1-1-2005

Influence of a riparian buffer on a deep loess soil

Dedrick DeWaun Davis
Iowa State University

Recommended Citation

Davis, Dedrick DeWaun, "Influence of a riparian buffer on a deep loess soil" (2005). *Retrospective Theses and Dissertations*. 18937.
https://lib.dr.iastate.edu/rtd/18937

Influence of a riparian buffer on a deep loess soil

by

Dedrick DeWaun Davis

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Soil Science (Soil Physics)

Program of Study Committee:
Sally D. Logsdon, Major Professor
Robert Horton
Mark D. Tomer

Iowa State University

Ames, Iowa

2005

Graduate College
Iowa State University

This is to certify that the master's thesis of

Dedrick DeWaun Davis

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

TABLE OF CONTENTS

ABSTRACT

Riparian buffers possess the capacity to serve as an effective tool against non-point source pollution, while, providing numerous benefits in a wide range of environmental settings. The use of riparian buffers as an effective conservation practice has been studied extensively in central Iowa but few if any research exists on the effect of a riparian buffer on the erosion prone loess hills of southwest Iowa. Rainfall simulations were performed in May of 2004 and 2005 within 1.22 m x 2.44 m plots on a Kennebec silt loam and were replicated five times per vegetation. The riparian buffer was composed three vegetation zones that included trees (cottonwoods, *Populus deltoids* Bartr.; black walnut, *Juglans nigra* L.), cool season grass (smooth bromegrass, *Bromus inermis* Leyss), and warm season grass (switchgrass, *Panicum virgatum* L.). Comparisons were made between the row-crop and the individual vegetation zones of the riparian buffer. Significantly higher infiltration rates were observed in the vegetation zones of the riparian buffer when compared to the row crop ($p < 0.05$). Noticeably higher antecedent surface soil moisture was found in the riparian buffer vegetations. The cottonwood trees of the riparian buffer proved to display higher soil moisture when compared to the other vegetations of the riparian buffer and the row crop. A significant amount of sediment loss occurred in the row crop during rainfall simulations. The amount of sediment loss during rainfall simulations performed in the vegetation zones of the riparian buffer was nearly 75 % less than that of the row crop. Lower soil bulk densities were also noticed when compared to the row crop rotation system. The results indicate the positive influence a riparian buffer has on soil physical and hydraulic properties on loess soil.

GENERAL INTRODUCTION

THESIS ORGANIZATION

This thesis contains research on infiltration studies performed on deep loess soil under a five-year-old riparian buffer located along a first order stream in the loess hills of southwestern Iowa. Contained within this thesis is one paper by the student and major professor written in format guidelines for submission to the Soil Science Society of America Journal.

The title of the paper: The Influence of a Riparian Buffer on Soil Water Infiltration of a Deep Loess Soil contains an abstract, introduction, materials and methods, results and discussion, conclusion, and the references cited. This thesis also contains a general introduction, which precedes the journal paper and is followed by a general conclusion.

LOESS HILLS OF SOUTHWESTERN IOWA

The home to some of the nation's most agriculturally productive soils is the Loess Hills of southwestern Iowa. These soils being composed of minerals such as quartz, feldspar, mica, and other minerals but mainly quartz make up layers of loess that are more than 60 meters in depth (Mutel, 1989; USGS, 1999). The extent of loess makes the Loess Hills of southwestern Iowa and Missouri second only to the Loess Hills of China in terms of the extent of loess deposits (USGS, 1999).

The advancement of glaciers into middle North America during the Ice Age resulted in the deposition of loess, an eolian material. The sediment was transported with large quantities of water down the Missouri River Valley as the glaciers melted and receded and were deposited on the flood plains (USGS, 1999). This process left the sediment exposed to wind erosion allowing the silt to be dried, transported, and deposited over a large area with the heaviest silt being deposited closest to the Missouri River and the lighter silt deposited further east. This episodic water and wind erosion is what distinguishes the surface features of the loess deposits in Western Iowa from those on other continents formed during the same time period (Bettis, 1990).

Three major geological units comprise the Loess Hills of southwestern Iowa. They are the Peoria Loess, Pisgah Loess, and the Loveland Loess (USGS, 1999). The most recent deposition is the Peoria Loess dating between 12,500 and 25,000 years (USGS, 1999). This unit thins to the east away from the Missouri River and includes several paleosols (Bettis, 1990). The Pisgah loess has been characterized as a fine material that is compact and slightly blue in color indicating slow permeability and good water retention (Iowa DNR, 2004). The oldest geologic unit is the water deposited Loveland loess ranging from 140,000 to 159,000 years in age and has a reddish brown color and good water retention that is usually has a large clay content (Iowa DNR, 2004; USGS, 1999).

The fine texture but large porosity of loess, combined with its depth, allows it to be well drained permitting the movement of water through it, but steep slopes are prone to runoff rather infiltration (Mutel, 1989). The quick changes in stream levels during rainstorms can be attributed to loess's inability to infiltrate precipitation rapidly. Loess displays great cohesiveness when dry but when it becomes saturated, the cohesiveness of loess disappears leading to a pattern of soil sloughing due to loess's inability to support its own weight (Mutel,1989). The result of this weakness is the presence of large gullies on the landscape of the Loess Hills.

Present Day Agriculture in Iowa and The Loess Hills

Agriculture in Iowa has had a pronounced effect on land use and management over the last century. The increased need for agriculture during the late 1800's and early 1900's resulted in the clearance of more than 80% of the original forest land and 99% of the original prairies and wetlands (Schultz et al., 2000). Nearly 50% of the land in Iowa has been found to be cultivated to the bank edge and 30% of it may be overgrazed pasture (Bercovici, 1994). The surface and subsurface hydrology of Iowa has been dramatically altered by the steps taken to increase the drainage of land by straightening stream channels. These steps have strongly influenced soil quality, soil erosion, soil moisture, and soil hydrology resulting in the inundation of surface water with phosphorus and nitrogen from Iowa cropland (Schultz et al., 2000).

The altering of the Loess Hills by humans did not take place until the 1800's even though humans inhabited the Loess Hills more than 12,000 years ago (USGS, 1999). As European settlers moved west the need for productive agricultural land grew, dramatically resulting in the clearing of native prairie vegetation. Accelerated rates of soil erosion and changes in hydrology have been found in the Loess Hills of Southwestern Iowa due to human interaction with the land. Loess is inherently susceptible to soil erosion due to its very loose structural arrangement and relatively low density (Mutel, 1989). Annual erosion rates of more than 16 tons/ha/yr, a threefold to fourfold increase over Iowa's average of 3.65 to 4.05 tons/ha/yr, have been observed in the Loess Hills (Mutel, 1989; USGS, 1999).

Major changes in the headwater streams of the Deep Loess Hills have been observed due to land surface modifications such as terraces and the expansion of row crop agriculture. The most notable changes in the hydrology of the Loess Hills have been increased infiltration and water table elevation as evidenced by measurable increases in baseflow at the expense of surface runoff (Kramer et al., 1999). These changes in hydrology have led to a pattern of soil sloughing from the increased infiltration and water table elevation resulting in gullies that have been found to be more than 25 meters in depth and more than 30 meters in width (Mutel, 1989; Bettis, 2005).

It has been suspected that vegetative riparian buffers which have many positive influences on erosion and hydrology may help provide a solution to the bank instability and soil sloughing that contributes to gully erosion in the Deep Loess Hills of Western Iowa. As water is lost due to evapotranspiration, water moves from below the root zone to replace the water lost and a portion of the drainage water can be intercepted by plant roots as it percolates through the soil profile (Van Bavel et al., 1968). The stabilization of sediments by roots, water uptake, and transpiration of the vegetation of a riparian forest buffer are thought to positively influence the soil and water balance in the Loess Hills thus providing a solution to the problem of bank instability and soil sloughing.

RIPARIAN BUFFERS

Riparian areas have been found to be a major part of the ecosystem playing an influential role in the hydrologic cycle, the movement of non-point source pollutants to surface and groundwater, and may address non-point source from higher landscape positions (Palone & Todd, 1997). A riparian area is a complex ecosystem consisting of plants, rivers, lakes, and floodplains that forms a transitional zone between upland and aquatic habitat (Welsh, 1991; Lowrance, 1985). Schultz et al. 2004, Welsch, 1991, and Isenhart et al. 1997 define a riparian forest buffer as a "three zone system consisting of an unmanaged woody zone adjacent to the water body followed upslope by a managed woody zone and bordered by a zone of grasses with or without forbs".

Riparian forest buffers can provide many benefits in a range of settings from forested to suburban areas, helping to maintain the integrity of a body of water and its shoreline (Palone & Todd, 1997). Riparian forest buffers provide a multifunctional ecosystem as opposed to vegetative filter strips, which are not designed for large runoff events (Schultz et al., 2000). Although riparian forest buffers have taken on forms such as grazed forest buffers in the eastern United States and narrow bands of forest buffers in the Midwest, their processes such as the filtering and processing of non-point source pollutants for the protection of the environment are still met if managed properly (Schultz et al., 2000). Riparian forest buffers provide vital links between upland ecosystems and aquatic systems even though they occupy less than 1% of the land area of a well-buffered watershed. Buffers can have an immense impact in headwater areas where more than 90% of streamlengths are in 1 to 3 order streams (Schultz et al., 2000). Riparian vegetation has many benefits for the aquatic environment due to several they perform (Karr & Schlosser, 1978). These functions include the filtering and retaining of sediment, controlling chemical inputs from uplands, controlling stream environments, controlling aquatic habitats, reducing floods, and providing water storage and recharge of subsurface aquifers (Schultz et al., 2000).

Riparian Buffer Influence on Sediment Retention

Riparian buffers have been found to play a major role in filtering and retaining sediment. They serve as an effective filter mechanism for bulk sediment removal between field edges and streams (Cooper et al., 1987). In a study of a multi-species riparian buffer

Lee et al. (2003) observed a switchgrass/woody buffer that had 39 times less sediment transported through it when compared to non-buffered plots. Palone and Todd (1997) observed significant reductions of incoming sediment in their evaluation of 30 m wide mature forest buffers. The filtering and retaining of sediment has been attributed to the vertical structure of standing plants and the organic litter on the soil surface that provides surface roughness, hence friction that slows surface runoff causing sediment to be deposited (Dillaha et al., 1989). Riparian forest buffers also have the capacity to remove nutrients and pesticides from surface runoff through processes such as infiltration, dilution, and adsorption and desorption (Schultz et al., 2000).

Riparian Buffer Influence on Nutrients and Chemicals

Two-thirds of non-point source pollutants identified in most states can be attributed to agriculture (Bosch et al., 1994). Riparian forests, which contain mature trees, have been found to effectively reduce non-point source pollution from agricultural fields (Lowrance et al., 1985). Riparian buffers are known to remove nutrients such as phosphorus and nitrogen usually associated with sediment. Dillaha (1989) noted that vegetative filter strips removed 97% of P_{total} and 78% of the N_{total} entering the vegetative filter strip that was sediment bound. Herbaceous vegetation and grasses of a non-cultivated riparian buffer significantly reduced NO_3-N concentrations of shallow ground water moving from grass seed fields (Wigington et al. 2003). The effective retention and immobilization of nutrients and chemicals will exist only if plants are growing actively and accumulating biomass (Schultz et al., 2000).

Riparian Buffer Influence on Stream Environment and Morphology

The ability of a riparian forest buffer to influence streambank stability is important because sediment from streambanks is a major non-point source pollutant in the United States. Upto 1.4 mt of sediment are delivered to surface waters in the United States annually (Schultz et al., 2004). In a study of non-buffered segments along an 11km stream reach, Zaimes (2004) found that if a riparian forest buffer had been established streambank loss would have been reduced by approximately 72%. Other researchers have found that riparian forest buffer have an effect on the stream environment by influencing water temperature, O_2 content, and biological diversity (Gregory et al., 1991; Karr and Schlosser, 1978).

Riparian Buffer Influence on Water Storage

Vegetated riparian buffers can attenuate flooding zones by encouraging water to spread out and soak into the soil, allowing recharge of local groundwater and increasing the baseflow (Schultz, 2000). Among the most noticeable changes in hydrology has been increased infiltration at the expense of surface runoff due to the multiple stems of forest buffers, which provide a frictional surface that slows the floodwater and runoff.

INFILTRATION

Infiltration is the process of water entering the soil surface, generally in a vertical downward direction. More simply, infiltration is the penetration of water into soil pores. The infiltration of water into the soil surface occurs due adsorptive (capillary) and gravitational forces that are dependent on the soil's texture (Logsdon, 2003). As the soil becomes more saturated with time, matric potential and gravity potential influences the advancement of water into the drier parts of the soil at the leading edge of the wetting pattern. However, during the early stages of infiltration, matric potential is the dominate force, rather than gravitational force, because the wetting front is near the surface (Jury and Horton, 2004). The first in-depth analysis of the wetting pattern during infiltration was performed by Bodman and Coleman (1944). The wetting profile of the soil as infiltration occurs can be divided into the following zones: saturation zone, transition zone, transmission zone, wetting zone, and the wetting front. The saturation zone extends to approximately 1.5 cm below the soil surface. The transition zone designates a zone where the soil moisture decreases rapidly with depth to a depth of 6 cm. The transmission zone has small change in soil moisture. The wetting zone is where rapid changes of soil moisture are observed and the wetting front which is the limit of water penetration (Bodman & Coleman, 1944).

Soil water infiltration can be described by the two important concepts of infiltration rate and infiltrability. The infiltration rate is defined the volume flux of water flowing into the soil across a known soil surface (Chow et al., 1988). The maximum infiltration rate of the soil is equal to the infiltration rate of ponded water (Miyazaki, 1993). The infiltrability of a dry soil is initially high and decreases over time due the decrease in the matric potential of the soil (Hillel, 1980). The final infiltration rate is closely equal to the saturated hydraulic conductivity of the soil (Miyazaki, 1993; Hillel, 1980).

Theory

The process of infiltration is a very complex process, which is described approximately using theoretical and empirical mathematical equations. Among the most noted and used equations are the following: Green-Ampt, Horton, Kostiakov, and the Phillip equations. Through the utilization of Darcy's Law the following assumptions allow for the determination of the infiltration rate (Eq. 1) when using the Green-Ampt model: "(i) the properties of K_o (hydraulic conductivity), D_o (diffusivity), θ_o (water content), and h_o(matric potential) are constant in the wet region (ii) the matric potential head at the moving front is constant and equal to h_F (matric potential of moving front)" (Jury & Horton, 2004).

$$i = Jw = -Ko\frac{hf - ho}{L} = Ko\frac{\Delta \mathrm{h}}{\mathrm{L}} \quad [1]$$

where *i* is the infiltration rate, *Jw* is water flux, Δh is change in matric potential, and L is thickness of the wet region. The infiltration rate is equal to the change of storage of water over time and depth, giving Eq. 2

$$i = \Delta\Theta\tfrac{dL}{dt} \quad [2]$$

which can be inserted into Eq. 1 resulting in a differential equation. Through the process of integration the cumulative infiltration may be determined from Eq. 3:

$$I = \Delta\Theta(2D_o t)1/2 \quad [3]$$

where *I* is the cumulative infiltration, ΔΘ is the change in water content, and *t* is time (Jury et al., 1991). Horton's equation gives the infiltration rate (Eq. 4)

$$i = i_f + (i_o - i_f)\,\mathrm{e}^{-\mathrm{kt}} \quad [4]$$

and can be integrated to determine the cumulative infiltration as a function of time

$$I = i_f + \frac{i_o - i_f}{k}\,[1\text{-}\mathrm{e}^{-\mathrm{kt}}]\ [5]$$

where i_f is the final constant infiltration, i_o is the final infiltration rate, k describes the rate of decrease of infiltration, and *t* is time. (Hillel, 1980). The Kostiakov equation [Eq. 6] notes that

$$i = Bt^{-n} \quad [6]$$

increasing time i will approach zero than opposed to a constant nonzero i_c when provided an infinite initial i (Hillel, 1980). The cumulative infiltration may be determined from the above equation where B and n are constants. The Philip model (Eq. 7) allows for the determination of the infiltration rate by assuming the following conditions apply: (i) the soil is infinitely long and a uniform water content exists and (ii) the water content at the boundary is higher (Jury & Horton, 2004).

$$i = \tfrac{1}{2} St^{-1/2} \quad [7]$$

When the S (sorptivity) is constant over time the cumulative infiltration is determined by [Eq. 8].

$$I = St^{1/2} \quad [8]$$

Factors affecting Soil Water Infiltration

The rate and amount of water that infiltrates a soil is affected by both surface and subsurface factors and both of these are affected by soil management and naturally occurring soil processes (Logsdon, 2003). The surface factors that affect soil water infiltration include surface sealing and crusting, rainfall intensity, antecedent soil moisture, soil management and residue cover, and the presence of macropores and fractures. Among the most important subsurface properties are hydraulic conductivity, continuity of macropores, and air pressure buildup.

Surface Sealing and Crusting

Surface seals and soil crusts have been extensively researched in their influence on infiltration. The forming of a surface seal or crust begins when a raindrop strikes the soil surface or through the slaking and breakdown of soil aggregates during wetting allowing larger pores to become filled with smaller particles and upon drying forming a hard crust or seal. Surface crust have been found to act as an impedence on infiltration due to the negative potential at the crust-soil interface leading to small moisture contents in the wetted region of the soil which is associated with the low hydraulic conductivity and soil moisture diffusivity Philip (1998). Moore (1981) noted that surface seals form a small thin sheet over soil from the external force of raindrop impact and when it dries it does not allow water to infiltrate thus promoting erosion and runoff and limiting the available water supply of the land. He later determined that surface sealing can decrease infiltration rates and volumes by as much as 80% and that ignoring this effect on a watershed scale could significantly underestimate predicted runoff (Moore, 1981). Eigel and Moore (1983) found that surface sealing involves the rearrangement and realignment of the primary soil particles in the surface seal zone. It has been stated that the formation of a surface seal by slaking and raindrop impact is one of two factors controlling the time to surface ponding and the subsequent infiltration response of bare soils. McIntyre (1958) identified two parts of a surface seal: a skin formed by compaction due to impact and a washed-in region of decreased porosity.

During his study McIntyre (1958) found a 2,000-fold decrease in the hydraulic conductivity of the surface layer of a fine sandy loam due to the formation of a surface seal. Both Moore (1981) and McIntyre (1958) noticed decreases in porosity of the surface seal due to the filling of large voids with smaller particles reducing the soil conductivity. McIntyre further noted the formation of a surface seal is influenced by soil texture, organic content, tillage practices, aggregate stability, cropping history, and rainfall intensity and duration.

Rainfall Intensity

Rainfall intensity also has an impact on the infiltration characteristics of a soil due to its influence in the formation of surface seal. Moore (1981) noted that the effect of raindrop impact on surface sealing were dramatic by comparing the infiltration rate vs. time curves and the time to surface ponding but further noted the importance of rainfall kinetic energy is diminished after surface ponding has occurred. Betzalel (1995) found that as the drop impact energy increased, the infiltration rate for any depth decreased during a study involving drop diameters of 2.53 and 3.37 mm and drop fall heights of 0.4, 1.0, 2.0, 6.0 and 10.0 m. Raindrop impact also strongly influences soil erosion along with infiltration. Ekern (1950) in a study involving the mechanics of drop erosion observed fine sand gave the largest amount of transport while smaller particles were compacted, resulting in the establishment of a surface seal thus affecting the infiltration and allowing water to pond at the surface which helped dissipate the energy of the falling drops.

Antecedent Soil Moisture

The antecedent soil moisture content is important in determining the amount of water that can infiltrate a soil. High amounts of water have been found to infiltrate initially dry soil but eventually decreases and levels off with time (Hillel, 1980). Infiltration can be severely limited due to a high water table but it also prevents the formation of a surface seal (Logsdon 2003). Small increases in the antecedent soil moisture have also been found to have a positive benefit on soil water infiltration. Bissonnais and Singer (1992) found that the infiltration rate for initially air dry soils was twenty-fold lower than for prewetted soils after 40mm of the first rainfall, and remained ten and two times lower after the second and third rain respectively.

Soil Physical Properties

The soil physical properties such as bulk density, soil aggregation, porosity, and saturated hydraulic conductivity greatly influence the infiltration potential and characteristics of the soil (Shaver et al., 2002; Benjamin, 1993). The effect of different tillage systems on these soil physical properties and soil water infiltration has been extensively researched. Conventional tillage has been found to increase porosity and decrease bulk density. Unger (1992) stated that tillage usually increases infiltration by loosening surface crusts, disrupting soil layers, and providing surface depressions for temporary storage of water. Tillage may also decrease infiltration whenever the tillage operation smooths the surface, disrupts aggregates, eliminates surface residue, or causes compaction. He further found that tillage methods used affected soil aggregate-size distribution and stability, surface roughness, and, hence water infiltration as determined with a rainfall simulator and depending on the tillage method used the time to achieve a constant infiltration rate was lengthened. Unger found that soil inverting tillage such as moldboard plow resulted in lower final infiltration rates due to the creation of less stable aggregates. Long-term effects of surface tillage on permeability are most likely to be negative, as governed by tendencies such as the loss of structure, increased surface crusting, blocking of continuous biopores and cracks, the tendency for impermeable plough and traffic pan development with repeated tillage, and insidious movement of clay particles in dispersive soils into the subsoil (Fischer, 1987). The loss of soil structure due to surface tillage also serves as a means for increased soil erosion due to raindrop impact.

Tillage

No-till systems also have been found to have a strong influence on soil physical properties that affect infiltration. While no-till systems often result in higher soil bulk densities than conventional tillage systems (Mielke et al., 1986; Wu et al., 1992), soil hydraulic properties such as hydraulic conductivity and infiltration are usually the same or greater as when compared to those exhibited by a conventional tillage system (Benjamin, 1993; Sauer et al., 1990). Many researchers have attributed this increase in hydraulic conductivity and infiltration to the presence of macropores. Wu et al. (1992) observed that even with a lower porosity and equal or higher K_{sat} the no-till system requires pores to conduct water more efficiently, which implies a greater continuity of macropores than when compared to a moldboard plow system. This same conclusion was also suggested by Ehlers (1975) and Sauer et al. (1990) when comparing the infiltration observed in no-till fields to that of tilled fields and attributed the increase in K_{sat} to a more stable soil structure. The residue that is left on a field in a no-till system also helps the increase in infiltration due to no-till. The residue helps to protect the soil surface by protecting areas prone to crusting and sealing from rain drop action and also by reducing the velocity of runoff, which allows more precipitation to infiltrate (Fischer, 1987).

Macropores

The importance of macropores and their relation to soil hydraulic properties has also been extensively studied. Even though macropores contribute a small fraction of the total porosity of a soil, they have a very important influence on the saturated hydraulic conductivity of soil and are particularly important in the process of the infiltration of rainfall and solutes into the soil (Beven & Germann, 1982). Mohanty et al. (1996) determined that approximately 90% of the saturated flux moves through macropores (>1-mm diameter), which constituted less than 3% of the total surface area at three field positions. Macropores whether they are biological or structural contribute significantly to preferential flow and in turn have a great influence on the depth of water percolation in no-tillage systems where the soil system can be largely bypassed (Vervoort et al., 2001). Logsdon (1993) determined that the function and continuity of macropores are often more important than visual observation. The introduction of tillage destroys the continuity of macropores, at the same time creates unstable tillage pores within the tilled layer, and influences the distribution of macropores that may provide pathways for preferential flow (Logsdon et al., 1990; Logsdon, 1995).

Riparian Forest Buffers

Riparian forest buffers have been found to be very effective in increasing soil water infiltration. Palone and Todd (1997) noted forests can capture and absorb 40 times more rainfall than agricultural land and and 15 times more than turfgrass or pasture covered soils. In the evaluation of a multispecies riparian buffer Bharati et al. (2002) noticed the infiltration rate was five times greater compared to grazed pastures and cultivated fields. The positive effect of forests on infiltration has been documented by other studies (Broersma et al., 1995;

Wood, 1977; Wilson & Luxmoore, 1988). Macroporosity and soil structure have been credited with maintaining the high infiltration rates associated with forests and riparian forest buffers. Macropores have been found to substantially control the subsurface water flow in forested watersheds (Wilson & Luxmoore, 1988). Marquez (2004) attributed the high infiltration rates found under riparian forest buffers to the improvement soil structure due to an increase in soil organic matter.

OBJECTIVE

The objective of this study was to evaluate a five-year-old riparian buffer located along a first order stream in the Loess Hills region of Southwest Iowa and compare it to a no-till corn soybean rotation. Rainfall simulations were performed to see how infiltration of the riparian buffer differed from that of the no-till rotation system and also how infiltration differed among the vegetations composing the riparian buffer. Other soil physical properties such as soil moisture and soil bulk density were evaluated to analyze the effect of the riparian buffer when compared to the no-tillage system.

REFERENCES

Benjamin, J.G. 1993. Tillage effects on near-surface soil hydraulic properties. Soil Tillage Res. 26:277-288.

Bercovici, M.M. 1994. Determining the need for riparian buffers strips in a Midwestern watershed. M.S. Thesis. Iowa State University, Ames.

Betzalel, I., J. Morin, Y. Benyamini, M. Agassi, and I. Shainberg. 1995. Water drop energy and soil seal properties. Soil Sci. 159:13-22.

Bettis, E.A. III. 1990. Holocene Alluvial Stratigraphy of Western Iowa, Midwest Friends of the Pleistrocene 37th Field Conference Guidebook, May 12-13, 1990. Iowa Department of Natural Resources, Geological Survey Bureau. Guidebook Series Number 9. Des Moines, IA

Bettis, E.A. III. 2005. Gully erosion [Online]. Available at www.igsb.uiowa.edu/browse/gullyero/gullyero.html (accessed 14 Apr. 2005). Iowa DNR Geological Survey, Iowa City, IA.

Beven, K. and P. Germann. 1982. Macropores and water flow in soils. Water Resour. Res. 18:1311-1325.

Bharati, L., K.H. Lee, T.M. Isenhart, and R.C. Schultz. 2002. Soil-water infiltration under crops, pasture, and established riparian buffer in Midwest USA. Agrofor. Syst. 56:249–257.

Bissonnais, Y. L. and M. J. Singer. 1992. Crusting, Runoff, and Erosion Response to Soil Water Content and Successive Rainfalls. Soil Sci. Soc. Am. J. 56:1898-1903.

Bodman, G.B. and E.A. Coleman. 1943. Moisture and energy conditions during downward entry of water in to soils. Soil Sci. Soc. Am. Proc.

Bosch, D.D., R.K. Hubbard, L.T. West, and R.R. Lowrance. 1994. Subsurface flow patterns in a riparian buffer system. Trans. ASAE 37:1783-1790.

Broersma, K., J.A. Robertson, and D.S. Chanasyk. 1995. Effects of different cropping systems on soil water properties of a boralf soil. Commun. Soil. Sci. Plant Anal. 26:1795-1811.

Chow V.T., D.R. Maidment, and L.W. Mays. 1988. Applied hydrology. McGraw-Hill, Inc., New York.

Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. Soil Sci. Soc. Am. J. 51:416-420

Dillaha, T.A., R.B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Trans. ASAE 32:513-519.

Eigel, J.D. and I.D. Moore. 1983. Effect of rainfall energy on iInfiltration into a bare soil. p.188-200. *In* Proc. Of the National Conference on Advances in infiltration,Chicago, IL. 12-13 Dec. 1983. ASAE, St. Joseph, MI.

Ekern, P.C. 1950. Raindrop impact as the force initiating soil erosion. Soil Sci. Soc. Am. Proc.

Ehlers, W. 1975. Observations on earthworm channels and infiltration on tilled and untilled loess soil. Soil Sci. 119:242–249.

Fischer, R.A. 1987 Responses of soil and crop water relations to tillage. p.194-221. *In* P.S. Cornish and J.E. Pratley (ed.) Tillage: New directions in Australian agriculture. Inkata Press, Melbourne.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41:540-551.

Hillel, D. 1980. Applications of soil physics. Academic Press, Inc., New York

Isenhart, T.M., R.C. Schultz, and J.P. Colletti. 1997. Watershed restoration and agricultural practices in the Midwest: Bear Creek in Iowa. Chapter 15. *In* J.E. Williams et al. (ed.) Watershed Restoration: Principles and Practices. American Fisheries Society.

Jury, W.A., W.R. Gardner, and W.H. Gardner. 1991. Soil Physics 5th ed. John Wiley & Sons, Inc., New York.

Jury, W.A. and R. Horton. 2004 Soil Physics. 6TH ed. John Wiley & Sons, Inc., Hoboken, NJ.

Karr, J.I. and I.J. Schlosser. 1978. Water resources and the water interface. Science 201: 229-234.

Kramer, L.A., M.R. Burkart, D.W. Meek, R.J. Jacquis, and D.E. James. 1999. Field-scale evaluations on deep loess soils: II. Hydrologic responses to different agricultural land management systems. J. Soil Water Conserv. 54:705-710.

Lee, K.H., T.M. Isenhart, and R.C. Schultz. 2003. Sediment and nutrient removal in an established multi-species riparian buffer. J. Soil Water Conserv., 58:1- 9.

Logsdon, S.D., R.R. Allmaras, L. Wu, J.B. Swan, and G.W. Randall. 1990. Macroporosity and its relation to saturated hydraulic conductivity under different tillage practices. Soil Sci. Soc. Am. J. 54:1096-1101.

Logsdon, S.D., E.L. McCoy, R.R. Allmaras, and D.R. Linden. 1993. Macropore characterization by indirect methods. Soil Sci., 156:316-324.

Logsdon, S.D. 1995. Flow mechanisms through continuous and buried macropores. Soil Sci., 160:237-242.

Logsdon, S. 2003. Soils, water infiltration and. p. 930-933. *In* B.A. Stewart and T.A. Howell (ed.) Encyclopedia of water science. Marcel Dekker, Inc., Lowrance, R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. J. Soil Water Conserv. 40:87-91.

Márquez, C. O. V. J. Garcia, C. A. Cambardella, R. C. Schultz, and T. M. Isenhart Aggregate-size stability distribution and soil stability. Soil Sci. Soc. Am. J. 2004 68: 725-735.

McIntyre, D.S. 1958. Permeability measurements of soil crusts formed by raindrop impact. Soil Sci., 85 (4):185-189.

Mielke, L.N., J.W. Doran, and K.A. Richards. 1986. Physical environment near the surface of plowed and no-tilled soils. Soil Tillage Res. 7:355-366.

Miyazaki, T. 1993. Water flow in soils. Marcel Dekker, Inc., New York.

Mohanty, B. P.; Horton, R., and Ankeny, M. D. 1996. Infiltration and macroporosity under a row crop agricultural field in a glacial till soil. Soil Sci. 161 (4):205-213.

Moore, I.D. 1981. Effect of surface sealing on infiltration. Trans. ASAE:1546-1551

Mutel, C.F. 1989. Fragile giants: A natural history of the Loess Hills. 1st ed. University of Iowa Press, Iowa City, IA.

Palone, R.S., and A.H. Todd (ed.) 1997. Chesapeake Bay riparian handbook: A guide for establishing and maintaining riparian forest buffers. USDA For. Serv. NA-TP-02-97. USDA-FS, Radnor, PA.

Phillip, J.R. 1998. Infiltration into crusted soils. Water Resour. Res. 34:1919-1927.

Sauer, T.J., B.E. Clothier, and T.C. Daniel. 1990. Surface measurements of the hydraulic characteristics of tilled and untilled soil. Soil Tillage Res. 15:359–369.

Schultz, R.C., J.P. Colletti, T.M. Isenhart, C.O. Marquez, W.W. Simpkins, and C.J. Ball. 2000. Riparian forest buffer practices. p.189-281. *In* H.E. Garrett et al. (ed.) North American agroforestry: an integrated science and practice. ASA, Madison, WI.

Schultz, R.C., T.M. Isenhart, W.W. Simpkins, and J.P. Colletti. 2004. Riparian forest buffers in agroecosystems- lessons learned from the Bear Creek Watershed, central Iowa, USA. Agroforestry Syst. 61:35-50.

Shaver, T. M., G. A. Peterson, L. R. Ahuja, D. G. Westfall, L. A. Sherrod, and G. Dunn. 2002. Surface soil physical properties after twelve years of dryland no-till management. Soil Sci. Soc. Am. J. 66:1296-1303.

Unger, P.W. 1992. Infiltration of simulated rainfall:tillage system and crop residue effects. Soil Sci. Soc. Am. J. 56:283-289.

USGS. 1999. Geology of the loess hills, Iowa. [Online]. Available at www.pubs.usgs.gov/info/loess/ (accessed 18 Aug. 2005; verified 5 July 2005). USGS, Washington, D.C.

Van Bavel, C.H.M., K.J. Brust, and G.B. Stirk. 1968. Hydraulic properties of a clay loam soil and the field measurement of water uptake by roots. II. The water balance of the root zone. Soil Sci. Soc. Am. Proc. 32:317-321.

Vervoort, R.W., S.M. Dabney, and M.J.M. Romkens. 2001. Tillage and row position effects on water and solute infiltration characteristics. Soil Sci. Soc. Am. J. 65: 1227-1234.

Welsch, D.J. 1991. Riparian forest buffers: Function and design for protection and enhancement of water resources. NA-PR-07-91. USDA-FS, Radnor, PA.

Wigington, P. J., Jr., S. M. Griffith, J. A. Field, J. E. Baham, W. R. Horwath, J. Owen, J. H. Davis, S. C. Rain, and J. J. Steiner. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in Western Oregon. J. Environ. Qual. 32:162-170.

Wilson, G.V. and R.J. Luxmoore. 1988. Infiltration, macroporosity, and mesoporosity distributions on two forested watersheds. Soil Sci. Soc. Am. J. 52:329-335.

Wood, H.B. 1977. Hydrologic differences between selected forested and agricultural soils in Hawaii. Soil Sci. Soc. Am. J. 41:132-136.

Wu, L., J.B. Swan, W.H. Paulson, and G.W. Randall. 1992. Tillage effects on measured soil hydraulic properties. Soil Tillage Res. 25:17:33.

Zaimes, G.N., R.C. Schultz, and T.M. Isenhart. 2004 Streambank erosion adjacent to riparian forest buffers, row-crop fields, and continuously-grazed pastures along Bear Creek in central Iowa. J. Soil Water Conserv. 59:19-28

The Influence of a Riparian Buffer on Soil Water Infiltration of a Deep Loess Soil

A paper to be submitted to Soil Science Society of America Journal

Dedrick Davis and Sally D. Logsdon

ABSTRACT

The capacity of riparian buffers to serve as an effective conservation practice has been well documented especially in Central Iowa. Riparian forest buffers provide many benefits in environmental settings ranging from forested areas to suburban areas, helping to maintain the integrity of a body of water and its shoreline. The purpose of this study was to evaluate a 5 yr. old riparian buffer located in the loess hills region of Southwest Iowa. We hypothesize that the riparian vegetation will increase soil water infiltration, soil moisture, and reduce soil erosion and soil bulk density. Rainfall simulations were performed within 1.22 x 2.44 m plots on a Kennebec (fine-silty, mixed, mesic Cumulic Hapludoll). The vegetation comparisons included corn (*Zea mays* L.)-soybean (*Glycine max* (L.) Merr.) rotation, a riparian buffer composed of three zones with trees (cottonwoods, *Populus deltoids* Bartr.; black walnut, *Juglans nigra* L.) , cool season grass (smooth bromegrass, *Bromus inermis* Leyss), and warm season grass (switchgrass, *Panicum virgatum* L.). Rainfall simulations were replicated five times per vegetation. The riparian buffer vegetations significantly improved infiltration when compared to the crop ($P<0.05$). Antecedent soil moisture (0-30 cm) was noticeably increased due to the vegetations of the riparian buffer, however, the cottonwoods proved to display higher soil moisture when compared to the other vegetations. The amount of sediment loss from the crop was 3.8 times more than that lost from the riparian buffer vegetations. The riparian buffer reduced soil bulk density compared to the

no-till row crop rotation system. The results show the ability of a riparian buffer to positively influence soil physical and hydraulic properties in the Loess Hills of southwestern Iowa.

INTRODUCTION

The home to some of the nation's most agriculturally productive soils is the Loess Hills of Southwestern Iowa. The extensive layers of loess make the Loess Hills of Southwestern Iowa second only to Loess Hills of China, which has more extensive layers (USGS, 1999).

The altering of the Loess Hills due to human settlement to meet the need for agricultural production land has resulted in the nearly complete removal of native prairie vegetation. Accelerated rates of soil erosion and changes in hydrology have been found in the Loess Hills of Southwestern Iowa due to these impacts. The most notable changes in the hydrology of the Loess Hills due to land surface modifications such terraces have been increased groundwater recharge and water table elevation as evidenced by measurable increases in baseflow at the expense of surface runoff (Kramer et al., 1999). Increased infiltration and water table elevation have led to a pattern of soil sloughing, resulting in gullies that have been found to be more than 25 meters in depth and more than 30 meters in width (Mutel, 1989; Bettis, 2005).

Vegetative riparian buffers, which have many positive influences on erosion, hydrology, and ecology may help provide a solution to the bank instability and soil sloughing that contributes to gully erosion in the Deep Loess Hills of Western Iowa. Riparian areas play an influential role in the hydrologic cycle and the movement of nonpoint source pollutants to surface and groundwater, are considered an effective practice for treating non-point source pollution in agricultural landscapes (Palone & Todd, 1997). In the study of a multi-species riparian buffer, Lee et al., (2003) observed a switchgrass/woody buffer that had 39 times less sediment transported through it than non-buffered plots. Herbaceous vegetation and grasses of a non-cultivated significantly reduced NO3-N concentrations of shallow ground water when moving from grass seed fields (Wigington et al., 2003). In a study of non-buffered segments along an 11 km stream reach, Zaimes (2004) suggested that if riparian forests had been established streambank loss would have been reduced by approximately 72%.

Perhaps the most important influence a riparian buffer has is its altering of hydrological conditions. Riparian forest buffers have been found to be very effective in increasing soil water infiltration. Palone and Todd (1997) noted forests could capture and absorb 40 times more rainfall than agricultural land and 15 times more than turfgrass or pasture covered soils. In the evaluation of a multispecies riparian buffer Bharati et al. (2002) noticed the infiltration rate was five times greater when compared to grazed pastures and cultivated fields. Rachman et al. (2004a) found in a study conducted in Treynor, IA on loess soil that grass hedges (switchgrass, *Panicum virgatum* L.) increased water infiltration when compared to a conventional row crop system. He observed a field saturated hydraulic conductivity that was seven times more than that observed in the row crop and attributed the difference to greater macroporosity and pore continuity found in the grass hedge position (Rachman et al., 2004a). In a separate study at the same location Rachman et al., (2004b) found that grass hedges had greater macroporosity, mesoporosity and lower bulk density when compared to a row crop and deposition areas and determined these two factors to be the most critical when determining saturated hydraulic conductivity. The positive effect of forest on infiltration has been documented by other studies (Broersma et al., 1995; Wood, 1977; Wilson & Luxmoore, 1988). Although many studies have been conducted on riparian buffers in central Iowa, few if any studies have been conducted on the highly erosive deep loess soils in western Iowa. The objective of this study was to compare infiltration in vegetated of a five-year-old, multipspecies riparian buffer located along a first order stream in the Loess Hills region of Southwest Iowa with a no-till corn soybean rotation.

MATERIALS AND METHODS

Site Description

The study was conducted at the USDA-ARS National Soil Tilth Laboratory Deep Loess Research Station near Treynor, IA located in a 6-ha watershed that is representative of the Iowa and Missouri Deep Loess Hills, Major Land Resource Area 107 (USDA-SCS, 1981). The soils loctaed in the riparian buffer of the watershed were Napier silt loam (Fine-silty, mixed, mesic Cumulic Hapludoll) and Kennebec silt loam (Fine-silty, mixed, mesic Cumulic Hapludoll). These soils are characterized as being moderately well drained with moderate permeability. The slope ranges from 2% to 5% for the Napier silt loam and 0% to 2% for the Kennebec silt loam. The watershed was under a no-till corn-soybean rotation since 1996 but was tilled in 2005.

The riparian buffer measures 183 m in length and is adjacent to the initiation of a first order stream. The riparian buffer is composed of three parallel strips of warm season grass, cool season grass, and trees. The strip of warm season consists of a 5 m wide zone of switchgrass located adjacent to the crop due to its resistance to herbicide drift. Directly adjacent to the zone of warm season grass is a 5 m strip of cool season grass (smooth bromegrass). Closest to the first-order stream are two rows of cottonwood trees with one row of walnut trees planted in between. The cottonwood trees were planted as root cuttings in 2001 utilizing a 3 m x 3 m spacing. Thinning of the cottonwood trees took place in subsequent years.

Data for this study was obtained in May of 2004 and May of 2005. The treatments for this study included the row crop area and the three vegetations that compose the riparian buffer. In 2004 corn was planted as the row crop and in 2005 the row crop consisted of soybeans. In 2004 the cropped was in no-till corn. In 2005 the experiment was carried out on soybeans following seedbed cultivation and planting.

Field Methodology

Rainfall simulation was used to evaluate the treatments in May 2004 and May 2005. A rainfall simulator similar to that described by Byars et al., (1996) was used to evaluate infiltration, runoff, and soil erosion of 1.22 m x 2.44 m plots located within the row crop, and each zone of vegetation composing the riparian buffer. Rainfall simulations were replicated five times per vegetation zone. The same general plot location was used in 2004 and 2005. The plots were rained on at an intensity of 72 mm h^{-1} with eight RainBird 8-VAN nozzles located along the perimeter of the rainfall simulator that were 2.43 m aboveground. The plots were constructed using steel borders that were inserted 6 cm deep to keep runoff contained within the plot.

Runoff was collected at the down-slope end of the plot where a V-shaped collector was placed above a collection trough to obtain cumulative runoff and interval runoff samples. The V-shaped collector was inserted carefully at the end of the plot to a depth at which level with the surface of the plot. Gaps present along this border were packed with soil excavated during the installation. Runoff from outside of the plot was directed to two additional troughs located on each side of the center trough. Steady state conditions were assumed when the amount of runoff was consistent for four consecutive minutes. Runoff samples were obtained twice before the establishment of steady state conditions, at the initiation of runoff and samples were then collected four times after steady state conditions had been established; sample were then collected Interval samples were obtained at the beginning of, and 3, 6, and 9 m after the establishment of steady state. The two samples taken before steady state were obtained for 90 s to large volume samples. The four samples taken after steady state were taken for a period of thirty seconds. If the container became full before 30 s, the exact amount of time required to fill the container was recorded.

Soil Samples

Prior to rainfall simulations one soil core per rainfall simulation measuring 1.9 cm (diameter) x 30 cm (length) was taken to determine antecedent soil moisture, post-rainfall soil moisture content, and soil bulk density. These samples were taken to adjacent to the plot and one post-rainfall moisture sample per rainfall simulation was taken within the plot. Additional soil cores one per rainfall simulation, measuring 76 mm in length x 72.5 mm in diameter were taken from within the plot after rainfall simulations to determine saturated hydraulic conductivity and bulk density. The soil cores were sealed and transported to the lab and stored at 4°C before measurements were conducted.

Laboratory Analyses

The small-diameter cores used to determine antecedent soil water content and bulk density were oven dried according to Topp and Ferre (2002). The large-diameter core for K_{sat} (saturated hydraulic conductivity) measurements were kept in sampling sleeves and covered with cheesecloth at the bottom. They were then saturated from below overnight in a pan of water. The falling head method was used to determine K_{sat} of the soil cores (Topp and Ferre 2002 Ch. 3.4).

The runoff samples were weighed to determine amount of runoff convert it to a volume. The amount of soil eroded was determined as described by Meyer (1960) in which sediment was allowed to settle and water siphoned off to a level that would avoid disturbing the sediment. The samples were then oven dried at 105°C until the weight of the sample was constant.

Statistical Analysis

The Proc Mixed procedure in SAS was used to analyze the infiltration, soil moisture, soil bulk density, runoff, and Ksat. This was due to the fixed effects presented by the arrangement of the riparian vegetation parallel with the headcut. The fixed effects of vegetation, year, and the year by vegetation were analyzed. Contrasts and the least square means between treatments were determined by utilizing Tukey's adjustment (SAS Institute, 1999). The K_{sat} data were log-normally distributed and therefore log-transformed for statistical analyses. All statistical differences were considered significant at $\alpha = 0.05$ level. Pairwise comparisons were made among all vegetated zones including crop, switchgrass, bromegrass, and cottonwoods.

RESULTS AND DISCUSSION

Infiltration & Runoff

The soil under the row crop system had a significantly lower infiltration rate and greater runoff than soil under cool-season grass ($P = 0.02$) and trees ($P= 0.01$) determined by pairwise contrasts (Table 1, Figs. 1 and 2). When both years were combined only the soil under the cool-season grass had a significantly greater ($P = 0.013$) infiltration rate than the row crop. Differences in infiltration were not significant in 2005. Recent tillage before soybean planting in 2005 on four of the five plots allowed for increased infiltration rates in the row crop. A significant year by vegetation interaction was observed for infiltration and runoff between the two years due tillage differences between the two years. The decrease in runoff for the cool-season grass and tree zones of the riparian buffer was only one-third that observed under corn in 2004 (Fig. 2).

Figures 3 and 9 show the cumulative runoff and infiltration plotted against time producing a family of infiltration curves for each vegetation zone. The difference in the infiltration rate and runoff rate can be clearly seen when comparing the curves from the row crop and cottonwood trees in 2004. The difference can be noted by the increase in time for the initiation of runoff and the time to steady state. Increased duration of rainfall simulations and time to the initiation of runoff for the vegetation zones of the multi-species riparian also shows the differences in infiltration observed between years (Appendix).

Table 1. Estimated difference between of the four vegetations.

Comparison	Infiltration Rate (cm/hr)	Runoff Rate (cm/hr)	Sediment Loss Rate (kg/ha/hr)	Antecedent Water Content	Bulk Density (g/cm3)	Ksat (cm/h)
2004						
CR - SWG	-0.78	0.78	82.12***	-1.96	-0.044	-3.10
CR - BG	-1.43*	1.43*	89.80***	1.69	0.014	-0.68
CR - CW	1.50*	1.50*	90.64***	-1.45	0.098*	0.28
SWG -BG	-0.65	0.65	7.68	3.65**	0.058	2.42
SWG - CW	-0.72	0.72	8.51	0.51	0.142***	3.38
BG - CW	-0.07	0.07	0.83	-3.14**	0.084*	0.96
2005						
CR - SWG	-0.38	0.38	66.88	0.42	0.036	
CR - BG	-0.23	0.23	63.43	1.30	0.104	
CR - CW	0.15	-0.15	66.34	-0.07	0.172	
SWG - BG	0.15	0.15	-3.45	0.88	0.068	
SWG - CW	0.53	0.53	-0.54	-0.49	0.136	
BG - CW	0.38	0.38	2.91	-1.37	0.068	
Years Combined						
YR 1 - YR 2	-0.60**	0. 60**	-5.38	0.57	0.019	
CR - SWG	-0.58	0.58	74.50**	-0.77	-0.004	
CR - BG	-0.83**	0.83*	76.62*	1.50	0.059	
CR - CW	-0.68	0.68	78.49**	-0.76	0.135**	
SWG - BG	-0.25	0.25	2.12	2.27*	0.063	
SWG - CW	-0.09	0.09	3.98	0.009	0.139**	
BG - CW	0.16	-0.16	1.87	-2.26*	0.076	
YR 1 CR - YR 2 CR	-1.41**	1.41**	-11.09	-0.27	-0.042	
YR 1 SWG-YR 2 SWG	-1.01	1.01	-4.15	2.10	0.038	
YR 1 BG - YR 2 BG	-0.21	0.21	-15.28	-0.66	0.048	
YR 1 CW - YR 2CW	0.24	-0.24	-13.20	1.11	0.032	

[a] Difference between treatments for the CR (Crop), SWG (Switchgrass), BG (Bromegrass), CW (Cottonwoods).

[b] *Significant differences occurring at the *0.05, **0.01, and ***0.001 probability levels.

[c] The mean of the second vegetation is subtracted from the mean of the first vegetation.

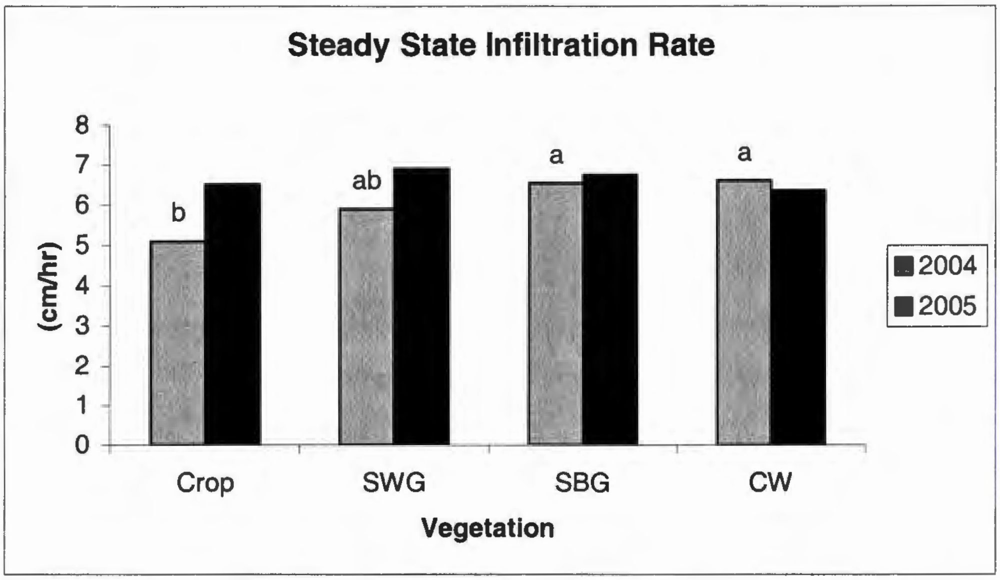

Figure 1. Average (n=5) steady state infiltration rate in 2004 and 2005 for the multi-species riparian buffer and row crop system. Columns followed by the same letter within a year are not significantly different at the p =0.05

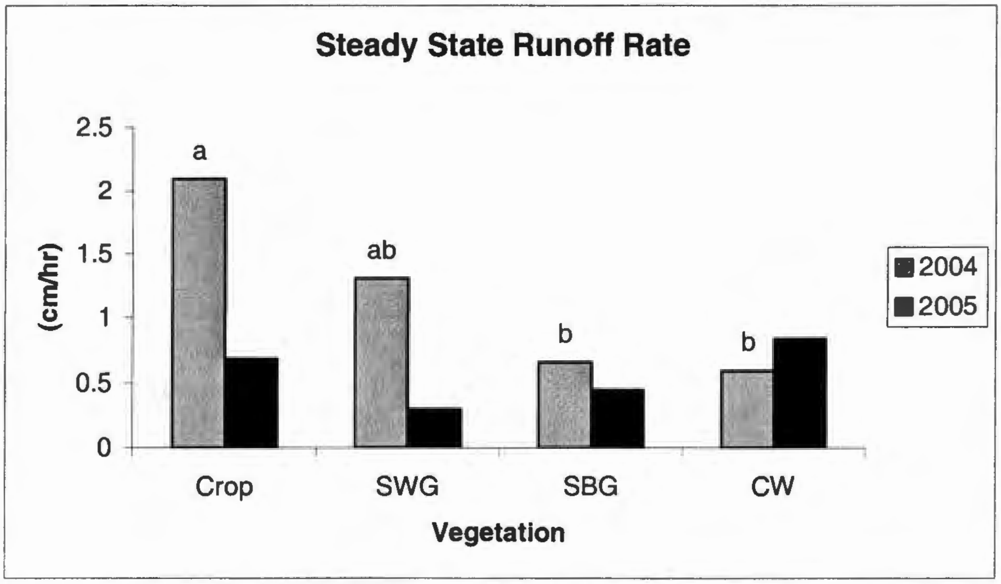

Figure 2. Average (n=5) steady state runoff rate in 2004 and 2005 for the multi-species riparian buffer and row crop system. Columns followed by the same letter within a year are not significantly different at the p =0.05

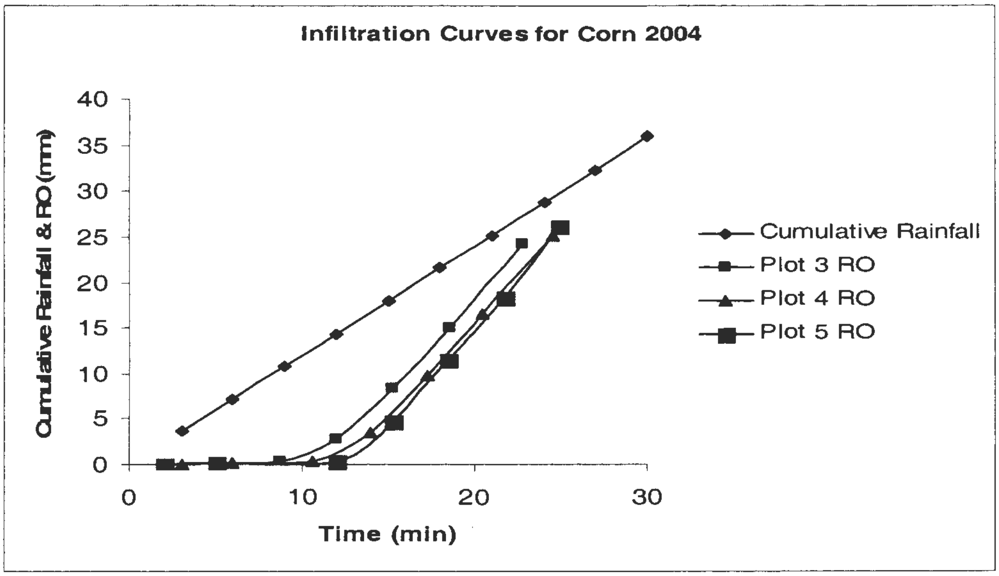

Figure 3. Infiltration curves for row crop plots 3, 4, and 5 in 2004

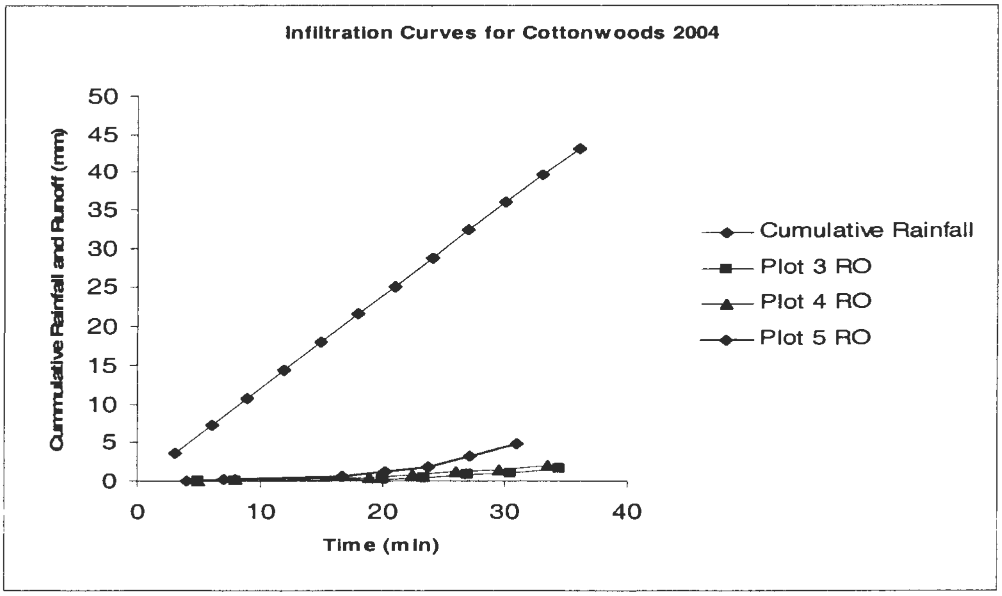

Figure 4. Infiltration curves for cottonwood plots 3, 4, and 5 in 2005.

The increase in the steady state infiltration rate and the reduction of runoff in the riparian buffer compared to the crop system was attributed to at least two factors. In 2004 corn was at the V2 stage and a surface residue of soybeans, which provided very little protection of the soil surface during the first year. The higher infiltration rates observed in the riparian buffer vegetations are mainly due to the high amounts of ground cover provided by the riparian buffer vegetations. In 2004 the exposed soil surface may have been susceptible surface sealing. Surface crusts restrict infiltration due to the negative potential at the crust-soil interface leading to wetting of the soil under conditions of low hydraulic conductivity and soil moisture diffusivity Philip (1998). Moore (1981) noted that surface sealing can decrease infiltration rates and volumes by as much as 80%.

Another reason could be a more continuous macropore system typically associated with soils under grass and trees that result from increased mesofauna and root activity associated with perennial vegetation. Soil systems under perennial vegetation usually exhibit improved structure, moisture retention capacity, and enhanced porosity. Meek et al., (1990) in a study of the infiltration rate as affected by an alfalfa and no-till cotton system found that the infiltration rates of the alfalfa were nearly double that of the no-till cotton system and he attributed this difference to flow that occurred through soil macropores. Broersma et al. (1995) also noticed higher infiltration rates associated with a continuous grass cover that consisted of bromegrass and he attributed the high infiltration rate to a stable surface horizon. In this present study the cottonwood trees displayed a high infiltration rate when compared to the crop system in 2004 and when both years were combined. This same result was also noticed by Wood (1977) in his study that compared the infiltration rates of soils under forest cover to those planted to sugarcane, pineapple, or used for pineapple. He noted that the forest soils were superior in water intake and accepted water faster due their greater porosity.

In 2005 there were no significant differences in the infiltration rate and runoff rate after establishment of steady state conditions (Table 1). This is due to tillage of the crop system, which consisted of planted planted soybeans with a corn residue cover. The tillage of the crop system provided small depressions in the soil surface, which allowed water to pond. Unger (1992) found that tillage usually initially increases infiltration by loosening surface crusts, disrupting soil layers, and providing surface depressions for the temporary storage of water. He also reported that tillage can result in later decreases in infiltration rates due to the presence of less stable soil aggregates.

Sediment Loss

In 2004 and for combined year, the soil under the row crop had a significantly higher sediment loss rate than for any of the riparian vegetations (Table 1, Fig. 5), but the differences were not significant in 2005 due to variability under soybean. In 2004, the sediment loss under corn was over five times that of any riparian vegetation (Fig. 5). Pairwise comparisons for 2004 showed the corn crop to lost significantly more sediment compared with warm-season grass ($P = 0.0005$), cool-season grass ($P = 0.0002$), and trees ($P = 0.0002$). The amount of sediment loss for same vegetation was consistent from year-to-year.

The primary reason for the reduction was the increased cover of the soil surface due the vegetation. The ability of riparian buffers to reduce soil erosion has been well documented. Young (1997) noted that trees and shrubs decrease soil erosion by increasing soil cover, providing permeable hedgerow barriers, and increasing the soil's resistance to erosion by maintaining the organic matter associated with the soil. The use of switchgrass as a means of reducing soil erosion has gained wide acceptance recently. Gilley et al., (2000) observed reductions in soil loss of 53%, 57%, and 63% when swithchgrass was used with corn residue and no-till, corn residue and tilled, and with corn residue removed, respectively, when compared to plots without the switchgrass hedges. Lee et al. (2003) noticed that a 7 m wide switchgrass buffer removed more than 92% of incoming sediment while a switchgrass/woody buffer removed more than 97% of sediment and attributed this reduction to have occurred due mainly to the switchgrass buffer.

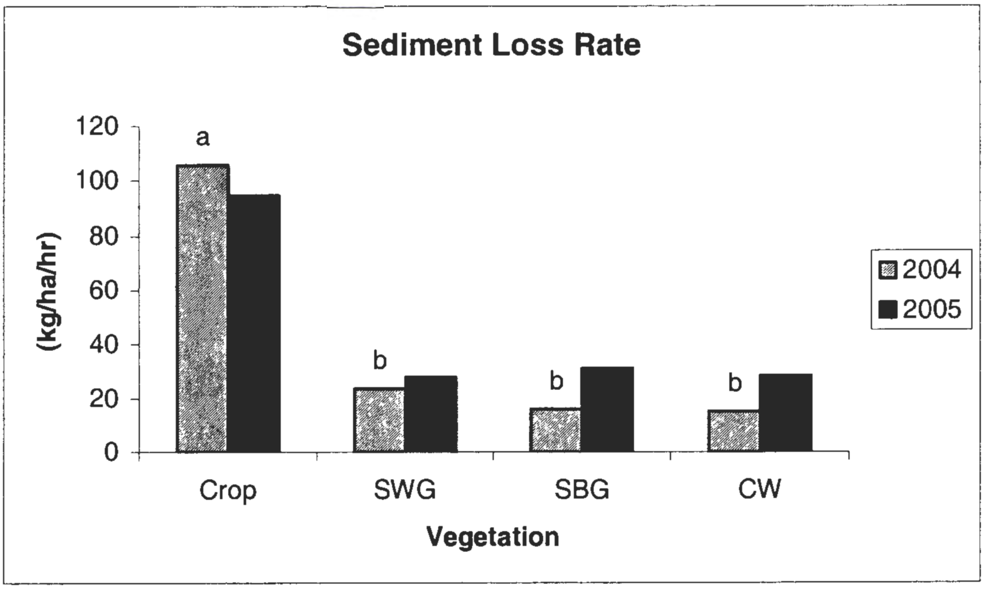

Figure 5. Average (n=5) steady state sediment loss rate in 2004 and 2005 for the multi-species riparian buffer and row crop system. Columns followed by the same letter within a year are not significantly different at the p =0.05

The bromegrass zone of the riparian buffer also effectively reduced soil loss when compared to the crop in 2004 and for the combined years. This reduction in soil loss occurred because bromegrass provided an adequate ground cover to reduce soil erosion, despite its lodging under flowing water. Smooth bromegrass has been found to aid in soil stabilization and increase soil structural stability to water (Carter et al., 1994). The trees provided the greatest reduction in soil loss due the ability of trees to positively influence soil structure (Wood, 1977; Young, 1997). The improved soil structure and water holding capacity typically associated with trees may have possibly reduced the soils erodibility by increasing the resistance of a soil aggregate to the forces of raindrop impact and overland flow, thus decreasing soil detachment (Truman et al., 1992).

Antecedent Surface Soil Moisture

The antecedent soil moisture was significantly different between vegetation zones (P =0.001) in 2004 and for the years combined (Table 1). The switchgrass was found to have the highest antecedent soil moisture (Figure 6). An interesting observation was the antecedent moisture of the cool season grass (bromegrass), which was the lowest. Pairwise contrasts were observed when the following vegetations were compared to the cool-season grass: warm-season grass (P = 0.001) and trees (P = 0.004). The antecedent soil moisture in 2005 was not significantly different (Table 1). The year by vegetation interaction proved that the antecedent soil moisture was practically the same from year to year for all vegetations.

The significant difference in antecedent soil moisture between vegetations found in 2004 and for combined years can be attributed to the high soil moisture exhibited by the switchgrass and cottonwood trees of the riparian buffer and the low soil moisture of the smooth bromegrass. They had higher soil moisture when compared to the other vegetation zones. The main reason for these differences can probably be attributed to differences in the seasonal water uptake associated with the vegetation zones of the riparian buffer. The optimum growth period for cool-season is the spring in which temperatures range 20°F - 25°F (Vogel et al., 1996). Young (1997) noted that trees help to improve the soil structure while enhancing the moisture holding capacity of the soil. He also noted that the canopy of the trees provide shade to the soil surface along with the leaf litter cover produced by trees which are very influential in reducing the soil surface temperature when compared to bare soils thus, reducing evaporation and increasing the soil moisture. The position of switchgrass in the riparian buffer, which allows it to be the first barrier to runoff and erosion could also be a reason for the high soil moisture found within this vegetation zone due to the high bulk densities from the accumulation of coarse particles. The low antecedent soil moisture displayed by the smooth bromegrass can also be attributed to the high number of shallow roots near the soil surface. Over 80% of the roots have been found to be in the top 0.3 m (Vogel et al., 1996). Switchgrass growth is slow in the spring which may explain the higher soil water content found beneath this vegetation. The landscape position of the cottonwoods also could be responsible for the higher soil moisture contents. Higher soil moisture contents are found at the foot and bottom of slopes as opposed to the top (Miyazaki, 1993).

Soil Bulk Density

In 2004 a significant difference ($P = 0.002$) was found to exist in soil bulk density between vegetation zones in 2004. Pairwise comparisons allowed for the contrasts of bulk density between vegetation. In 2005 there were no significant differences in soil bulk density

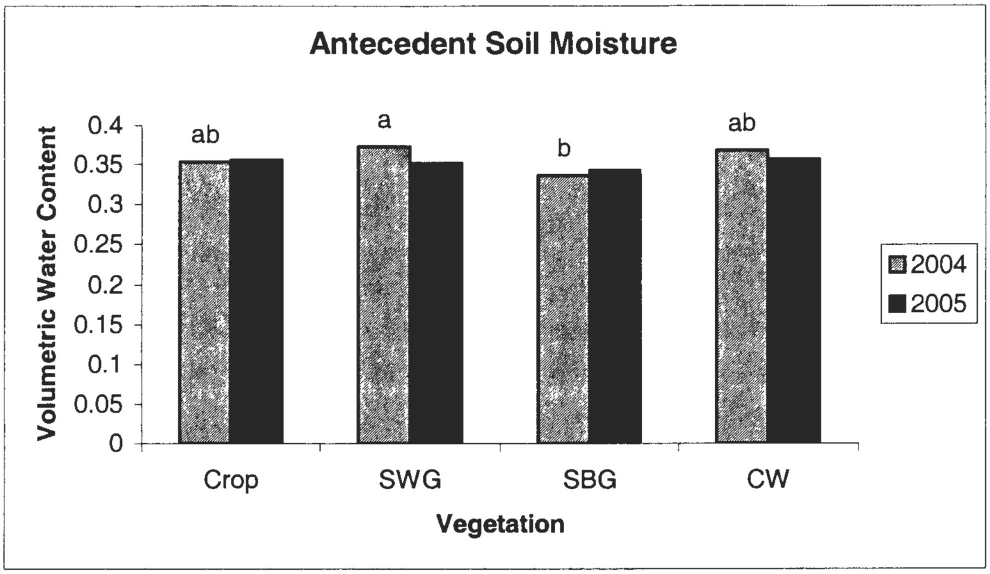

Figure 6. Average (n=5) antecedent surface soil moisture contents in 2004 and 2005 for the multi-species riparian buffer and row crop system. Columns followed by the same letter within a year are not significantly different at the p =0.05.

(Table 1). Pairwise comparisons to determine contrasts in soil bulk density between vegetation zones also yielded no significant results. For the combined years a significant difference was only found for the vegetation fixed effect (P = 0.001). The cottonwoods had significantly smaller soil bulk density when compared to switchgrass and the crop area (Table 1).

Others observed smaller bulk densities under riparian buffers and forest conditions compared to those under row crop systems (Bosch et al., 1994; Broersma et al., 1995; Jaiyeoba, 1995;). Jaiyeoba attributed the reduction in soil bulk density to an increase in soil microbial activity and porosity that is usually associated with forested conditions. A decrease in soil bulk density can be expected for soils under a riparian buffer due the penetration of roots and increased mesofauna activity. Bharati et al., (2002) noted that planting perennial vegetation on a previously cultivated field significantly reduced soil bulk density after six growing seasons. In this study the bulk density of the soil under switchgrass vegetation was not significantly different from that under the crop system for both years combined. The increased soil bulk density was probably due to the accumulation of coarse sediment particles at the soil surface since it is the first vegetation zone that runoff encounters.

Saturated Hydraulic Conductivity

The saturated hydraulic conductivity (K_{sat}) was not significantly different for core samples taken from the riparian and crop areas due to variability. The K_{sat} was greatest for switchgrass (Figure 6), almost triple that observed in the crop area. The increase in K_{sat} in the switchgrass could possibly be attributed to increases in pore size due to the presence of larger particles as a result of deposition from runoff. The high K_{sat} found in the switchgrass may also be due to the extension of pores formed from roots and worms extending to the end of the soil core (Rachman et al., 2004b). K_{sat} decreased as one would move further into the riparian buffer. The lowest K_{sat} value was observed in the cottonwood trees. It is thought the low K_{sat} values observed in the cottonwood trees might be due to the plugging of large pores with fine particles which did not deposit in the grass area of the buffer. Rachman et al., (2004b) found greater clay content in a row crop position than in grass hedges positioned upslope and attributed the increase to the passing of clay particles through the hedge during erosion. Other researchers have found the K_{sat} in forested areas to generally be greater when compared to a crop area.

CONCLUSION

The purpose of this study was to evaluate a 5 yr. old riparian buffer located in the loess hills region of Southwest Iowa and to test the hypothesis that the riparian vegetation will increase soil water infiltration, soil moisture, and reduce soil erosion and soil bulk density. Rainfall simulations were performed within 1.22 m x 2.44 m plots. The vegetation comparisons included a corn -soybean no-till rotation system, a riparian buffer, and the vegetation that composed the riparian buffer, which were trees (cottonwoods), cool season grass (smooth bromegrass), and warm season grass (switchgrass). Rainfall simulations were replicated five times per vegetation.

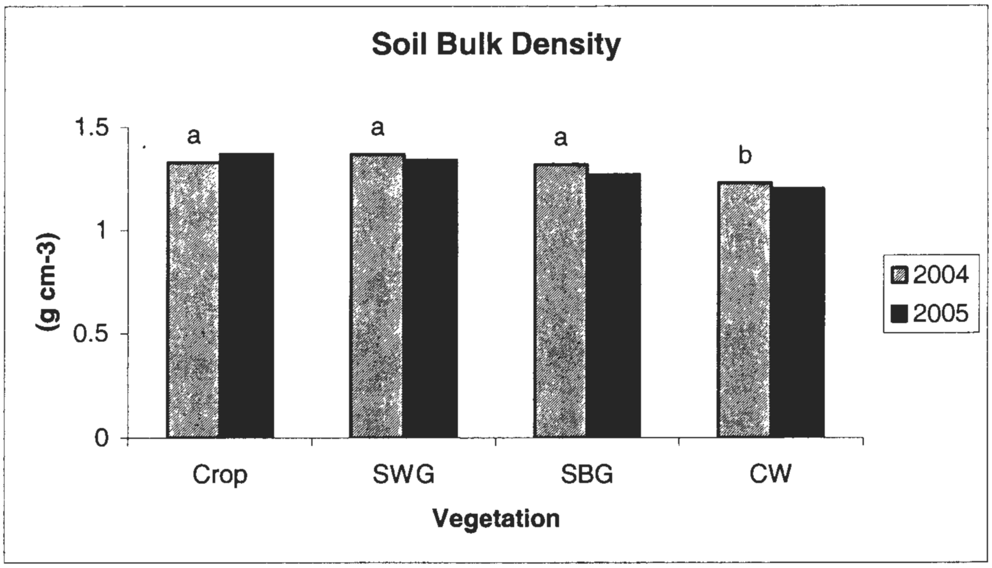

Figure 7. Average (n=5) soil bulk density in 2004 and 2005 for the multi-species riparian buffer and row crop system. Columns followed by the same letter within a year are not significantly different at the p =0.05

The no-till crop system constantly had less infiltration than the riparian buffer and the vegetation zones that composed the riparian buffer. The increased infiltration within the riparian buffer was attributed to an increase in ground cover, which prevented formation of a

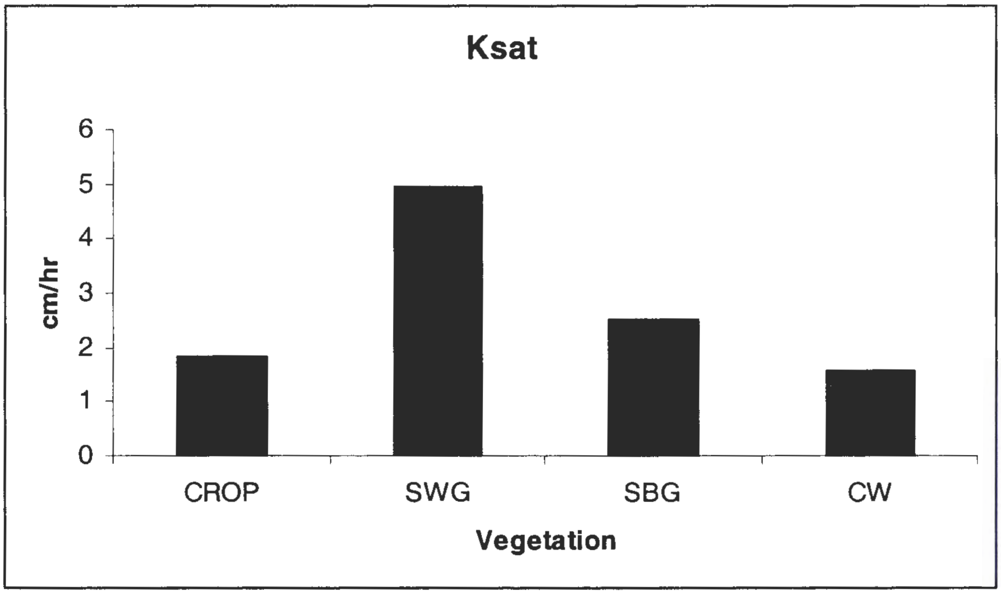

Figure 8. Average (n=5) K_{sat} in 2004 for the multi-species riparian buffer and row crop system.

surface seal, and increased porosity and macropores that generally enhance soil water infiltration. The soil moisture in the vegetation zones of the riparian buffer was also greater than that of the crop. The cottonwoods overall proved to be superior in soil moisture due to the effect the canopy of the trees have on the soil environment. The increase in ground cover that improved the infiltration of the riparian buffer compared to the crop system served as a means to reduce soil erosion. Overall soil erosion was reduced nearly 74% by the riparian buffer. The riparian buffer showed smaller soil bulk density but the only significant difference was between the cottonwoods and the crop. This decrease could possibly be due to increased microbial activity usually that is of soils under trees.

Soil properties such as bulk density and antecedent soil moisture affected infiltration, runoff, and sediment loss. Lower infiltration rates and high runoff and sediment loss rate were generally observed as the soil bulk density increased. The smaller bulk density observed in the riparian buffer resulted from better soil structure, which allowed for high infiltration rates and reduced runoff. Perhaps the most noticeable effect is that of the different vegetation zones. These results indicate the ability of a riparian buffer to positively influence soil physical properties and soil water infiltration of loess located in southwestern Iowa.

REFERENCES

Bettis, E.A. III. 2005. Gully erosion [Online]. Available at www.igsb.uiowa.edu/browse/gullyero/gullyero.html (verified 14 Apr. 2005). Iowa DNR Geological Survey, Iowa City, IA.

Bharati, L., K.H. Lee, T.M. Isenhart, and R.C. Schultz. 2002. Soil-water infiltration under crops, pasture, and established riparian buffer in Midwest USA. Agrofor. Syst. 56:249–257.

Bosch, D.D., R.K. Hubbard, L.T. West, and R.R. Lowrance. 1994. Subsurface flow patterns in a riparian buffer system. Trans. ASAE 37:1783-1790.

Broersma, K., J.A. Robertson, and D.S. Chanasyk. 1995. Effects of different cropping systems on soil water properties of a boralf soil. Commun. Soil. Sci. Plant Anal. 26:1795-1811.

Byars, B. W., P. M. Allen, and N. L. Bingham. 1996. A portable rainfall simulator for assessing infiltration. J. Soil Water Conserv. 51:508-511

Carter, M. R., D. A. Angers, and H. T. Kunelius. 1994. Soil Structural Form and Stability, and Organic Matter under Cool-Season Perennial Grasses. Soil Sci. Soc. Am. J. 58:1194-1199

Gilley, J.E., B. Eghball, L.A. Kramer, and T.B. Moorman. 2000. Narrow grass hedge effects on runoff and soil loss. J. Soil Water Conserv. 55:190–196.

Jaiyeoba I.A. 1995. Changes in soil properties related to different land uses in part of the Nigerian semi-arid savannah. Soil Use Manage. 11:84–89.

Kramer, L.A., M.R. Burkart, D.W. Meek, R.J. Jacquis, and D.E. James. 1999. Field-scale evaluations on deep loess soils: Hydrologic responses to different agricultural land management systems. J. Soil Water Conserv. 54:705-710.

Lee, K.H., T.M. Isenhart, and R.C. Schultz. 2003. Sediment and nutrient removal in and established multi-species riparian buffer. J. Soil Water Conser. 58:1- 9.

Meek, B.D., W.R. DeTar, D. Rolph, E.R. Rechel, and L.M. Carter. 1990. Infiltration rate as affected by an alfalfa and no-till cotton cropping system. Soil Sci. Soc. Am. J. 54:505–508.

Meyer, L.D. 1960. Use of the rainulator for runoff plot research. Soil Sci. Soc. Am. Proc. 24:319-322.

Miyazaki, T. 1993. Water flow in soils. Marcel Dekker, Inc., New York.

Moore, I.D. 1981. Effect of surface sealing on infiltration. Trans. ASAE:1546-1551

Mutel, C.F. 1989. Fragile giants: A natural history of the Loess Hills. 1st ed. University of Iowa Press, Iowa City, IA.

Palone, R.S., and A.H. Todd (ed.) 1997. Chesapeake Bay riparian handbook: A guide for establishing and maintaining riparian forest buffers. USDA For. Serv. NA-TP-02-97. USDA-FS, Radnor, PA.

Phillip, J.R. 1998. Infiltration into crusted soils. Water Resour. Res. 34:1919-1927.

Rachman, A., S.H. Anderson, C.J. Gantzer, and E.E. Alberts. 2004a. Soil hydraulic properties influenced by stiff-stemmed grass hedge systems. Soil Sci. Soc. Am. J. 68:1386–1393.

Rachman, A., S.H. Anderson, C.J. Gantzer, and A.L. Thompson. 2004b. Influence of stiff-stemmed grass hedge systems on infiltration. Soil Sci. Soc. Am. J. 68:2000-2006.

SAS Institute. 1999. SAS/STAT user's guide. SAS Inst., Cary, NC.

Topp, G.C. and P.A. Ferre. 2002.Water content. p. 417–547. *In* J.H. Dane and G.C. Topp (ed.) Methods of soil analysis.Part 4.Ch. 3.4 2nd ed. SSSA Book Series. 5. ASA and SSSA, Madison, WI.

Truman, C.C., J.M. Bradford, and J.E. Ferris. 1990. Antecedent water content and rainfall energy influence on soil aggregates breakdown. Soil Sci. Soc. Am. J. 54:1385–1392.

Unger, P.W. 1992. Infiltration of simulated rainfall: tillage system and crop residue effects. Soil Sci. Soc. Am. J. 56:283-289.

USGS. 1999. Geology of the loess hills, Iowa. [Online]. Available at www.pubs.usgs.gov/info/loess/ (verified 18 Aug. 2005). USGS, Washington, D.C.

Vogel, K.P., K.J. Moore, and L.E. Mosser. 1996. Bromegrass. p. 535-567. *In* L.E. Mosser, D.R. Buxton, and M.D. Casler (ed.) Cool-season forage grasses. ASA Monograph 34. ASA, Madison, WI.

Wigington, P. J., Jr., S. M. Griffith, J. A. Field, J. E. Baham, W. R. Horwath, J. Owen, J. H. Davis, S. C. Rain, and J. J. Steiner. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in Western Oregon. J. Environ. Qual. 32:162-170.

Wood, H.B. 1977. Hydrologic differences between selected forested and agricultural soils in Hawaii. Soil Sci. Soc. Am. J. 41:132-136.

Zaimes, G.N., R.C. Schultz, and T.M. Isenhart. 2004. Streambank erosion adjacent to riparian forest buffers, row-crop fields, and continuously-grazed pastures along Bear Creek in central Iowa. J. Soil Water Conserv. 59:19-28

GENERAL CONCLUSION

This study showed that the infiltration in no-till row crop system was significantly less when compared to the vegetation zones in a multi-species riparian buffer located in the loess hills of southwest Iowa when compared to the vegetation zones of a multi-species riparian buffer in 2004 and when infiltration results from 2004 and 2005 were combined. No differences in infiltration occurred in 2005 due to tillage that occurred on four of the five plots allowing greater infiltration in the row crop. The greater infiltration observed in the vegetation zones of the riparian buffer could be possibly attributed to the greater ground cover and the enhanced porosity found in these systems as a result of increased mesofauna activity.

The soil moisture in the vegetation zones except the cool season grass of the riparian buffer was also greater than that of the crop. The cottonwoods overall proved to display higher soil moisture due to the effect the canopy of the trees have on the soil environment. Differences in seasonal water uptake of the row crop and the vegetation zones of the riparian buffer possibly contributed to the differences in surface soil moisture.

Overall soil erosion was reduced nearly 74% by the riparian buffer. The riparian buffer showed smaller soil bulk density but the only significant difference was between the cottonwoods and the crop. This decrease could possibly be due to increased microbial activity that is typical of soils under trees. The high soil bulk density observed in the warm season vegetation zone of the riparian resulted from the possible contribution of coarse particles present due to deposition from runoff.

The results of soil properties such as bulk density and antecedent were found to affect infiltration, runoff, and soil loss. As soil bulk density increased low infiltration rates were observed. The result of these increases in bulk density were generally increases in runoff and sediment loss. The smaller bulk density found in the multi-species riparian buffer as a result of improved soil structure allowed for higher infiltration rates. The results of this study show the effect a five-year-old riparian has on the soil in the Loess Hills of southwest Iowa.

While these results display some positive benefits a riparian buffer has on a loess soil located in the southwest Iowa further study is needed at larger scales. As for this study future research involving determination of soil properties such as the pore size distribution, aggregate stability, particle size analysis, and the soil organic matter content associated with the vegetation zones found in the multi-species riparian buffer could serve as means for providing information relating to the increased infiltration rates found in the riparian buffer.

APPENDIX: RAW DATA

Summer 2004: Rainfall Simulation Data
PA1

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	05:00	20	05:23-05:53	99.09	14209.04	0.478	1.8	0.358	1.442	1.434	5.766
			08:23-08:53	162.82							
			11:53-11:23	298.52							
			15:23-15:53	328.1							
SWG	09:30	24:30	09:40-10:10	218.83	22960.92	0.772	1.8	0.473	1.327	1.891	5.309
			13:10-13:30	298.20							
			16:30-16:47	297.89							
			19:47-20:00	303.21							
SBG	23:00	38:00	23:00-23:21	302.06	34987.93	1.177	1.8	0.465	1.335	1.858	5.342
			26:21-26:35	294.24							
			29:35-29:46	303.73							
			32:46-32:54	301.02							
CW	19:43	34:43	19:43-20:13	249.29	12178.35	0.410	1.8	0.177	1.623	0.708	6.492
			23:13-23:43	249.29							
			26:43-27:13	259.30							
			30:13-30:43	263.99							

Summer 2005: Rainfall Simulation Data
PA1

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (cm:min)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	10:00	25:00	10:00-10:20	304.34	30546.31	1.027	1.8	0.616	1.184	2.466	4.734
			13:20-13:33	300.68							
			16:33-16:48	301.78							
			19:48-20:01	299.27							
SWG	14:30	29:30	14:30-15:00	85.24	4841.75	0.163	1.8	0.083	1.717	0.331	6.869
			18:00-18:30	86.87							
			21:30-22:00	92.87							
			25:00-25:30	104.66							
SBG	18:00	33:00	18:00-18:30	67.47	9984.89	0.336	1.8	0.153	1.647	0.611	6.589
			21:30-22:00	77.64							
			25:00-25:30	92.67							
			28:30-29:00	288.68							
CW	34:13	49:13	34:13-34:27	298.41	42727.02	1.437	1.8	0.439	1.361	1.755	5.445
			37:27-37:39	299.04							
			40:39-40:51	298.52							
			43:51-44:04	299.04							

Summer: 2004 Rainfall Simulation Data
PA2

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	05:05	20:05	05:15-05:33	304.46	27885.29	0.938	1.8	0.70	1.10	2.80	4.40
			08:33-08:48	303.11							
			11:48-11:58	304.88							
			14:58-15:08	304.88							
SWG	26:00	41:00	26:15-26:45	118.18	7254.09	0.244	1.8	0.09	1.71	0.36	6.84
			29:45-30:15	168.45							
			33:15-33:45	223.10							
			36:45-37:15	262.01							
SBG	26	41:00	26:00-29:30	24.72	4403.58	0.148	1.8	0.05	1.75	0.22	6.98
			29:30-30:00	33.90							
			33:00-33:30	34.42							
			36:30-37:00	43.81							
CW	29:20	44:20	29:40-30:10	244.07	23911.86	0.804	1.8	0.27	1.53	1.09	6.11
			33:10-33:30	299.35							
			36:30-36:47	300.50							
			39:47-40:02	301.65							

Summer: 2005 Rainfall Simulation Data
PA2

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	32:22	47:22	32:22-32:52	78.35	27885.29	0.938	1.8	0.70	1.10	2.80	4.40
			35:52-36:22	61.55							
			39:22-39:52	80.86							
			42:52-43:22	79.37							
SWG	19:06	34:06	19:06-19:36	43.04	2281.97	0.077	1.8	0.033	1.766	0.135	7.065
			22:36-23:06	53.27							
			26:06-26:36	50.30							
			29:36-29:06	67.23							
SBG	36:36	51:36	36:54-37:11	299.43	27299.72	0.918	1.8	0.271	1.529	1.085	6.115
			40:11-40:26	300.00							
			43:26-43:41	299.42							
			46:41-46:55	300.01							
CW	45:06	60:06	45:06-45:20	298.70	30060.77	1.011	1.8	0.253	1.547	1.012	6.188
			48:20-48:33	298.92							
			51:33-51:46	299.10							
			54:46-54:58	297.70							

Summer: 2004 Rainfall Simulation Data
PA3

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (cm:min)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	07:45	22:45	08:45-09:04	298.41	21546.46	0.725	1.8	0.478	1.322	1.911	5.289
			12:04-12:20	303.11							
			15:20-15:34	303.31							
			18:34-18:48	302.58							
SWG	12:30	27:30	13:00-13:30	205.69	10755.24	0.362	1.8	0.789	1.603	0.789	6.411
			16:30-17:00	243.55							
			20:00-20:30	272.44							
			23:30-24:00	275.99							
SBG	19:45	34:45	20:00-20:30	34.63	2768.94	0.093	1.8	0.040	1.760	0.161	7.039
			23:30-24:00	27.85							
			27:00-27:30	35.98							
			30:30-31:00	35.36							
CW	19:30	34:30	20:00-20:30	54.03	2768.94	0.119	1.8	0.052	1.748	0.206	6.994
			23:30-24:00	69.15							
			27:00-27:30	60.39							
			30:30-31:00	83.34							

Summer: 2005 Summer Infiltration Data
PA3

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	19:30	34:30	19:30-20:00	65.75	2643.06	0.089	1.8	0.039	1.761	0.155	7.045
			23:00-23:30	64.01							
			26:30-27:00	67.03							
			30:00-30:30	71.58							
SWG	19:00	34:00	19:00-19:30	54.68	2606.27	0.088	1.8	0.039	1.761	0.155	7.045
			22:30-23:00	50.24							
			26:00-26:30	55.93							
			29:30-30:00	59.64							
SBG	34:30	49:30	34:30-35:00	28.04	4350.28	0.146	1.8	0.044	1.756	0.177	7.023
			38:00-38:30	31.12							
			41:30-42:00	36.33							
			45:00-45:30	29.59							
CW	26:30	41:30	26:30-27:00	34.58	2276.98	0.077	1.8	0.028	1.772	0.111	7.089
			30:00-30:30	38.41							
			33:30-34:00	41.73							
			37:00-37:30	40.67							

Summer: 2004 Rainfall Simulation Data
PA4

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	9:30	24:30	10:40-11:00	303.31	24659.71	0.829	1.8	0.508	1.292	2.031	5.169
			14:00-14:14	303.21							
			17:14-17:27	304.25							
			20:27-20:40	302.79							
SWG	13:20	28:20	13:45-14:01	302.27	30455.74	1.024	1.8	0.539	1.261	2.157	5.043
			17:01-17:14	303.31							
			20:14-20:27	301.96							
			23:27-23:40	301.96							
SBG	10:40	25:40	11:45-12:15	109.41	8201.06	0.276	1.8	0.161	1.639	0.645	6.555
			15:15-15:45	216.74							
			18:45-19:15	237.39							
			22:15-22:45	122.56							
CW	18:25	33:25	19:00-19:30	77.60	3987.73	0.134	1.8	0.060	1.740	0.241	6.959
			22:30-23:00	76.77							
			26:00-26:30	72.80							
			29:30-30:00	85.84							

Summer: 2005 Rainfall Simulation Data
PA4

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	22:11	37:11	22:11-22:41	91.52	5131.23	0.173	1.8	0.070	1.730	0.279	6.921
			25:41-26:11	91.16							
			29:11-29:41	99.19							
			32:41-33:11	87.36							
SWG	13:00	28:00	13:00-13:30	124.27	6825.04	0.230	1.8	0.123	1.677	0.492	6.708
			16:30-17:00	133.41							
			20:00-20:30	155.49							
			23:30-24:00	157.68							
SBG	31:16	46:16	31:16-31:46	45.63	3477.00	0.117	1.8	0.038	1.762	0.152	7.048
			34:46-35:16	57.75							
			38:16-38:46	74.58							
			41:46-42:16	96.76							
CW	23:04	38:04	23:04-23:34	60.54	2826.90	0.095	1.8	0.037	1.763	0.150	7.050
			26:34-27:04	56.99							
			30:04-30:34	66.23							
			33:34-34:04	63.15							

Summer: 2004 Rainfall Simulation Data
PA5

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	9:50	24:50	12:00-12:17	303.52	28591.63	0.962	1.8	0.581	1.219	2.324	4.876
			15:17-15:30	304.88							
			18:30-18:43	303.63							
			21:43-21:55	305.71							
SWG	11:37	26:37	12:20-12:47	303.84	18505.92	0.622	1.8	0.351	1.449	1.403	5.797
			15:48-16:12	303.31							
			19:12-19:40	302.69							
			22:40-23:06	304.04							
SBG	14:30	29:30	15:25-15:55	142.27	6414.76	0.216	1.8	0.110	1.690	0.439	6.761
			18:55-19:25	135.59							
			22:25-22:55	115.36							
			25:55-26:25	112.44							
CW	15:55	30:55	16:40-17:10	118.70	11249.12	0.378	1.8	0.184	1.616	0.734	6.466
			20:10-20:40	140.50							
			23:40-24:10	299.45							
			27:10-27:40	304.25							

Summer: 2005 Summer Infiltration Data
PA5

Vegetation	Steady State Time (min:sec)	Total Time of Rainfall Simulation (min:sec)	Runoff Interval Sample Time (min:sec)	RO Interval Sample (cm^3)	Total RO During Simulation (cm^3)	Total RO (cm)	Total Rain After SS (cm) in 15 min	Total RO after SS (cm) in 15 min	Total Inf. After SS (cm) in 15 min	Total RO after SS (cm/hr)	Total Inf. After SS (cm/hr)
Crop	24:30	39:30	24:30-25:00	122.10	6186.69	0.208	1.8	0.079	1.721	0.316	6.884
			28:00-28:30	99.59							
			31:30-32:00	143.15							
			35:00-35:30	94.56							
SWG	13:15	28:15	13:15-13:45	119.11	5564.26	0.187	1.8	0.099	1.701	0.398	6.802
			16:45-17:15	103.72							
			20:15-20:45	120.22							
			23:45-24:15	116.02							
SBG	18:00	33:00	18:00-18:30	81.43	4206.24	0.141	1.8	0.064	1.736	0.257	6.943
			21:30-22:00	73.73							
			25:00-25:30	75.78							
			28:30-29:00	77.84							
CW	26:00	41:00	26:00-26:19	299.74	23498.30	0.790	1.8	0.289	1.511	1.157	6.043
			29:19-29:37	300.19							
			32:37-32:54	300.70							
			35:54-36:09	300.81							

SUMMER 2004
Soil Moisture, Bulk Density , & Saturated Hydraulic Conductivity

		Antecendent Water Content (cm^3/cm^3)	Post-Rainfall Water Content (cm^3/cm^3)	Soil Bulk Density (g/cm^3)	Ksat (cm/h)
PA1					
	Crop	.3582	.4048	1.24	1.71
	SWG	.3901	.4233	1.38	2.17
	SBG	.3647	.4342	1.38	0.44
	CW	.3810	.3901	1.22	0.067
PA2					
	Crop	.3592	.3875	1.33	0.047
	SWG	.3753	.4364	1.42	17.70
	SBG	.3400	.4045	1.28	0.758
	CW	.3443	.4209	1.24	6.813
PA3					
	Crop	.3593	.3691	1.37	2.03
	SWG	.3849	.4175	1.36	4.84
	SBG	.3477	.3850	1.33	9.96
	CW	.3875	.4109	1.24	0.11
PA4					
	Crop	.3382	.3903	1.35	0.026
	SWG	.3557	.3952	1.37	0.0014
	SBG	.3219	.3699	1.29	0.064
	CW	.3581	.3839	1.2	0.825
PA5					
	Crop	.3520	.3540	1.36	5.41
	SWG	.3588	.3958	1.34	0.029
	SBG	.3079	.2646	1.3	1.406
	CW	.3685	.4000	1.26	0.003

SUMMER 2005
Soil Moisture, Bulk Density , & Saturated Hydraulic Conductivity

		Antecendent Water Content (cm^3/cm^3)	Post-Rainfall Water Content (cm^3/cm^3)	Soil Bulk Density (g/cm^3)
PA1				
	Crop	.3633	.3958	1.36
	SWG	.3570	.4051	1.37
	SBG	.3880	.4429	1.27
	CW	.3942	.4291	1.19
PA2				
	Crop	.3524	.3977	1.35
	SWG	.3447	.3906	1.35
	SBG	.2906	.3995	1.02
	CW	.3659	.3807	1.24
PA3				
	Crop	.3602	.4083	1.4
	SWG	.3844	.4267	1.34
	SBG	.3592	.3715	1.33
	CW	.3910	.4363	1.22
PA4				
	Crop	.3698	.4071	1.33
	SWG	.3256	.3760	1.32
	SBG	.3577	.3843	1.39
	CW	.3206	.3206	0.99
PA5				
	Crop	.3346	.4213	1.42
	SWG	.3478	.3965	1.3
	SBG	.3198	.3147	1.33
	CW	.3123	.3761	1.36

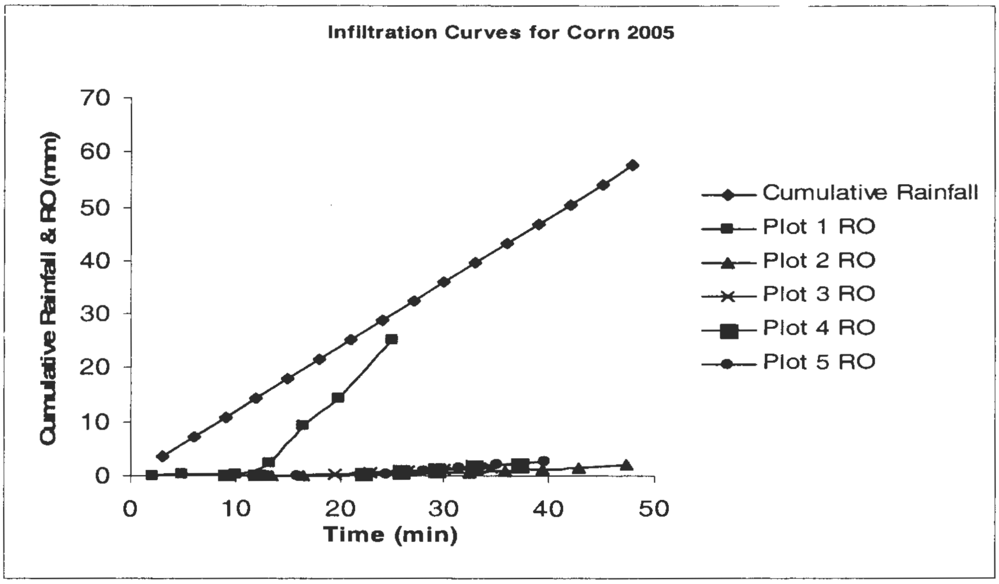

Figure 9. Infiltration curves for row crop plots 1-5 in 2005.

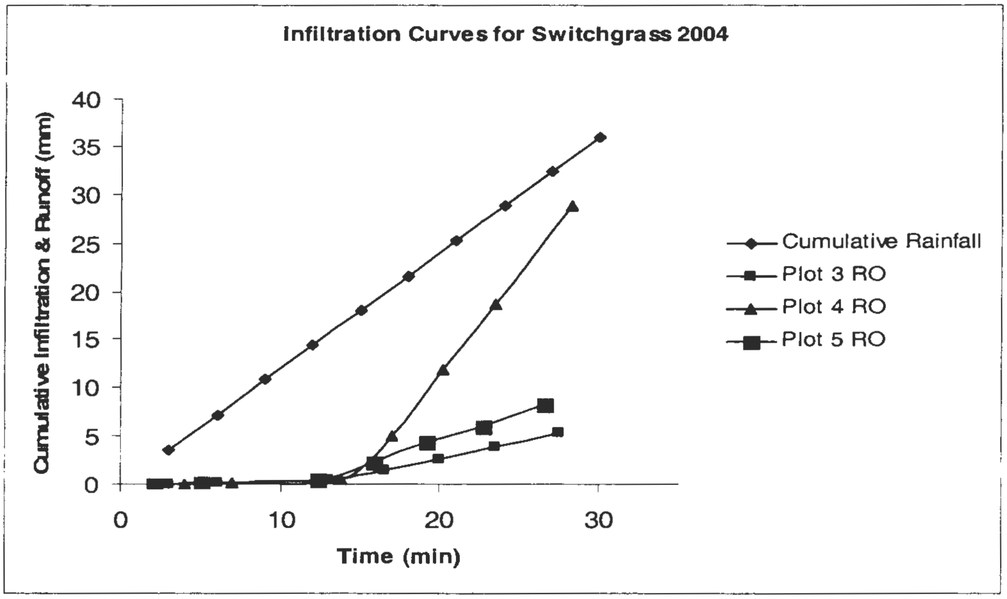

Figure 10. Infiltration curves for switchgrass plots 3, 4, and 5 in 2004.

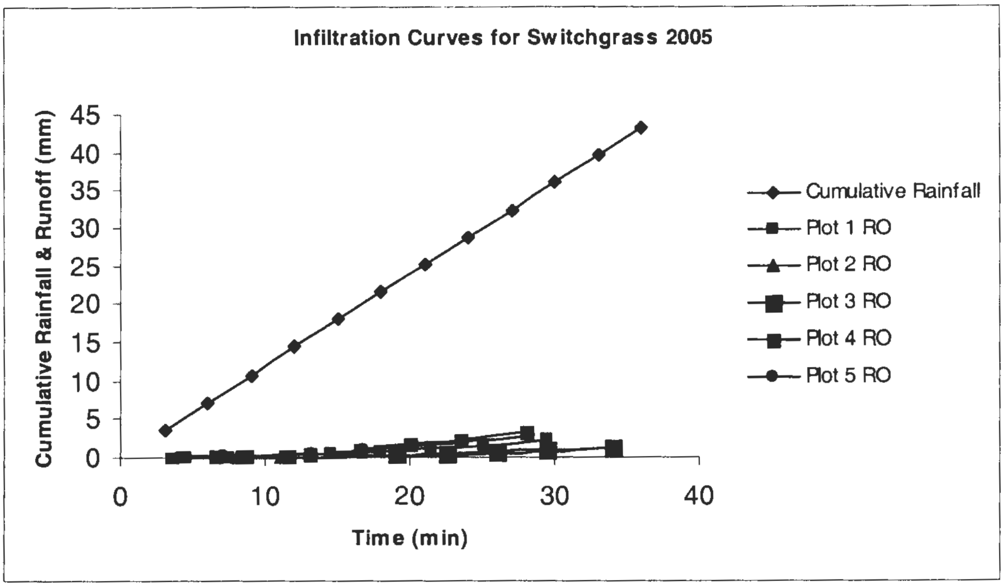

Figure 11. Infiltration curves for switchgrass plots 1-5 in 2005.

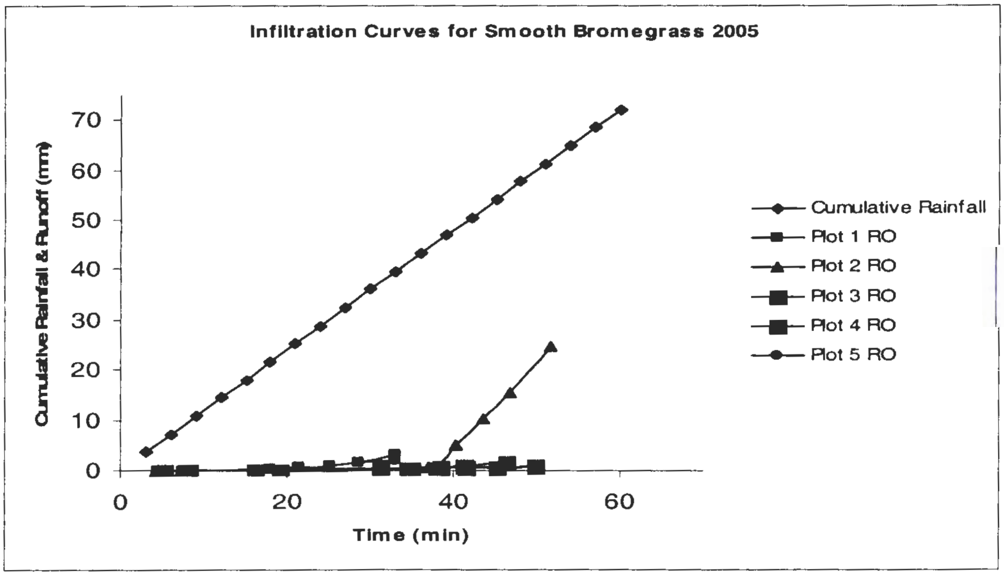

Figure 12. Infiltration curves for smooth bromegrass plots 3, 4, and 5 in 2004.

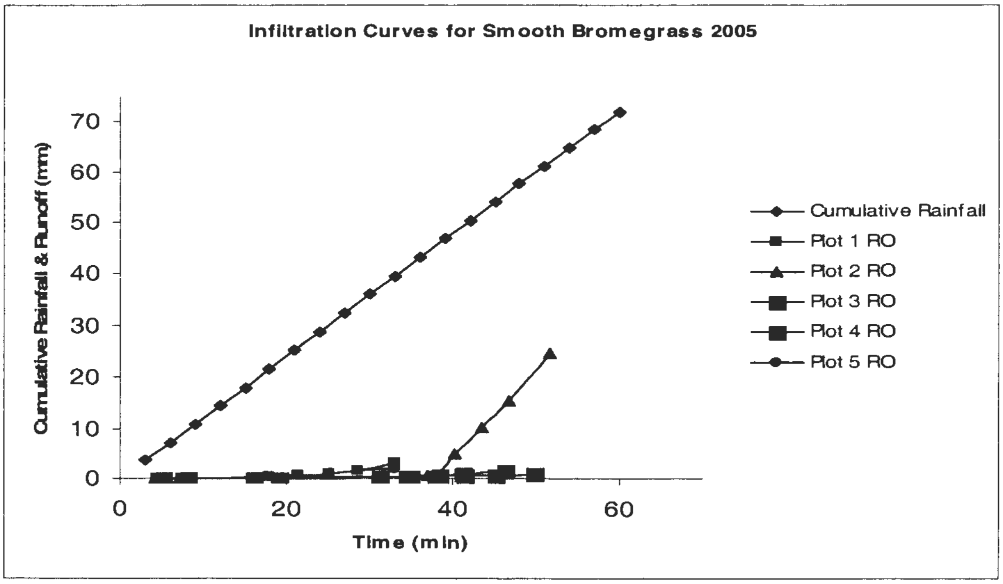

Figure 13. Infiltration curves for smooth bromegrass plots 1-5 in 2005.

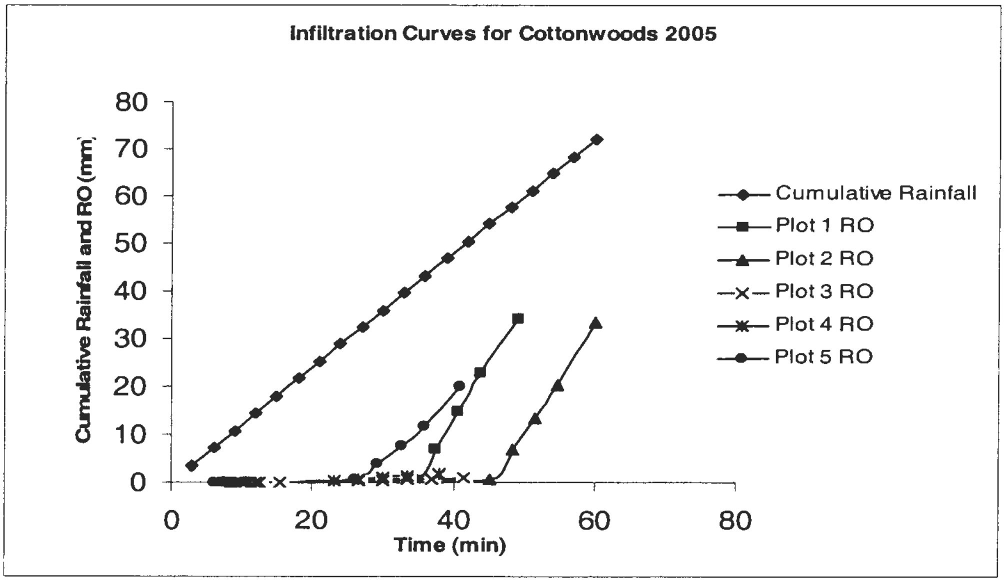

Figure 14. Infiltration curves for cottonwood plots 1-5 in 2005.

ACKNOWLEDGEMENTS

I would like to thank the following people who have contributed to the completion of this thesis:

- Sally Logsdon for accepting me as a graduate student and being a wonderful major professor. Whenever I had a question you always made yourself available to answer it and I greatly appreciate it along with your never-ending encouragement.
- Gavin Simmons for your help in the field and the lab. You were someone that I could talk with about anything and your spiritual support is greatly appreciated.
- Robert Horton for serving on my committee and being someone that I could talk with.
- Mark Tomer, for so graciously agreeing to serve as a committee member at the last minute.
- Aaron Jeffries, Carasella Nance, and Shelly Moeller for your encouragement.
- My parents and siblings who have always been supportive of everything that I have done in life.
- Jesus for allowing me not to give up and to appreciate the present moment by taking it one day at a time.