INFLUENCE OF AGROFORESTRY BUFFERS ON ROOT LENGTH DENSITY AND SOIL WATER CONTENT

Ranjith P. Udawatta
Research Associate

Stephen H. Anderson
Professor of Soil Science

Harold E. Garrett
Professor of Forestry

Agroforestry and grass buffers when adopted as an alternative resource management system in agriculture can bring environmental and economic benefits. These buffers improve water quality by reducing sediment and nutrient losses from row crop watersheds (Jin et al., 2000; Udawatta et al., 2002). Buffer strips of permanent vegetation have been shown to reduce runoff by increasing infiltration, water use, nutrient uptake, and soil water storage; while trapping sediment and sediment-bound nutrients (Schmitt et al., 1999; Seobi et al., 2005; Vellidis et al., 2003).

Few studies have examined buffer effects on root distributions and changes in soil water relative to sediment and nutrient runoff reduction in agroforestry systems. We feel that permanent vegetation with deep roots and a longer active transpiration and growing season will reduce soil and nutrient runoff from row crop agriculture by removing excess water and nutrients. The objectives of this study were to investigate (i) root length density under trees, grasses, and crops on agroforestry and contour grass buffer strips and (ii) changes in soil water content during 2004 for these management systems.

Study Methods:
The experiment was conducted at the University of Missouri Greenley Memorial Research Center in Knox County, Missouri, USA (40^0 01' N, 92^0 11' W; Fig.1). One-m deep soil cores were collected with a soil auger on August 12-13, 2004 from the middle sections of the agroforestry and contour strip watersheds to estimate roots. Roots were separated into three diameter classes (< 1, 1-2, > 2 mm) by soil horizon. Root length was determined using a flatbed scanner assisted with computer software (WinRhizo 2003b, Regent Instruments Inc., Montreal, Canada).

Campbell water content sensors were horizontally installed at 5-, 10-, 20- and 40-cm depths in four replicate locations for the agroforestry and contour strip (3rd buffer) buffers and row crop treatments (between the 2nd and 3rd buffers) in the watersheds. The sensors were connected to a data-logger to record water content every 10-minutes. Within the contour strip watershed, sensors were placed at four locations; two southern and two northern edges of the 3rd buffer. Weekly water content values were obtained using data measured at 12:00 noon each day starting from June 14.

Study Results:
Root Length Density. Average root lengths for the 1.0-m depth were 1,263, 1,961, and 890 m m^{-2} for trees, grass, and corn, respectively (Fig. 2). Comparing more than 3000 records of root systems, Schenk and Jackson (2002) stated that annual plants had the least root length, grasses had intermediate root length and trees had the greatest root length. They stated that root system sizes were proportional to above ground plant biomass. Among the three oak species in our study, pin oak had the largest root density followed by swamp white oak and bur oak (Fig. 2).

The root density of pin oak and swamp white oak were 32 and 23%, respectively, greater than the root density of bur oak. In a previous study, Udawatta et al. (2005) observed that pin oak had the highest cross-sectional area of roots compared to swamp white and bur oak with bur oak showing dominance with deeper roots. The root length densities at the three locations (north edge, south edge, and middle) within a grass buffer were not significantly different ($p < 0.05$). Values ranged from 1,283 to 3,283 m m^{-2} (Fig. 3A). The middle portion of the grass buffers had more roots than the edges. The smaller root density at the edge might indicate that grass was competing minimally for soil water and nutrients with the corn. Roots were sampled when the corn was about 2.0 m tall. Although most of the buffer length was on an east-west orientation, some shade occurred during the day. The smaller root length at the edge of the grass buffer could be attributed to shading from corn plants. Similar to our results, reductions in root length, biomass, number, and turn over were reduced by shading in a temperate grassland community (Edwards et al., 2004).

The mean crop root length within a crop alley ranged from 632 to 1,063 m m^{-2} (Fig. 3B). As expected, root length density varied among sampling locations, although it was not significantly different ($p<0.05$). The most southern position (1) had more roots compared to the other three positions. One of the middle positions had the smallest density among the four positions. The observed variability in root length could be due to natural variation in the field.

Total root length or surface area is an indicator of the potential for exploitation of water and most nutrients from the soil zone (Horn, 1971; van Noordwijk et al., 1994). In northern climates, a critical period for nutrient loss is over the winter, between harvest and planting, due to lack of crop growth and greater water availability. Agricultural practices such as cropping systems can change soil nutrient leaching. However, little is known on whether certain combinations of agricultural practices may reduce leaching and surface losses. Extensive root systems with horizontal and vertical root masses could remove some of the accumulated nutrients. Trees and grasses in an agroforestry system that use excess water may reduce leaching and runoff losses and reduce antecedent soil water content prior to infiltration events. Antecedent soil water content affects runoff, soil and nutrient losses (Zheng et al., 2004). Therefore, it should be possible to develop a practice that retains most of the soil applied nutrients and pesticides in the same watershed. It seems that a properly designed combination of tree and grass buffers might help reduce sediment and nutrient runoff from row cropped watersheds.

Volumetric Soil Water Content. Weekly volumetric soil water contents among the treatments show that soil water content was lower in the tree and grass areas compared to the row crop areas (Fig. 4). Corn was planted on May 22. The initial lower soil water content can be attributed to greater transpiration by trees and grass in the watershed during the early corn growth period. At the five cm depth, trees and grass had, respectively, 19 and 10 of the 25 weekly measurement dates with significantly lower soil water compared to corn (Fig. 4A). This significantly lower soil water content for the buffers could reduce water runoff from row cropped watersheds.

For the 10, 20, and 40 cm depths, the number of weekly measurement dates with significantly different soil water content among the treatments was fewer compared to the five cm depth. Only 13 and six dates had significantly lower soil water content at the 10 cm depth under trees and grasses, respectively, compared to the corn treatment (Fig. 4B). Trees and grasses had 10 and four dates with significantly lower soil water than corn at the 20 cm depth (Fig. 4C). In general, soil water use at the 40 cm depth was lower for all four treatments (Fig. 4D). Soils under the trees had seven measurement dates with significantly less water than the corn treatment. However, tree roots extracted more water than the grass and corn treatments at this depth. Soil water content at 40 cm under the trees was significantly lower than for grass on September 27 and October 4.

Results during the study period clearly demonstrate that perennial vegetation such as trees and grasses reduce soil water content more than the corn crop. However, differences exist between species and therefore, selection of proper tree species is important in designing an environmentally and economically beneficial agroforestry system. Studying soil water depletion and root densities of a crop field bordering a tree line agroforestry system, Radersma and Ong (2004) observed that water content was significantly reduced by the fast growing trees (*Eucalyptus grandis and Grevillea robusta*) and not by the slower growing trees (*Cedrella serrata*). The three tree species selected for the watershed protection in this study grow slowly compared to *Eucalyptus* and *Grevillia* spp. but they have better timber value. Also, the cool season grasses help to reduce sediment and nutrient runoff in spring and during the fallow periods when crop water use is negligible.

Conclusions:

Tree and grass areas had more roots compared to the crop areas although the differences were not significant. Among the three oak species, pin oak had more roots than the swamp white and bur oak. Trees have more roots in the subsurface horizons than annual crops. There was significantly lower water content in the agroforestry treatment compared to the row crop treatment. This was attributed to greater transpiration by the trees and grasses compared to the corn plants. Buffer treatments continuously maintained lower soil water content than the crop areas. Lower evapotranspiration and greater precipitation during the months of October-March increase soil water content irrespective of management. Results showed that buffers maintained lower soil water levels throughout the year allowing the soil to store more water during runoff events.

A question that often arises is, “what proportion of a field area should be allocated for tree and grass buffers to create optimum environmental benefits?” This is a very difficult question to answer because it greatly depends on land owner objectives and management. However, substantial information has been presented in this paper relative to changes in soil water content and root length density, during a corn growing season. Precipitation distribution and soil water content during the growing season and corn yield indicated that crops did not suffer any moisture deficiency due to the buffers. The buffers are 4.5 m wide with seven year old trees. As of 2004, it appears that tree roots have not yet significantly penetrated the crop areas. In this study, only 10% of the field surface area was allocated for tree-grass buffers and significant reductions in sediment and nutrient runoff were observed. It is anticipated that as trees mature, environmental and water quality benefits will increase even more. Incorporation of tree/grass buffers appears to significantly increase runoff water quality for claypan soils under row crop management.

References:

Horn, F.W. 1971. The prediction of amounts and depth distribution of water in a well-drained soils. M.S. thesis. University of Missouri, Columbia, MO, USA.

Jin, C.X., M.J.M. Romkens, and F. Griffioen. 2000. Estimating Manning's roughness coefficient for shallow flow in non-submerged vegetative filter strips. Trans. ASAE 43: 1459-1466.

Radersma, S. and C.K. Ong. 2004. Spatial distribution of root length density and soil water of linear agroforestry systems in sub-humid Kenya: implications for agroforestry models. For. Ecol. Manage. 188: 77-89.

Schenk, H.J. and R.B. Jackson. 2002. Rooting depths, lateral root spreads and below-ground/above-ground allometries of plants in water-limited ecosystems. J. Ecol. 90: 480-494.

Schmitt, T.J, M.G. Dosskey, and K.D. Hoagland. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. J. Environ. Qual. 28: 1479-1489.

Seobi, T., S.H. Anderson, R.P. Udawatta, and C.J. Gantzer. 2005. Influence of grass and agroforestry buffer strips on soil hydraulic properties for an Albaqualf. Soil Sci. Soc. Am. J. 69: 893-901.

Udawatta, R.P., P. Nygren, and H.E. Garrett. 2005. Growth of three oak species during establishment in an agroforestry practice for watershed protection. Can. J. For. Res. 35: 602-609.

Udawatta, R.P., J.J. Krstansky, G.S. Henderson, and H.E. Garrett. 2002. Agroforestry practices, runoff, and nutrient loss: a paired watershed comparison. J. Environ. Qual. 31: 1214-1225.

van Noordwijk, M., L.Y. Spek, and P. de Willigen. 1994. Proximal root diameter as predictor of total root size for fractal branching models. Plant Soil 164: 107-117.

Vellidis, G., R. Lowrance, P. Gay, and R.K. Hubbard. 2003. Nutrient transport in a restored riparian wetland. J. Environ. Qual. 32: 711-726.

Zheng, F., C. Huang, and L.D. Norton. 2004. Effects of near-surface hydraulic gradients on nitrate and phosphorus losses in surface runoff. J. Environ Qual. 33: 2174-2182.

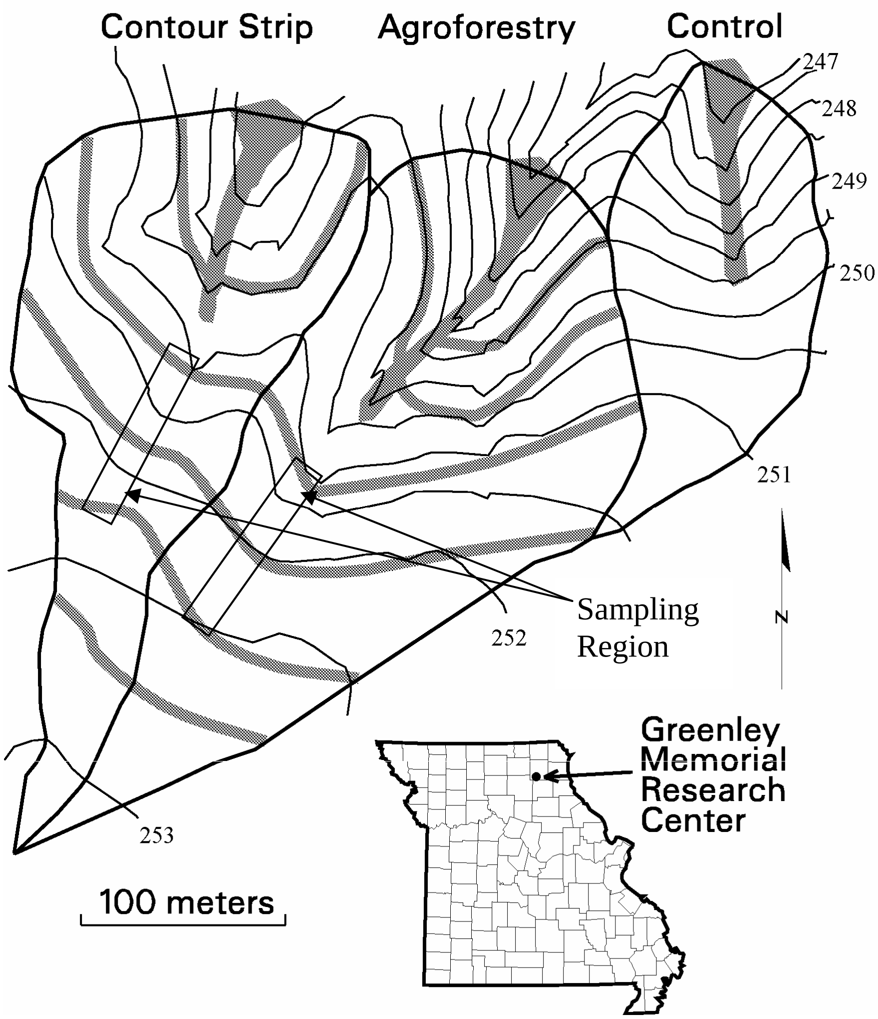

Figure 1. Topographic map of study site with 0.5 m elevation interval contour lines (black), agroforestry buffers (wide gray), grass buffers (wide gray), and sampling region (super imposed box). Grass waterways (wider gray) are located at the outflow end of the three watersheds. Wide gray bands represent tree-grass strips on the agroforestry watershed and grass strips on the contour strip watershed. The inset map shows the location of watershed in Missouri.

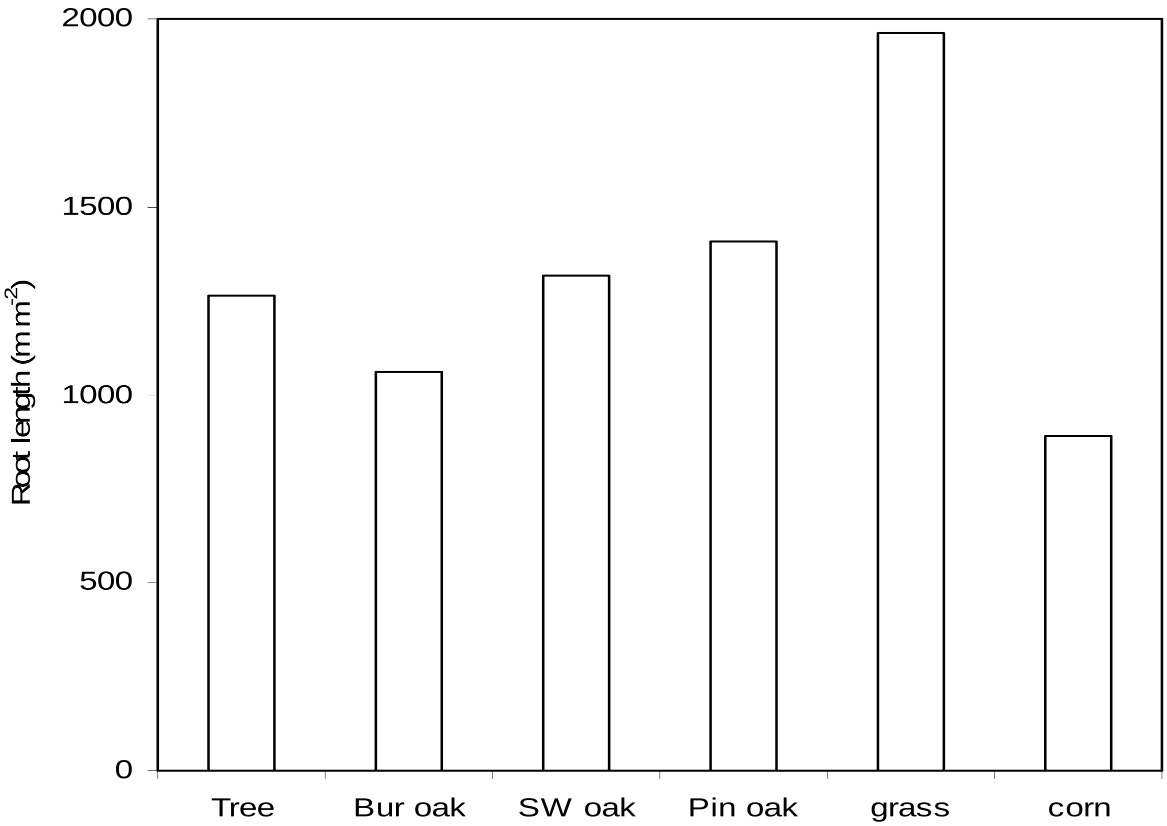

Figure 2. Mean root length density for trees (mean for the three oak species), bur oak, swamp white (SW) oak, pin oak, grass and corn in 2004 at the Greenley Memorial Research Center, Novelty, Missouri.

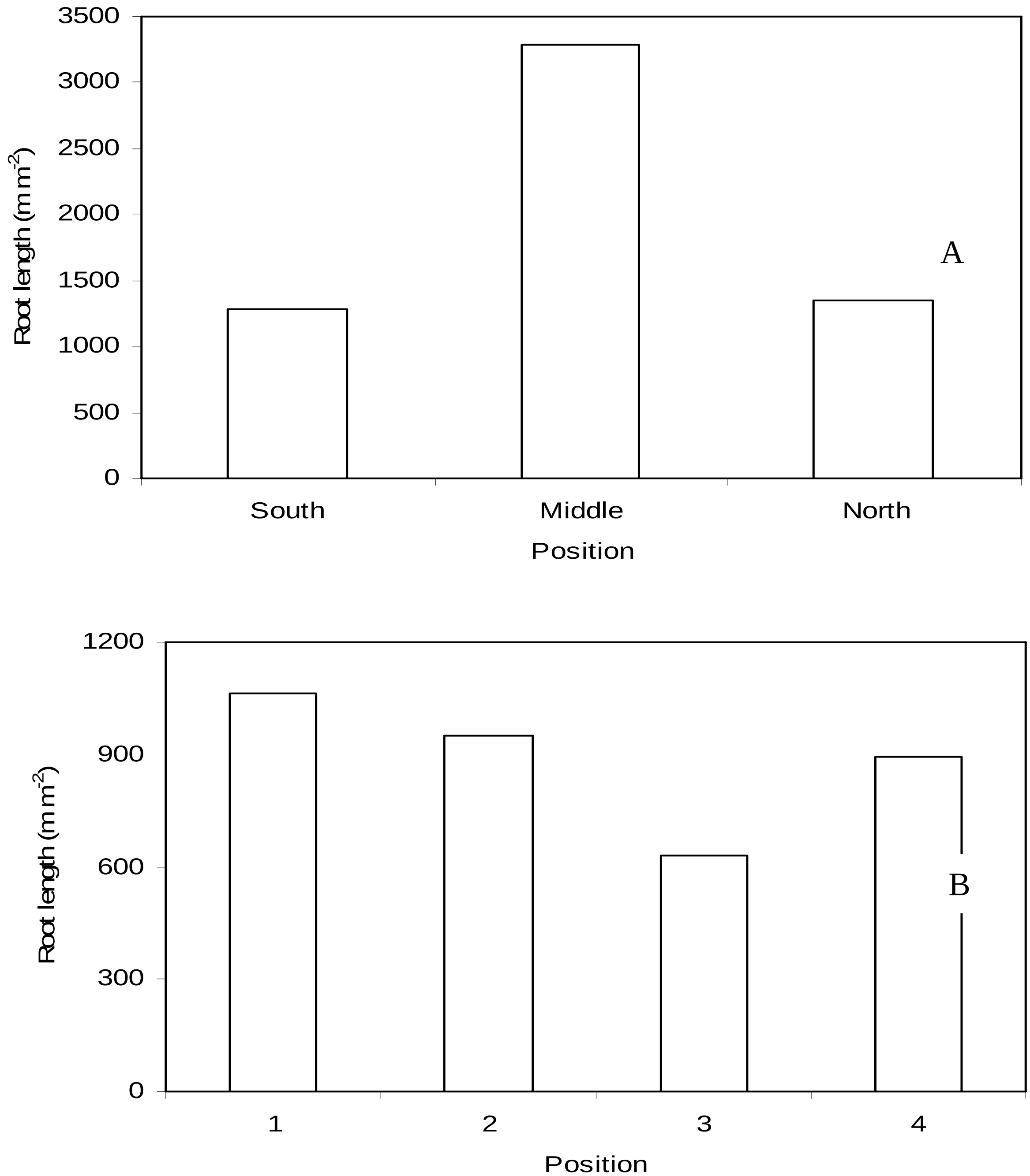

Figure 3. Mean root length density for (A) grass and (B) corn for selected positions within the grass buffers and row crop areas in 2004 at the Greenley Memorial Research Center, Novelty, MO. The positions for the grass buffer included the northern edge (North), southern edge (South) and 2.25 m from either edge (Middle). The positions for the row crop areas included the following distances from one buffer edge to the next across the row crop area: 3 m (1), 13 m (2), 23 m (3), and 33 m (4) with 1 through 4 following a southern to northern direction.

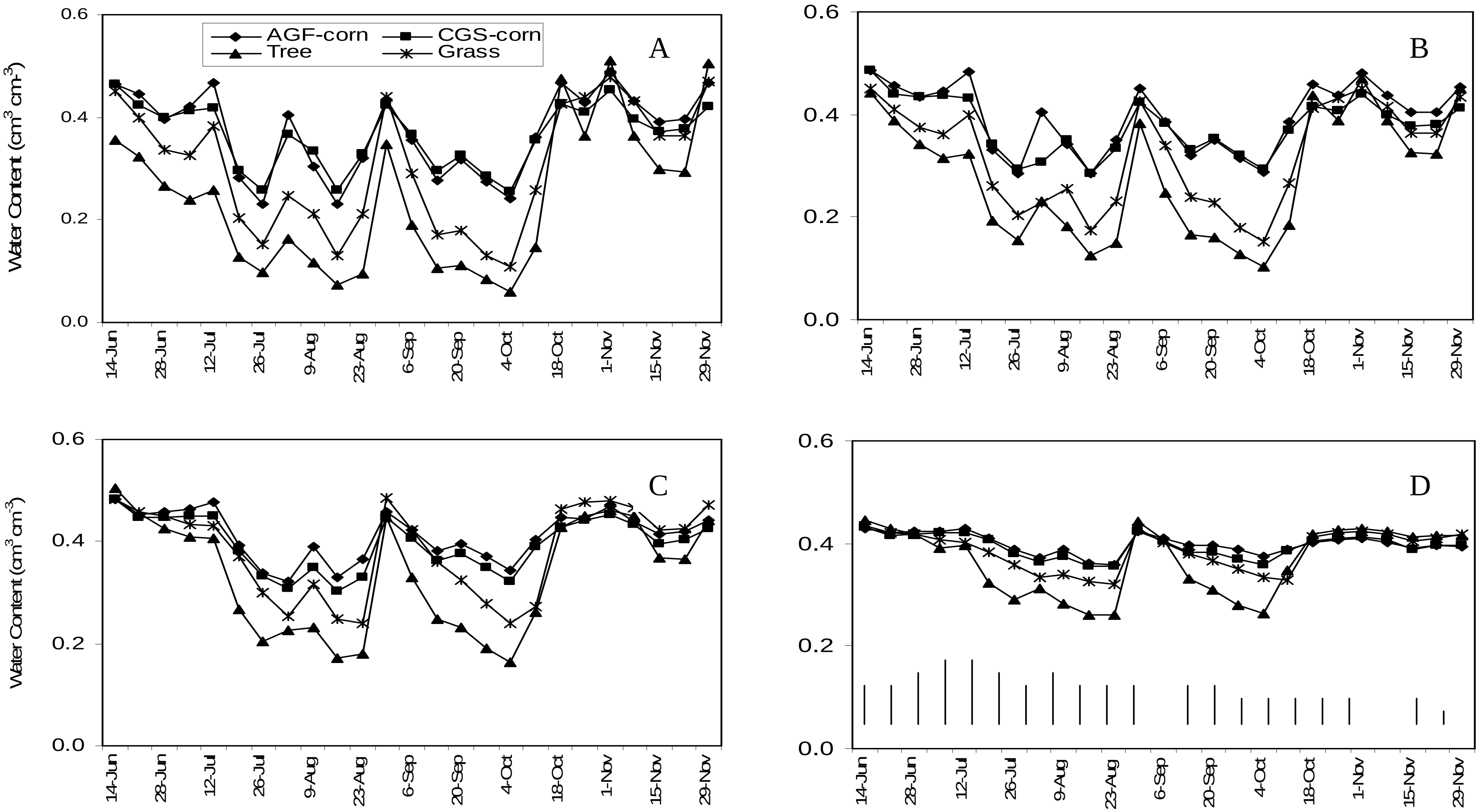

Figure 4. Average volumetric soil water content detected at 12:00 noon each week from June 14 to November 30, 2004 at the Greenley Memorial Research Center, Novelty, Missouri for (A) 5 cm, (B) 10 cm, (C) 20 cm, and (D) 40 cm depths (n=4). AGF-corn = Corn area in agroforestry watershed, CGS-Corn = Corn area in contour grass strip watershed, Tree = trees in agroforestry watershed, and Grass = grass buffers in contour strip watershed. Bars indicate LSD (0.05) values for dates with differences among treatments to determine significance among treatments for each soil depth.