass buffer watersheds were 26 and 22% based on the calibration equation (Table 1). Annual TP losses from the control, agroforestry, and contour grass buffered watersheds averaged 0.03, 0.02, and 0.03 kg ha^{-1}. During the study period, watersheds with buffers lost 0.16 kg ha^{-1} compared to 0.20 kg ha^{-1} for the control watershed.

CONCLUSIONS:

Buffer studies that incorporate trees as a treatment are, out of necessity, of a longer duration than similar trials with grasses. In this study, a sufficient time period had elapsed before the effects of buffers were evaluated to allow the tree species to become fully established. Thus, disturbances due to soil amendments and other physiological changes were also allowed to reach equilibrium while the buffers were establishing.

Results support the hypothesis that agroforestry and grass buffers significantly reduce NPSP losses from row cropped watersheds. Results show that runoff, sediment, TN, and TP losses were significantly reduced by establishment of buffers under row crop management practices. In addition to improvements in water quality, in-field upland buffers, as a watershed protective measure, can help retain soil and soil nutrients in the field as contrasted to field-edge buffers. It is assumed that greater beneficial effects from buffers will occur with time, as the permanent vegetation occupies larger soil volumes and improves soil physical and biological properties. Results of this study suggests that more emphasis should be placed on management strategies that minimize runoff and NPSP losses such as the strategic placement of buffers on sensitive areas and in watersheds in general.

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Table 1. Agroforestry and grass buffer effects on percentage reduction of sediment, total nitrogen, and total phosphorus losses on row crop management practices as compared to the control treatment.

Parameter	Agroforestry	Contour Grass
	--------------- % ---------------	
Sediment	30	28
Total nitrogen	11	13
Total phosphorus	26	22

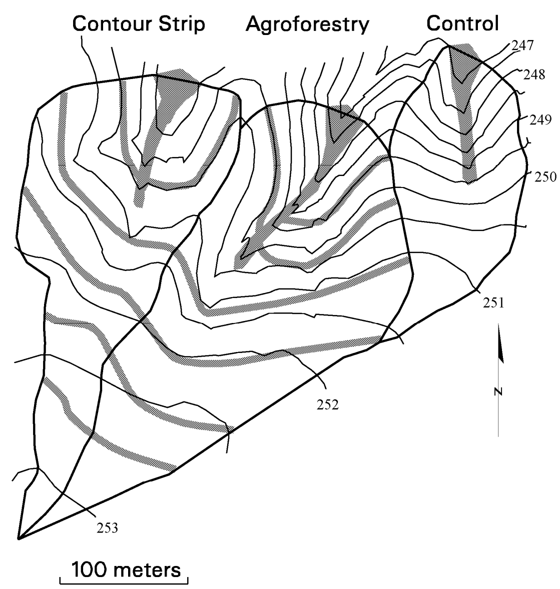

Figure 1. Three watersheds of the paired watersheds study at Greenley Research Center, Novelty, Missouri (After Udawatta et al., 2002). Wide gray bands represent grass buffers on the contour grass strip watersheds and agroforestry buffers (tree+grass) on the agroforestry watershed. Narrow lines represent 0.5 m interval contour lines.

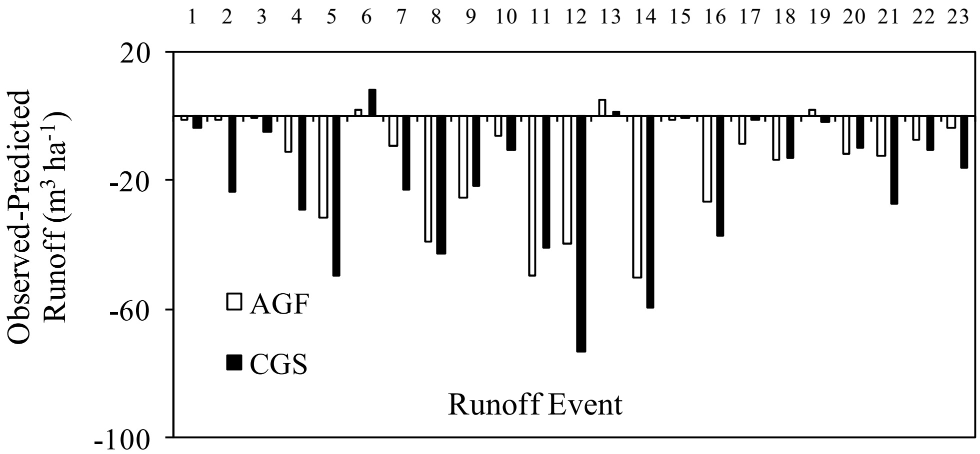

Figure 2. Observed minus predicted runoff volumes for agroforestry (AGF) and grass buffer (CGS) watersheds at the Greenley Research Center from 2004 to 2008.