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Variation in infiltration with landscape position: Implications for forest productivity and surface water quality

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Abstract

Variation of infiltration rates with landscape position influences the amount, distribution, and routing of overland flow. Knowledge of runoff patterns gives land managers the opportunity to affect changes that optimize water use efficiency and reduce the risk of water quality impacts. The objective of this study was to assess the effect of landscape position and associated soil properties on infiltration in a small (147 ha) forest/pasture watershed in the Ozark Highlands. Three previously reported studies measured infiltration rates using double ring, sprinkling, single ring, and tension infiltrometers on soils at varying landscape positions. Although large variation in infiltration rates was observed among measurement techniques, upland and side slope soils (Nixa and Clarksville) had consistently lower infiltration rates compared to the soil in the valley bottom (Razort). A conceptual understanding of watershed runoff is developed from these data that includes infiltration excess runoff from the Nixa and Clarksville soils and saturation excess runoff on the Razort soil. Management of the soil water regime based on this understanding would focus on increasing infiltration in upland soils and maintaining the Razort soil areas in forest. Forest productivity would be enhanced by increasing plant-available water in upland soils and decreasing flooding on the Razort soil. Surface water quality would be improved by reducing the transport of potential water contaminants from animal manure applied to upland pastures.

Keywords: Infiltration; Landscape position; Soil properties

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1. Introduction

Characterization of the spatial relationships of surface runoff generation has been an active area of research for several decades (Betson and Marius, 1969; Dunne and Black, 1970; Anderson and Burt, 1978; Bernier, 1985). Locations within watersheds with differing infiltration characteristics have been referred to as variable-source areas, partial area contributions, or hydrologically-active areas, all of which refer to the nonuniform occurrence of surface runoff in response to precipitation. Often, the distinction is made between areas where runoff is generated when precipitation occurs at a rate greater than the soil's infiltration rate

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(infiltration excess runoff) and areas where runoff occurs because the soil is saturated to the surface (saturation excess runoff). Spatial variation of surface soil hydraulic properties therefore influences the amount and distribution of infiltration and the routing of overland flow following precipitation events.

Nonuniform infiltration within a watershed leads to differences in plant-available water stored in the root zone and influences the partitioning between evaporation from the soil and plant transpiration (Luxmoore and Sharma, 1980; Luxmoore, 1983; Kachanoski and De Jong, 1988; Grayson et al., 1997). In addition to fiber production, forested watersheds provide several important ecosystem functions including the production of clean water suitable for municipal, industrial, and agricultural uses. Water moving through the root zone or across the soil surface also transports sediment, nutrients, pesticides, and pathogens that may be delivered in quantities that impair ground or surface waters. Understanding the spatial variation of infiltration within watersheds is therefore critical to developing and implementing management practices that optimize plant-available water and minimize nonpoint source pollution (Or and Hanks, 1992; Gburek and Sharpley, 1998; Walter et al., 2000).

There has been a dramatic expansion of poultry and livestock production into nontraditional animal-producing regions of the U.S., in particular, the Mid-South and Southeast. Many of the new production facilities are located in areas with soils that were never cultivated or cultivation ceased due to excessive erosion and/or low productivity. A large percentage of land in these areas is now a mosaic of pasture and forest, which is managed for livestock grazing and pulp or timber production. Manure generated by the animal feeding operations is typically disposed by land-application, primarily to pasture (McLeod and Hegg, 1984; King et al., 1990; Liu et al., 1997) and to a much lesser extent, forest land (Minkara et al., 1995; Samuelson et al., 1999; Sauer et al., 2000).

The Savoy Experimental Watershed (SEW) is a field research site for the study of water quality impacts from land application of animal manure in landscapes typical of the Mid-South U.S. The SEW is located in Northwestern Arkansas and is comprised of six small watersheds within and surrounding the 1250 ha Savoy Substation of the University of Arkansas. Intensive hydrologic investigations in the SEW have focused on Basin 1, a 147 ha watershed with an ephemeral channel that discharges onto the Illinois River floodplain. A distinctive characteristic of Basin 1 hydrology is that there is often no surface discharge at the outlet following intense storm events. This occurs even though discharge from adjacent springs increases significantly and debris trails (leaves and branches) on the forested side slopes indicate that surface runoff had occurred within the watershed.

Three previously published studies have addressed various features and scales of interaction between the surface hydrology and surface soil properties of Basin 1 (Table 1). The first study involved measurements of soil physical, chemical and hydraulic properties along transects located in soil map units between the riparian forest adjacent to the Illinois River and the ridge top on the north side of Basin 1 (Sauer et al., 1998). The second study utilized simulated rainfall on pairs of 1 m × 2 m runoff plots at varying slopes and aspects, on pasture and forest sites within Basin 1 to determine nutrient runoff from applied poultry litter (Sauer et al., 2000). The third study used ring and tension infiltrometers to measure saturated and unsaturated hydraulic properties of soils in varying landscape positions on three transects across Basin 1 (Sauer and Logsdon, 2002).

Taken independently, none of the three studies provided a comprehensible representation of infiltration patterns in the watershed or of any consistent relationship between infiltration rate and soil properties. As animal production and human population both continue to increase rapidly in Northwestern

Table 1
Summary of infiltration data collected on soils of Basin 1

Infiltrometer type	Soils	No. of measurements	Area of measurement	Measurement site distribution	Reference
Double ring	Rg, CaC, and NaC	60	0.07 m^2	Transects within soil map units	Sauer et al. (1998)
Sprinkling	ClG and NaC	32	2 m^2	Paired plots	Sauer et al. (2000)
Single ring	Rg, ClG, and NaC	42	44.2 cm^2	Transects across main channel	Sauer and Logsdon (2002)

Arkansas, effective land development and management strategies are needed to sustain existing forest productivity and to protect regional water resources. The objective of this paper is to synthesize infiltration and supporting ancillary soils data from three studies into a unifying, conceptual understanding of runoff dynamics for a small watershed in the mantled karst terrain of Northwestern Arkansas. Potential to enact management practices that would enhance infiltration, improve timber production, as well as reduce nonpoint source pollution, are also be proposed.

2. Materials and methods

2.1. Field site

The SEW lies within the Springfield Plateau of the Ozark Highlands (36–38°N, 91–95°W) where the landscape is characterized by steep-sided valleys cut into the highly dissected plateau. Mississippian-age sedimentary deposits including the St. Joe formation, which is a thin-bedded limestone formation, dominate the regional geology. The land surface is a mantled karst terrain, with stony soils over fractured bedrock, including caves and springs associated with the St. Joe formation. Land use is determined by the topography, with the steep side slopes and narrow ridge tops in hardwood forest, and the broader ridge tops and valley bottoms in permanent pasture. Basin 1 is located adjacent to the Illinois River near the town of Savoy, Arkansas (36°7′N, 94°21′W, Fig. 1). Elevation in Basin 1 ranges from 317 m at the outlet to 376 m on the eastern boundary of the watershed.

Land use within Basin 1 is typical of the Springfield Plateau with 57% of the area in hardwood forest and 43% of the area in pasture. The forested areas are composed of an uneven-aged oak-hickory stand with *Quercus alba*, *Q. velutina*, *Q. falcata*, and *Carya cordiformis* the dominant species. Marketable timber was harvested from the watershed in the early 1950s. There have been no thinning or timber stand improvement activities on the site since the timber harvest. The current stand is fully-stocked with a stand height of 15–25 m, average stem count (>5 cm) of 783 ha^{-1}, average dbh of 20.6 cm, and basal area of 8.79 m^2.

Tall fescue (*Festuca arundinacea* Schreb.) and bermudagrass (*Cynodon dactylon* (L.) Pers.) are the primary forage species in the pasture areas of Basin 1. Pastured areas of the watershed were cultivated until the 1930s when the property came under control of the U.S. Forest Service. Many of the fields had been severely eroded, thus the Forest Service converted the fields to pasture and managed the area for grazing until sale of the property to the University of Arkansas in 1952. Since that time, all areas of the watershed including the forest have been used for grazing by beef cattle.

Major upland soils in the SEW include the Clarksville cherty silt loam (loamy-skeletal, siliceous, semiactive, mesic Typic Paleudults) and Nixa cherty silt loam (loamy-skeletal, siliceous, active, mesic, Ochreptic Fragiudults), which comprise 49 and 30%, respectively, of the Basin 1 area. These soils formed from cherty limestone residuum and have sufficient amounts of rock fragments to warrant the family particle size class ‘‘skeletal’’. The soil in the valley bottom is the Razort gravelly silt loam (fine-loamy, mixed, active, mesic Mollic Hapludalfs), which formed in alluvial deposits. Basin 1 also includes small areas of Captina silt loam (fine-silty siliceous, active, mesic Typic Fragiudults) and Pickwick silt loam (fine-silty, mixed semiactive, thermic Typic Paleudults) formed on alluvial terraces, and the Waben (formerly Guin) cherty silt loam (sandy-skeletal siliceous, mesic Ultic Hapludalfs) formed from colluvium at foot slope positions.

2.2. Infiltration measurements

Double ring infiltrometer measurements were made at 20 locations at 3 m intervals in each of Razort, Captina, and Nixa soil map units during the summer of 1997 (Sauer et al., 1998, Fig. 1). The inner and outer rings of the infiltrometers had diameters of 0.3 and 0.45 m and the ponding depth was 0.05 m. Measurements were made until steady-state flow rates were attained, a minimum of 1.5 h. Sprinkling infiltrometer measurements were made on 16 pairs of 1 m × 2 m plots on Nixa and Clarksville soils in July 1998 (Sauer et al., 2000, Fig. 1). Simulated rainfall was applied for 1 h at a 75 mm h^{-1} intensity (25 year return interval) with a two-nozzle simulator based on the design of Miller (1987). Runoff was collected from troughs on the downslope side of the plots with a vacuum system that continuously

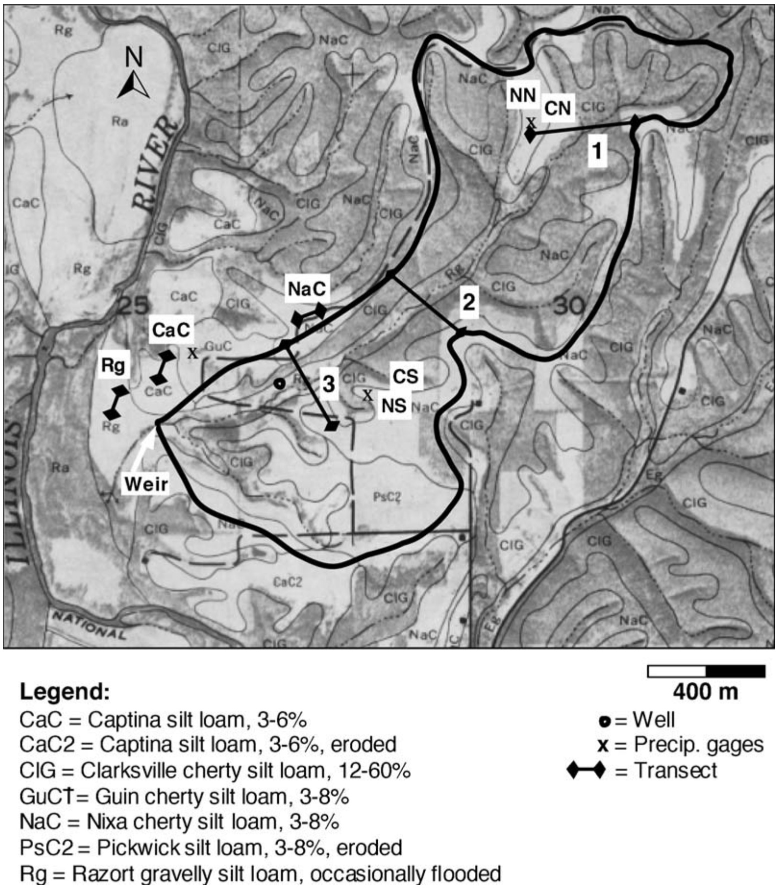

Fig. 1. Soil map of Basin 1 and vicinity including location of weir at basin outlet and location of groundwater monitoring well (Harper et al., 1969). Labels Rg, CaC, and NaC refer to double ring infiltrometer sites of Sauer et al. (1998). Labels NN (Nixa North), CN (Clarksville North), NS (Nixa South), and CS (Clarksville South) refer to sprinkling infiltrometer sites of Sauer et al. (2000). Labels 1, 2, and 3 refer to single ring/tension infiltrometer transects of Sauer and Logsdon (2002).

recorded runoff volume. Infiltration rates were calculated from the runoff rate at the end of each simulation. Single ring and tension infiltrometer measurements were made in August of 1998 at 42 locations on each of three transects across the main drainage channel (Sauer and Logsdon, 2002, Fig. 1). Three measurement sites were identified within each soil map unit (Nixa, Clarksville, and Razort soils) on each side of the main drainage channel except transect 1 where three measurement sites were located on each side of the channel within the Clarksville soil map unit. A 0.075 m diameter ring was pressed into the soil to measure ponded infiltration rate under 0.01 m of head. Infiltration was manually recorded until steady-state conditions were established. Infiltration rate at −0.03, −0.06, and −0.12 m pressure head was measured at all single ring infiltrometer sites using tension infiltrometers with 0.076 m-diameter bases (Ankeny et al., 1988). Rock fragment content, soil texture, and bulk density were determined from soil samples collected at each of the double ring (0.076 m-diameter by 0.10 m-deep cores) and single ring/tension infiltrometer measurement sites (0.15 m-diameter by 0.05 m-deep excavations). Soil water retention characteristics from 0 to 0.4 m of tension were measured on the fine earth fraction from all single ring/tension infiltrometer sites.

One-way analysis of variance (ANOVA) and Fisher's least significant difference test (FLSD) at $P = 0.05$ were used to determine statistically significant differences among measured parameters. Statistical comparisons were made among data in various groupings including by soil type, surface cover (forest versus pasture), aspect, and transect.

2.3. Additional hydrologic measurements

Precipitation in Basin 1 was monitored with three tipping bucket gages (Model 529, Texas Electronics Inc.,[1] Dallas, TX) located in pasture areas of the watershed. A v-notch weir was installed in 1998 at the watershed outlet to measure basin discharge. Water level at the weir was measured with a pressure transducer (Model 169, Keller America, Inc., Newport News, VA) mounted in a stilling well at the base of the weir. Several groundwater monitoring wells were installed in Basin 1 beginning in 1998. These wells were located at various landscape positions and typically extended to bedrock. One 0.15 m-diameter well was located approximately 450 m up gradient from the runoff weir at the toe slope near the Clarksville/Razort soil map unit boundary (Fig. 1). A pressure transducer (Model PS9105, Instrumentation Northwest, Inc., Kirkland, WA) was installed in this well to monitor changes in shallow groundwater elevation. All sensors signals were recorded on dataloggers (CR10, Campbell Scientific Inc., Logan, UT).

3. Results

The double ring infiltrometer data indicate a small decrease in infiltration rate from 26.0 mm h^{-1} for the Razort soil in the valley to 20.4 mm h^{-1} for the Nixa soil on the ridge top (Fig. 2). There were no statistically significant differences among soils due to the large variation in infiltration rate within transects. Efforts to relate the measured infiltration rates to soil properties including bulk density, coarse fragment, sand, silt, or clay content, however, failed to produce any strong relationships (maximum $R^2 = 0.18$). The double ring infiltrometer technique has several shortcomings, including an unnaturally high ponding depth, relatively small measurement area, and inability to make measurements on slopes. The sprinkling infiltrometer overcomes each of these limitations as it approximates natural rainfall over a larger area and is feasible on steep slopes. Four plots for the sprinkling infiltrometer measurements at each location were intended to capture the effects of varying slope, aspect, and ground cover on infiltration. Results of the sprinkling infiltrometer measurements, however, indicate little effect by any of these parameters on infiltration rate (Fig. 3). Clarksville plots with leaf litter cover and little understory on steep (22–36%) side slopes within the forest did not have infiltration rates significantly different from pasture plots with 60 to 95% plant cover and 4.4 to 15.4% slopes. Mean infiltration rates for the Nixa and

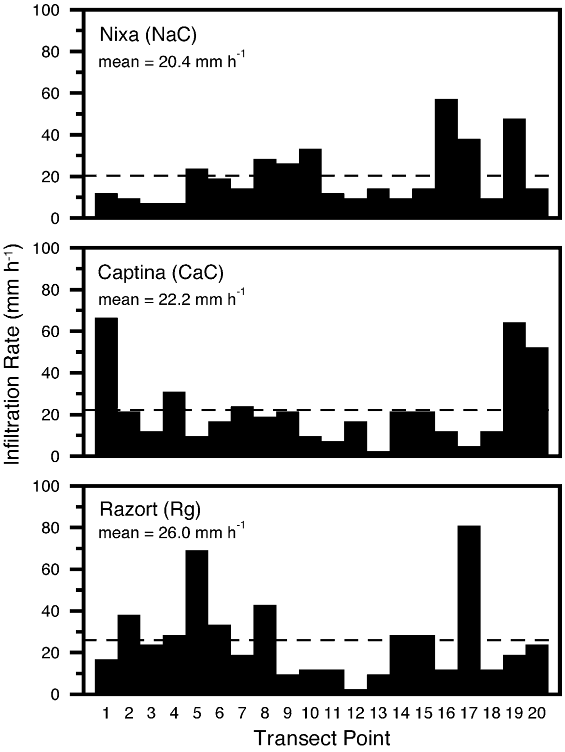

Fig. 2. Infiltration rate measured with the double ring infiltrometer with position along transects within soil map units from the valley (Razort) to the ridge top (Nixa).

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[1] Names of proprietary products are necessary to report factually on available data; however, the USDA-ARS neither guarantees nor warrants the standard of the products, and the use of the product by USDA implies no approval to the exclusion of others that may also be suitable.

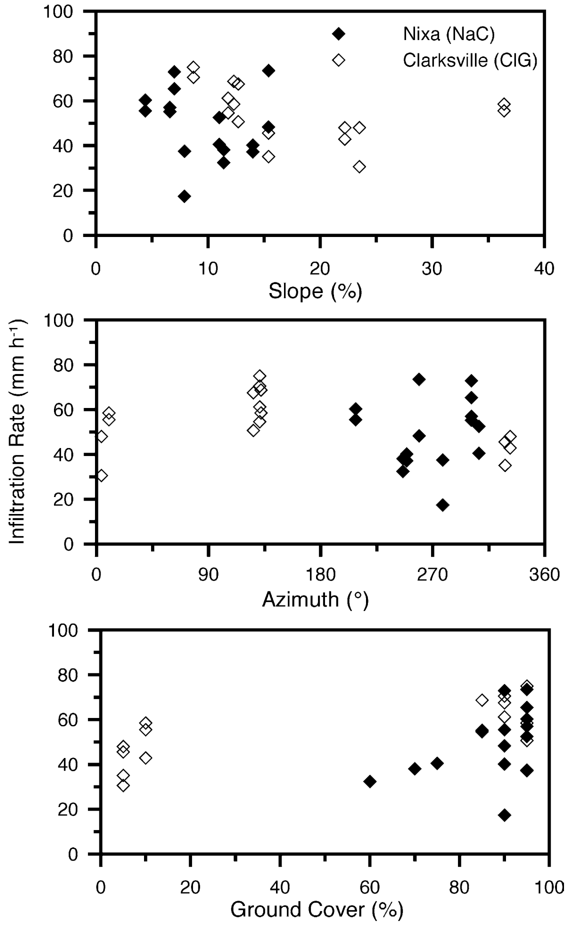

Fig. 3. Infiltration rate measured with the sprinkling infiltrometer vs. slope, azimuth, and percent ground cover (live plant) for Nixa and Clarksville soils.

Clarksville soils were not significantly different (49.0 and 54.4 mm h^{-1}, respectively).

Ponded infiltration rate measured with the single ring infiltrometers showed no significant differences among transects or between forest and pasture sites. However, significant differences between soils and aspect were detected. The Razort soil had significantly ($Pr > 0.0002$) greater infiltration than the Nixa and Clarksville soils (2340 versus 158 and 139 mm h^{-1}, respectively). The Razort soil occupies a neutral aspect in the valley bottom and its mean infiltration rate was significantly ($Pr > 0.0002$) greater than either the south/east or north/west slope aspects (146 and 149 mm h^{-1}, respectively). Another effect of aspect was noted for water retention at −0.40 m tension as volumetric water content in soil samples from Nixa and Clarksville soils on north-facing slopes (0.46 $m^3\ m^{-3}$) was significantly ($Pr > 0.0001$) greater than for samples from south-facing slopes (0.37 $m^3\ m^{-3}$). Again, efforts to establish relationships between infiltration rate and soil properties such as rock fragment content and bulk density failed to provide any strong relationships (Fig. 4). Significant differences among soils were, nonetheless, found for several parameters including rock fragment content, as the Razort soil had a significantly ($Pr > 0.0034$) greater amount of rock fragments than the Nixa and Clarksville soils (68.5% versus 43.0 and 46.8% by weight, respectively).

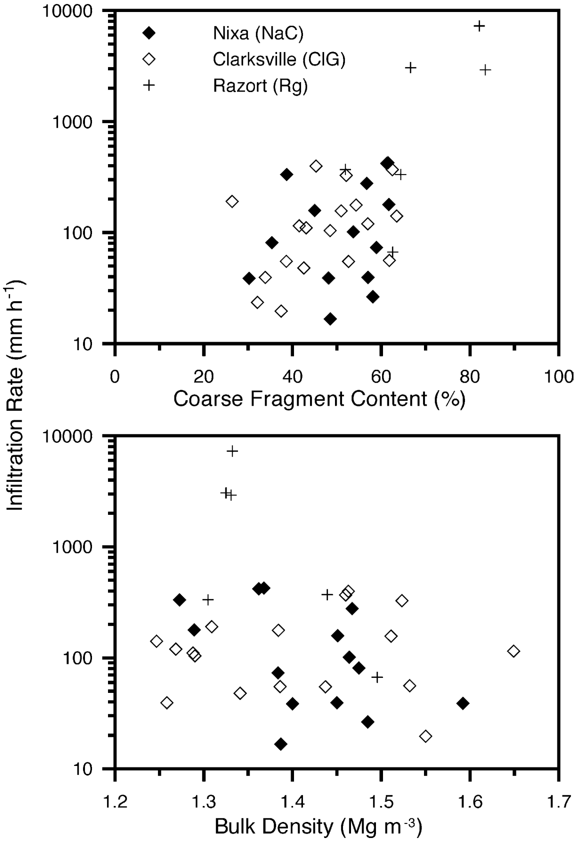

Fig. 4. Infiltration rate measured with the single ring infiltrometer vs. coarse fragment content (% by weight basis) and bulk density for Nixa, Clarksville, and Razort soils.

4. Discussion

Accurate infiltration measurements are difficult to obtain and techniques to estimate infiltration rates from soil properties are much sought after. In each of the three field studies significant effort was exerted in attempting to correlate soil and/or canopy characteristics with observed trends in infiltration rate. These efforts met with limited success, suggesting at best a weak relationship between infiltration rate and rock fragment content in the soil. This result serves as a testament to the complexity of infiltration processes in this landscape. Dunne (1983) pointed out that comprehensive understanding of runoff generation in headwater areas of watersheds remains elusive. Bonell (1993) concurred, indicating that the dynamics of runoff producing areas is much more complex than previously thought. It does not appear feasible to accurately estimate infiltration rate for Basin 1 soils using more readily attainable site properties.

There was considerable variation in infiltration rates for the same soils among studies. Differences among infiltration rates for the same soil can be related to attributes of the measurement techniques including varying measurement areas, ponding depth, and degree of site disturbance (Mallants et al., 1997) and spatial variation of soil properties in this terrain. Nonetheless, when infiltration rates are available for both the Nixa and Clarksville soils using the same technique, the infiltration rates for these soils are unexpectedly very similar and always less than for the Razort soil (Table 2). In fact, for all infiltration measurements completed at Basin 1, soils located on ridge tops and side slopes (Nixa, Clarksville, and Captina) have lower infiltration rates than the soil of the valley floor (Razort). Despite the absence of any strong relationships between infiltration and site properties at discrete locations, there is this distinct relationship among soils based on landscape position.

This finding supports field observations of runoff from upland areas that have been observed on several occasions following large rainfall events (i.e. debris trails on side slopes) although little or no discharge was measured at the watershed outlet. The infiltration data and field observations both suggest that infiltration excess runoff occurs relatively frequently following intense storm events. Runoff water from upland areas, however, can infiltrate into the Razort soil of the valley bottom due to this soil's greater infiltration rate. Discharge at the watershed outlet is more likely to occur when upland runoff raises the shallow groundwater level to near the surface in the Razort soil. Under these conditions, saturation excess runoff can occur on the Razort soil, as runoff from up slope can no longer infiltrate and instead flows across the surface to the ephemeral channel and on to the watershed outlet.

A runoff event from May 1999 illustrates the interaction between discharge from Basin 1 and the depth to saturation in the Razort soil at the groundwater observation well (Fig. 5). Rainfall began at approximately 0200 (Central Standard Time, CST) on day 124 (May 4) when the depth to groundwater measured in the monitoring well in the valley floor was 1.45 m. The most intense rainfall (14.2 mm in 20 min) occurred near the end of the event between 1400 and 1420 CST (total storm precipitation = 54 mm). Within minutes (1426 CST), a very small amount of runoff was observed at the basin outlet. However, over the next 24 h, water level in the monitoring well increased 0.94 m and the bulk of the discharge equivalent to 0.56 mm of runoff from the watershed occurred (2346 CST on day 124 to 0952 CST on day 125). Although the groundwater level was still 0.5 m from the surface at the monitoring well, the well is located up slope and ~20 m from the ephemeral channel. Visual observations on day 125 confirmed that the Razort soil nearer to the ephemeral channel was

Table 2
Comparison of infiltration rate for dominant soils of Basin 1 (means ± STD)

Method	Soil		
	ClG (mm h^{-1})	NaC (mm h^{-1})	Rg (mm h^{-1})
Double ring infiltrometer	–	20.4 ± 14.2	26.0 ± 19.8
Sprinkling infiltrometer	54.4 ± 12.6	49.0 ± 15.4	–
Single ring infiltrometer	139 ± 113	126 ± 138	2340 ± 2520

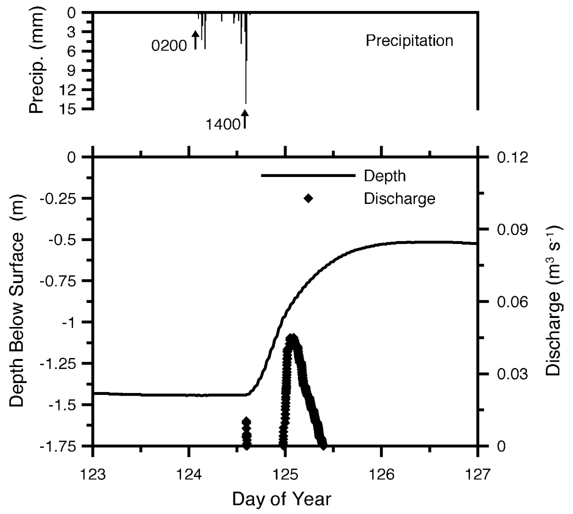

Fig. 5. Precipitation, depth to groundwater, and discharge from Basin 1 during a storm event in May 1999.

saturated to the surface. The discharge from Basin 1 is likely reduced by "pirating" of water from the ephemeral channel to two adjacent springs. Tracer studies and visual observations have verified that flow in the upper reaches of the ephemeral channel is diverted to the springs through cracks in the channel bottom before reaching the weir.

The estimated timber productivity of Basin 1 soils illustrates the ramifications of a soil's ability to infiltrate and store plant available water. The Razort soil is among the most productive soils (Woodland Group 1) with estimated site indices (Doyle rule) of 80–90 board feet per acre for common hardwood species (Harper et al., 1969). The primary soil-related factor impacting production on Razort soils is an excess of water (short duration flooding). Nixa and Clarksville soils are divided between Woodland Groups 6 and 10 based on slope aspect. Northerly slopes of Nixa and Clarksville soils have site indices of 60–65 for hardwoods while southerly slopes of these soils are placed in Woodland Group 10 as only suitable for shortleaf pine (*Pinus echinata*) and eastern redcedar (*Juniperus virginiana*) with site indices of just 30–55. The separation of Nixa and Clarksville soils by slope aspect is likely related to greater evaporation and lower available water on south-facing slopes. Water retention data on soil samples collected at the single ring/tension infiltrometer sites also showed greater water retention at −0.40 m tension for north-facing Nixa and Clarksville soils. Although differences in measured infiltration rates were not observed for the different slope aspects (Sauer et al., 2000; Sauer and Logsdon, 2002), the differences in water retention observed may be due to greater accumulation of organic matter under cooler, more moist conditions on the north-facing slopes.

Available water is a significant factor limiting forest productivity in the Ozark Highlands. Microclimate measurements at another research site 45 km east of Basin 1 indicated that, in 1997, potential evapotranspiration exceeded normal precipitation by 67 mm during the months of June, July, and August (Sauer et al., 2002). This shortfall of precipitation during summer months is typical of the humid, temperate climate of the region and likely contributed to the failure of arable cropping in locations such as Basin 1. Luxmoore (1983) also found a significant shortfall (∼100 mm) in available moisture during summer months (July–September) in a oak-hickory stand in Tennessee. At one site in the Luxmoore (1983) study, significant recharge of water up into the root zone occurred to help meet transpiration demand. The ability of soils to store sufficient water to sustain tree growth during periods of high evaporative demand and inadequate rainfall is a primary factor in determining site index. Management practices that increase infiltration and/or the retention of plant available water in Nixa and Clarksville soils would enhance tree growth on these soils during periods of rainfall deficit and also reduce short term flooding on the Razort soil.

One strategy to increase rainfall harvesting by upland soils in Basin 1 would be to construct grade stabilization structures at flow concentration points. The topography of Basin 1 includes side channels of the main drainage that branch out and ascend the ridges. These channels continue to cut back into the ridges and represent surface conduits for runoff water from up slope areas, primarily pastures. It is a common practice in the region to construct earthen berms across such feeder valleys just above the forest/pasture interface to impound runoff water, which reduces headcutting by the ravine and also provides a drinking water supply for cattle. Contributing area, soil properties, and paddock boundaries determine the number, arrangement and size of these structures.

Some of the impounded water will seep into the soil and move laterally down slope where it may become available to tree roots, however, this is likely a minor and localized effect. The potential for increasing available water for trees growing on the side slopes has not been investigated. In Basin 1, several sites on the south side of the main channel are typical of locations used for these structures.

Due to the local topography, there are no significant flow concentration points along the northern and eastern boundaries of Basin 1 or on Cellar Ridge, a grazed ridge top within the watershed. A second rainfall harvesting strategy with greater areal impact would be to improve infiltration in pastures by changing grazing management or through pasture renovation practices. The increased compaction and decreased infiltration effects due to grazing animal traffic are well established (Tanner and Mamaril, 1959; Linnartz et al., 1966; Gifford and Hawkins, 1978; Tollner et al., 1990). Pasture soil compaction can be prevented by modifying grazing management, in particular, rotational grazing among several small paddocks within pastures, avoiding overgrazing, and the siting of sheltered areas (shade, windbreaks) and water sources in less vulnerable areas. Another practice common in southern U.S. pastures is the use of mechanical renovation. Pasture renovators or aerators vary widely in design but are some form of shallow tillage implement that is pulled across pastures to create small openings or depressions at the soil surface. These small depressions are thought to improve soil aeration and enhance infiltration by creating greater surface storage. However, there are at present no studies published that quantify the potential amount of increased infiltration in pasture soils under enhanced grazing management or after mechanical renovation.

Increasing infiltration in pastures of Basin 1 would have the added benefit of improving surface water quality. Runoff from poultry litter-treated grass and pasture plots in the Ozark Highlands has been shown to contain greater amounts of nutrients, metals, pathogens, and hormones than untreated areas (Edwards et al., 1997; Nichols et al., 1997; Sauer et al., 1999, 2000). Thus, any practice that decreases runoff from litter-treated pastures will likely reduce the amount of these contaminants transported to surface water bodies. Since most forested areas in Basin 1 are on Clarksville soil, which does not have an appreciably different infiltration rate than the pasture soils, it is assumed that the forested side slopes are not likely to effectively retard contaminant transport. Sauer et al. (2000) reported nutrient (N and P parameters) losses from plots on forested Clarksville soil that were comparable and sediment losses that were greater than from pasture plots. A critical factor in understanding contaminant export from Basin 1 is the fate of contaminants contained in runoff water that infiltrates into the Razort soil. Whether this water flows rapidly to the ephemeral channel or remains in the shallow water table, flow rates, chemical properties, and biological processes in the shallow aquifer will determine the degree of retention and type of chemical transformations.

5. Conclusions

Increased confined animal production in mixed forest/pasture landscapes of the Southeast and Mid-South U.S. has created the need to study and adapt land management strategies. Understanding surface hydrologic processes is a key element in the management of soil water regime for improving forest production and reducing transport of potential water quality contaminants. Observations of infiltration patterns in Basin 1 led to the development of a conceptual understanding of runoff generation dynamics. Increasing infiltration in upland areas of Nixa and Clarksville soils would reduce runoff and contaminant transport from areas that are routinely grazed and receive animal manures. Allowing areas of the Razort soil currently in forest to stay in timber production will maintain the most productive areas of forest growth and also reduce direct animal manure inputs to this highly conductive soil. Further study is needed to assess to what degree capture of runoff water by the Razort soil facilitates the retention and/or transformation of contaminants.

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