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AGROFORESTRY INTERACTIONS AND SOIL WATER USE IN WATERSHEDS UNDER CORN-SOYBEAN MANAGEMENT

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Abstract: Agroforestry and grass buffer practices reduce non point source pollution from corn-soybean watersheds, yet little is known about the processes and mechanisms involved. The objective of this study was to compare the soil water dynamics in crop, grass, and agroforestry areas throughout the growing season to understand soil water use and recharge differences among the treatments. The study was conducted on two corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotational watersheds with grass and agroforestry buffers at the Greenley Research Center, Knox County, MO. Campbell soil moisture sensors were installed in crop, grass, and agroforestry areas with six replications at 5, 10, 20, and 40 cm depths to record volumetric soil water content at 10 minute intervals for 2004 through 2007. Initial soil moisture was lower in tree and grass buffer areas than crop areas probably due to water use by the permanent vegetation before crops were established. The differences were larger for shallower depths as compared to the 40 cm depth. The trend continued throughout the growing season. Weekly soil moisture content was significantly higher in the crop treatment as compared to the buffer treatments. During rain events water content increased in all depths and treatments and the differences in water content among treatments diminished. At the end of the growing season, soil water content increased when water use was low and as the profile recharged by rain events. The results of the study suggest that establishment of grass and agroforestry buffers help reduce non point source pollution from row crop agriculture by using additional water that would have otherwise have been lost in runoff carrying sediments, nutrients, and pesticides.

Key Words: Water content sensors, grass buffer, Greenley Center, Putnam soil,

INTRODUCTION

Establishment of agroforestry and grass buffers on agricultural watersheds is a soil conservation practice that will results in environmental and economic benefits. Agroforestry is also considered as a sustainable land management practice for maximum benefits (Nair, 1998). Within these management systems, trees, grass, shrubs, and crops occupy the same land either in a spatial or temporal progression. The fundamental understanding of agroforestry is that the roots of plants occupy various soil layers leading to complementarity of soil use (Schroth, 1999). In contrast, competition for the water and resources could result in reduced crop yields (Ong et al. 1991). According to Cannell et al. (1996) biophysical advantages of agroforestry can be only achieved if the companion vegetation utilizes resources that were not utilized by the major crop.

The study system evaluated in this paper consists of agroforestry and grass buffers on contours on watersheds managed under corn-soybean rotation in northeast Missouri. Average rainfall is 920 mm and approximately 72% falls between April and October. Therefore, soil water is not a limiting factor for crop production in many years. However, rain events that occur during the fallow period (no crop period) cause significant sediment and nutrient loss from the watersheds (Udawatta et al. 2004; 2006). Furthermore, infrequent larger events as well as closely spaced smaller events that occur during the cropping period also cause significant sediment and nutrient losses.

The area is underlain by an impervious claypan with very low saturated hydraulic conductivity (Blanco-Canqui et al., 2002). Soil horizons above the claypan have greater Ksat values. Therefore, the region is vulnerable to significant sediment, nutrient, pesticide losses from row-crop watersheds during fallow periods and cropping seasons. Hence, these farming systems face significant challenges in meeting water quality standards.

Conservation practices that use excess water during the fallow and cropping periods are required to reduce sediment and nutrient losses, to maintain water quality and to reduce fertilizer costs. It has been shown that buffers improve water quality by using nutrients and water, increasing infiltration rates, and improving soil hydraulic conductivity and other associated properties. A better understanding of below-ground interactions within agroforestry buffers is needed to assist in selecting appropriate species to improve economic and environmental benefits of these systems. There is a need to understand soil water dynamics to explain differences in runoff among treatments and to develop guidelines for use of these practices. We hypothesize that permanent vegetation with deep roots and a longer active transpiration and growing season will reduce non-point source pollution (NPSP) from row crop agriculture by removing excess water and nutrients. This paper (1) examines changes in soil water content in crop, grass buffer, and agroforestry buffer areas, (2) compares differences in soil moisture dynamics as influenced by treatments, and (3) estimates differences in water use and recharge by treatment.

MATERIALS AND METHODS

Experimental Site

Agroforestry and contour grass buffer watersheds located at the University of Missouri Greenley Memorial Research Center in Knox County, Missouri, USA were studied for four consecutive years (40° 01' N, 92° 11' W; Fig.1). Details on watershed characteristics, soils, and weather and management practices can be found elsewhere (Udawatta et al., 2004; 2006). The 4.44 ha agroforestry and 3.16 ha grass buffer strip watersheds were under a corn-soybean rotation with no-till management since 1991. The contour strips for both watersheds were 4.5 m wide and 36.5 m apart (22.8 m at lower slope positions) and were planted in redtop (*Agrostis gigantea* Roth), brome grass (*Bromus* spp.), and birdsfoot trefoil (*Lotus corniculatus* L.) in June 1997. Pin oak (*Quercus palustris* Muenchh.), swamp white oak (*Q. bicolor* Willd.), and bur oak (*Q. macrocarp* Michx.) were planted 3-m apart in the center of the buffers for the agroforestry watershed in November 1997.

The soils in the study area were mapped as Putnam silt loam (fine, smectitic, mesic Vertic Albaqaulfs) and Kilwinning silt loam (fine, smectitic, mesic Vertic Epiaqaulfs). The watershed has a drainage restrictive B horizon with a claypan at a variable depth. The restrictive claypan produces surface runoff during high rainfall periods in combination with periods of low evapotranspiration during winter, spring, and early summer. The area chosen for installation of water sensors was a Putnam silt loam soil and had on average 1 - 2 % slope, 219 g kg^{-1} clay, 729 g kg^{-1} silt, 21g kg^{-1} organic C and 6.8 pH$_w$ in the surface horizon; while the argillic horizon started at about the 38 cm depth, and had 531g kg^{-1} clay, 439 g kg^{-1} silt, 0.9 g kg^{-1} organic C and 5.5 pH$_w$ (Seobi et al., 2005).

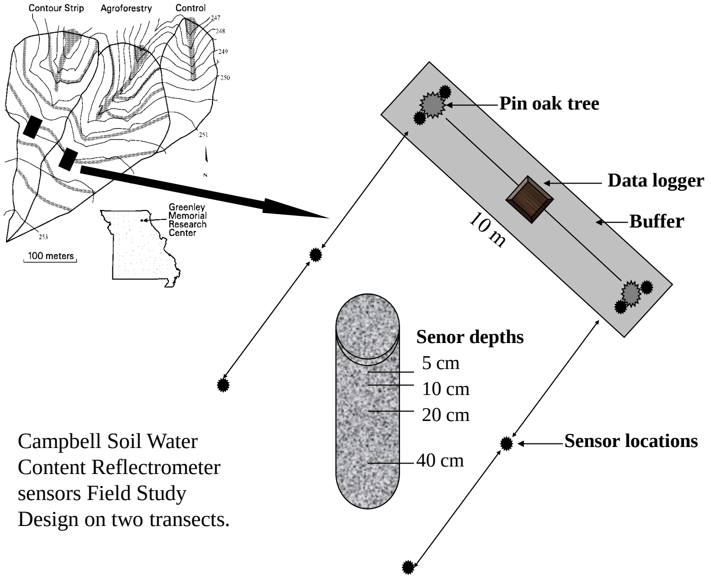


Figure 1. Study location in the State of Missouri, USA and a topographical map with 0.5-m interval contour lines on watersheds. Gray bands indicate grass-legume contour buffers (Contour Strip) and tree-grass-legume buffers (Agroforestry) on watersheds. Black bands indicate location of grass waterways. Campbell CS 616 sensor design with a data logger in the crop and buffer areas is shown on the colored diagram. Soil cylinder indicates sensor depths at each location.

Daily and hourly rainfall data were obtained from a University of Missouri webpage (http://agebb.missouri.edu/weather/stations/knox/). Weather data were accessed for daily and hourly time frequencies for Knox County.

Water content monitoring

Campbell CS-616 (Campbell Scientific Inc, Logan, UT) reflectometer water content sensors (Or and Wraith, 1999) were horizontally installed at 5-, 10-, 20- and 40-cm depths in four replicate locations for the agroforestry and grass (3rd buffer; counting from south) buffers and row crop treatments (between the 2nd and 3rd buffers). For the agroforestry treatment, two sets of sensors were placed under two different pin oak trees (48 cm from tree trunk) for a total of four replicates. The selected pair of trees was about 10 m apart. For the grass buffer treatment, sensors were placed at four locations with all four depths. Sensors were placed at four locations within the crop areas. These locations were 10 and 20 m from the south edge of the buffer. All sensors were connected to a CR23X data logger through a multiplexer and powered by a deep cycle marine battery. Sensors readings in period and volumetric moisture content data were collected at 10-minute intervals. Data were extracted from the data logger each week from 14 June 2004 through 19 November 2007. Weekly water content values were obtained using data measured at 12:00 noon each Tuesday.

Data were downloaded to a laptop computer and analyzed for differences among treatments and depths. No differences were found between the positions around the trees and therefore these two positions were used as replicates. No differences were found between the two locations within the row crop treatment and therefore the two locations were used as replicates.

Statistical Analysis

Homogeneity of variance tests were conducted to check for variability within treatments for measured infiltration and water content due to the systematic arrangement of treatments. Analysis of variance (ANOVA) was further conducted with SAS using the GLM procedure when variances within treatments were homogeneous (SAS Institute, 1999). Data for all properties had homogeneous variances. Least significant differences (Duncan's LSD) were calculated to find significant differences between treatments at each soil depth. LSD values were calculated using the Proc Mixed procedure from SAS with the appropriate error terms. Volumetric water content values for treatments were analyzed by date.

RESULTS AND DISCUSSION

Precipitation

In 2004, the area received 2% more rain than the long-term mean of 920 mm. During this year August rainfall was 233% of the normal (205 mm). The rainfall amounts were lower than the long-term mean during the next three years which varied between 774 and 892 mm (Fig. 2). In 2005, 2006, and 2007 rainfall values were 16, 14, and 3% lower than the long-term mean. However, total rainfall amounts were almost the same between April and October and similar to the long-term amounts, except for 2004. These amounts ranged from 68% to 80% of the annual rainfall.

In 2004 the crop was corn. Soil water content values were similar among the treatments at the beginning of the measurement period irrespective of the treatment (Fig. 3). In general water content was close to 40% for all four measured depths except for the 5-cm depth of the agroforestry treatment (Fig. 3). During 2004, data collection began in June and trees may have used surface soil water thus reducing the soil water content at the 5-cm depth. As the growing season continued, vegetation began to use more water from all four depths. The greatest depletion occurred in the surface 5- and 10-cm depths. As less water was depleted from the 40-cm depth, differences between treatments were smaller. Compared to the crop treatment, grass and agroforestry buffer treatments maintained lower soil water content during the growing season.

Precipitation events during this period increased the water content in all four depths. Some small rain events increased water content only in the surface soil. The rain amount of 143 mm between August 17 and 27 improved soil water content in four depths. Soil water depletion decreased towards the end of growing season. And small rainfall events recharged the profile. Although the deeper horizons were recharged early in the fall, the surface two horizons took a little longer to replenish.

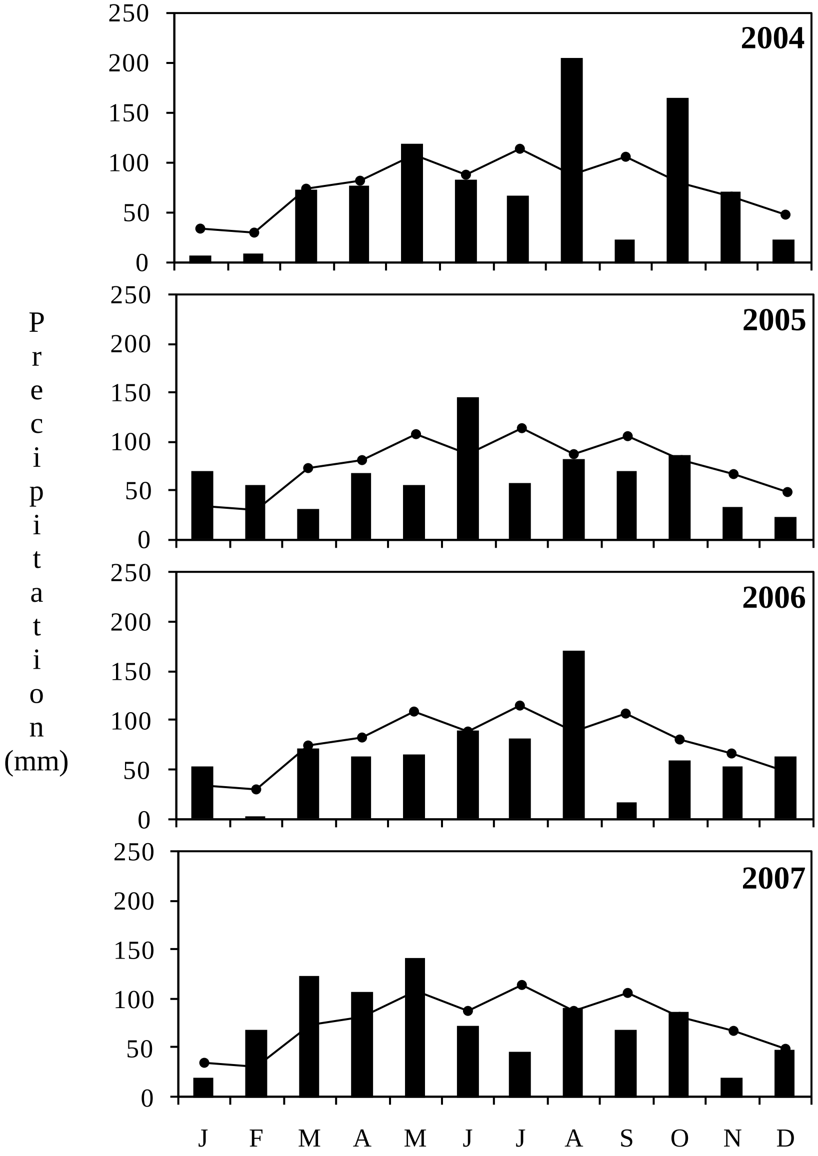


Figure 2. Monthly rainfall in mm (bars) for 2004, 2005, 2006, and 2007 at the Greenley Research Center, Novelty, MO. The line represents the long-term mean for the study location.

In 2007, the crop was soybean and soil water data are presented from March 12 to November 23 (Fig. 4). Soil water content was lower than 40% for the three surface depths at the beginning of the measurement period. This could be due to below normal rainfall amounts in 2005 and 2006. There was no difference in soil water content between the soybean and agroforestry treatments for all four depths until June 4 (Julian 155). Soil water content was lower in the agroforestry areas as compared to crop areas for all four depths until October 8 (Julian 281). Similar to the corn year, rain events recharge the soil profile and differences in water content were not significant after the growing season. Since there were only a few large events, only the surface soil was recharged during the growing season.

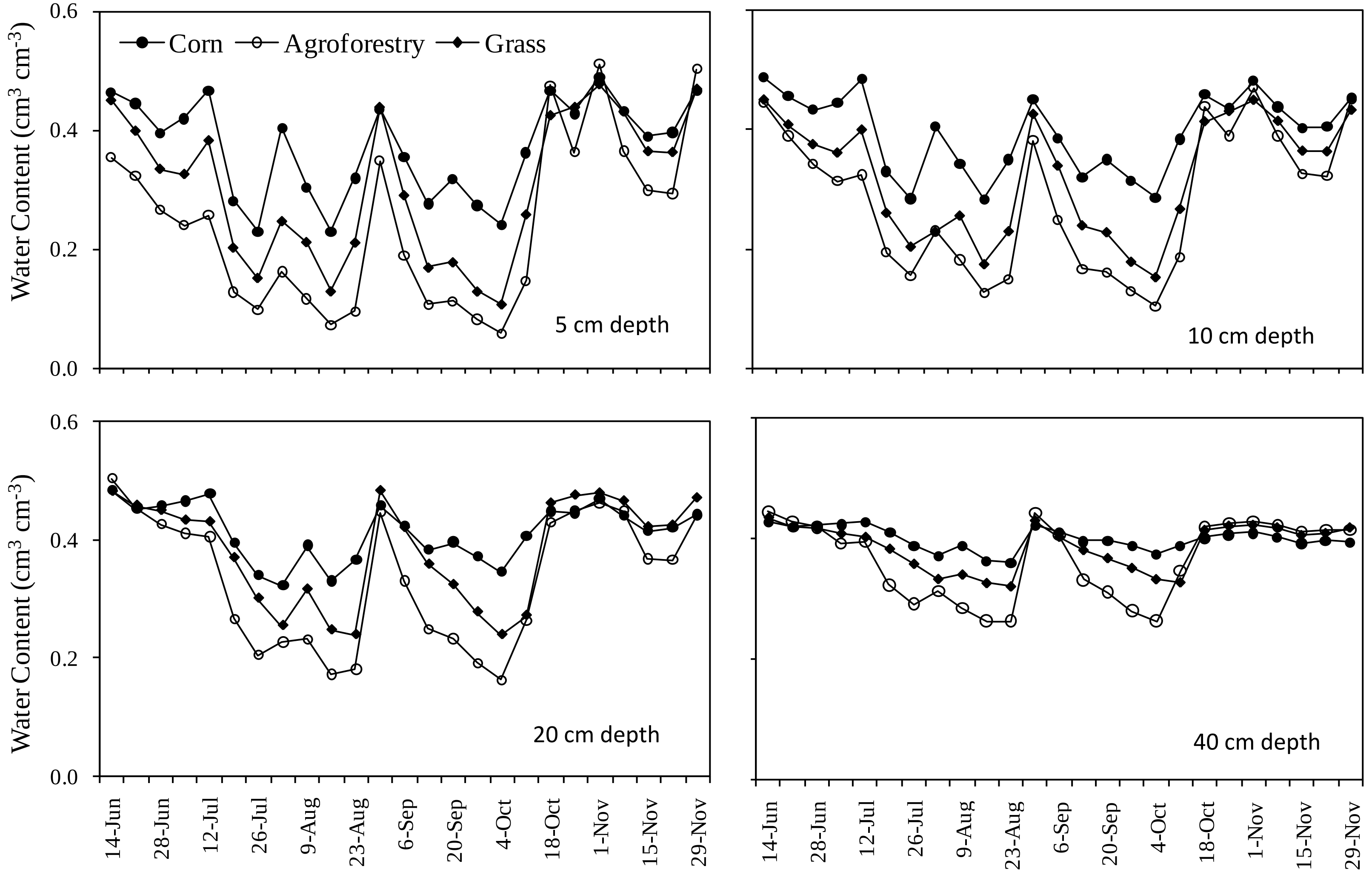
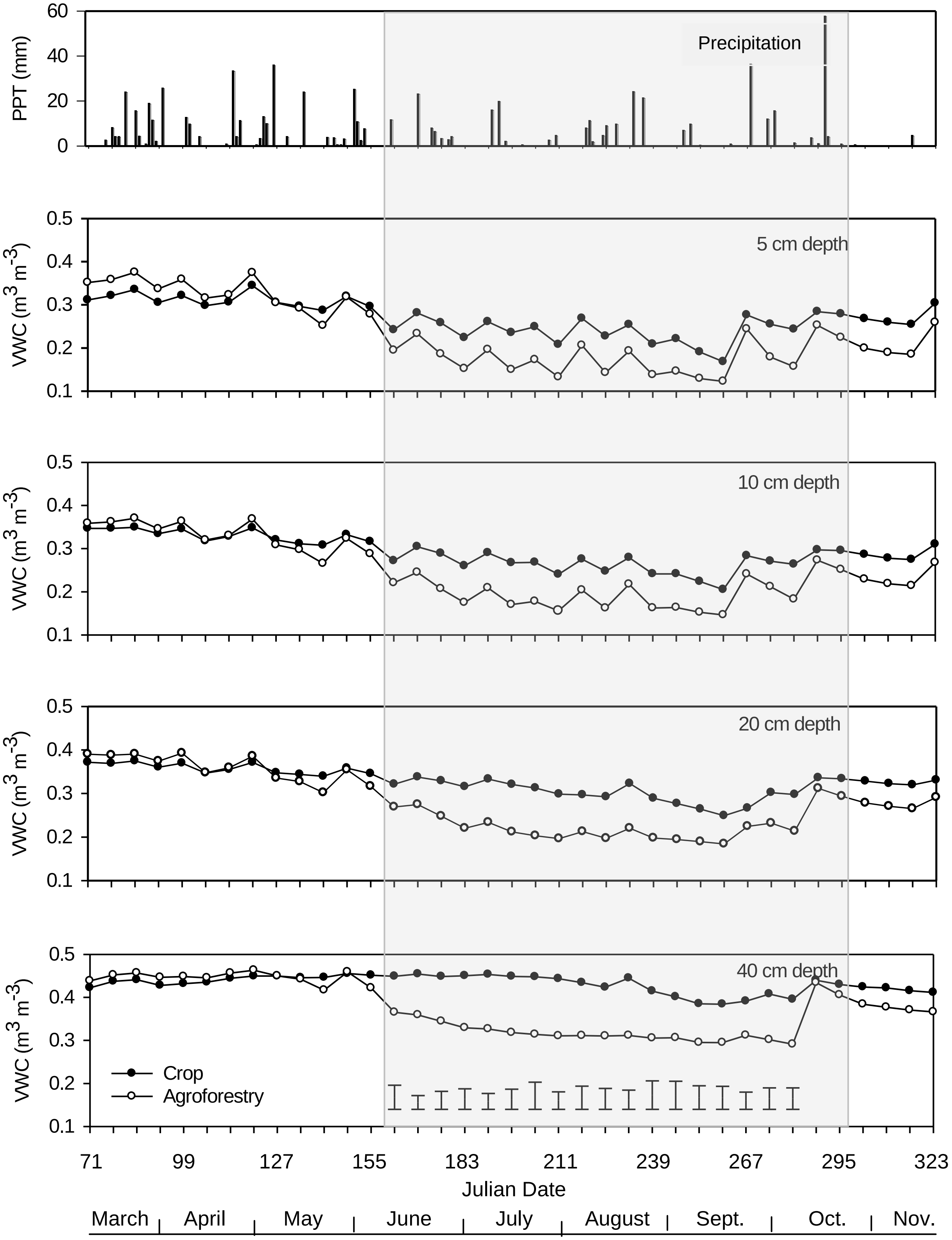


Figure 3. Volumetric soil water content estimated with the linear calibration at 12:00 noon (n=4) for crop, agroforestry, and grass treatments at the paired watershed study for 5, 10, 20, and 40 cm depth during 2004. Bars on the 40-cm depth graph indicate LSD values for significant differences in water content between crop and agroforestry treatments at the α=0.05 level.



PPT (mm)
60
40
20
0
Precipitation
VWC (m^3 m^{-3})
0.5
0.4
0.3
0.2
0.1
5 cm depth
10 cm depth
20 cm depth
40 cm depth
Crop
Agroforestry
71
99
127
155
183
211
239
267
295
323
Julian Date
March
April
May
June
July
August
Sept.
Oct.
Nov.

Figure 4. Daily precipitation and volumetric soil water content estimated with the linear calibration at 12:00 noon (n=4) for crop and agroforestry treatments at the paired watershed study for 5, 10, 20, and 40 cm depth during 2007. The gray area shows the crop period for soybeans. Bars on the 40-cm depth graph indicate LSD values for significant differences in water content between crop and agroforestry treatments at the α=0.05 level.

The lower water content in the agroforestry and grass treatments compared to the row crop treatment was probably due to more water depletion by the trees compared to the row crop areas. This was attributed to the greater transpiration from the trees in the agroforestry and grass buffer treatments compared to the corn and soybeans in the row crop treatment. In addition, trees and grass begin transpiration before the crop is established thus reducing initial soil water content. They continue to transpire after the crop is harvested. It is assumed that incorporation of agroforestry and/or other permanent vegetation with longer growing seasons might reduce runoff and NPSP from watersheds under row crop management.

CONCLUSIONS

This study was conducted to examine influences of agroforestry and grass buffers on changes in water content throughout the growing season. Agroforestry and grass buffer treatments had lower water content compared to the row crop treatment irrespective of the crop. The results of the study indicate that agroforestry and grass buffer strips had more water use/transpiration during the growing season that allowed more water to be stored in the profile through increased water infiltration thus reducing runoff and soil loss for watersheds under this management system. Incorporation of agroforestry practices may help reduce non-point source pollution from row crop agriculture.

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