A MODELING APPROACH TO ASSESS THE WATER BALANCE OF A TYPICAL SOUTHERN PIEDMONT CATCHMENT UNDER LONG-TERM NO-TILL USAGE

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Abstract. We used the Root Zone Water Quality Model to simulate runoff and seepage below the root zone from a 2.7 hectare watershed to look at rates of ground water recharge under long-term, no-till crop production systems in the Piedmont of Georgia. The watershed is located at the USDA-ARS-JPCNRCC (J. Phil Campbell Sr., Natural Resource Conservation Center) in Watkinsville, Georgia. It has been in crop production under no-till and winter cover cropping management practices since 1974. The model over predicted soil moisture and slightly over predicted runoff, however, the pattern of deep seepage to ground water was distinctly different for rainfall patterns that were small and consecutive versus large rain events. Ground water depth immediately responded when root zone soil moisture was at field capacity or greater. This indicates that under saturated or field capacity soil moisture conditions, larger rain events of short duration (> 15 cm and < 30 hours in this case) are recharging ground water rather than creating significant runoff. Simulations of watershed management practices such as long-term no-till and cover cropping can serve as a useful tool to show the effects of long-term management on potential surface water contamination.

INTRODUCTION

The J. Phil Campbell Sr., Natural Resource Conservation Center is located in the Southern Piedmont physiographic region extending from Virginia into Alabama and between the southern Appalachian mountains and the Southern Coastal Plains in the southeastern U.S. (Figure 1.) The region is underlain by schists, gneisses, and granites but several narrow belts of sandstones and slates are also present. The topography is gently rolling with slopes of 2-6%. Ground water supplies in the Piedmont are small, and the major sources of water for municipal, industrial, and agricultural use are perennial streams, impoundments, and rainfall (Smith et al., 1978). Recent drought conditions beginning in June, 1998 along with the increase of urbanization in the region have drawn significant attention to both water quality and water supplies for the future.

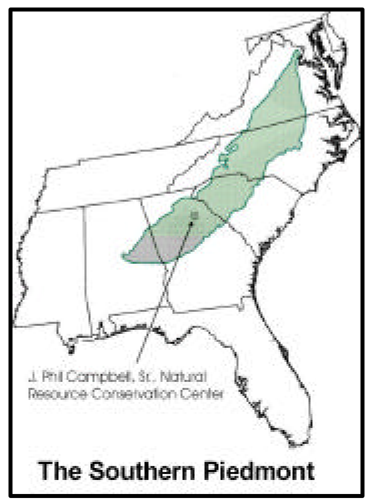

Figure 1. Location of J. Phil Campbell, Sr. Natural Resource Conservation Center

The Conservation Center is located in Oconee county, Georgia, where greater than 25% of the land area is still in agricultural production and ranked 21st in total Farm Gate value out of 159 counties in the state (UGA Center for Agribusiness and Economic Devlopment, 2001). As urbanization increases in the county, the awareness of the impacts of agriculture on ground and surface water resources increases both locally and statewide. Many studies have shown that agricultural management practices such as no-till and cover cropping reduce runoff potential and improve soil physical properties such as infiltration rates and tilth.

The watershed we modeled has been studied extensively since 1960 to look at the surface hydrology and transport of chemicals and nutrients on Piedmont watersheds, but no attempt has been made previously to model its sub-surface hydrology to look at the potential to predict the impact of agriculture on ground and surface water supplies. Models can be powerful tools for evaluation of watershed processes as influenced by climate, topography, soils and land use. Careful calibration and verification are necessary for subsequent application in decision management support. The Root Zone Water Quality Model (RZWQM, Ahuja, et al., 2000) has been developed over the past several years by USDA-ARS scientists at the Great Plains System Research unit in Ft. Collins, Colorado. RZWQM is a process-based model that simulates major physical, chemical and biological processes in crop production systems under a range of common management practices. It includes simulation of a tile drainage system and runoff as well as predictions of the potential for ground- and surface-water flow and contamination. The model is parameterized for corn and soybeans, but also includes a simple growth and yield model that can be used for simulation of more than 100 crop types using basic parameters of leaf area index, maximum nitrogen uptake, root distribution and plant height which allow the crop to interact with the soil water and nutrients similar to a fully parameterized crop. Though the model is one-dimensional designed to simulate conditions on a unit-area basis, it has undergone extensive verification, evaluation and refinement in representative areas of agricultural cropping systems in the Southeast, Midwest and Great Plains, and is proving to be a valuable tool for research and simulation of field and watershed hydrology in agricultural systems throughout the U.S.

The objective of this study was to look at the RZWQM as a tool to predict the watershed hydrology, specifically runoff and seepage below the root zone, in order to better understand the pattern of rain events that recharge ground water and contribute to runoff relative to current agricultural management practices that effect water supplies in the Piedmont region.

MODEL PARAMETERS

We previously parameterized and calibrated the RZWQM for the Cecil soil series which occupies approximately two-thirds of the cultivated land in the Southern Piedmont region (Hendrickson et al., 1963), and is the dominant soil type in the watershed modeled. The Cecil sandy loam soil (typic Hapludult; clayey, kaolinitic, thermic family) is characterized by a permeable sandy clay loam or loamy sand in the top 20 cm, with a somewhat impermeable clay pan between 20 and 30 cm and a clay horizon which limits infiltration to less than 1 cm hr^{-1} between one and three meters in the soil profile (Bruce et al., 1983). Macropores from old tree roots and earthworm holes may also occur throughout the rooting zone and contribute to bypass flow to ground water. The model includes an option for soil macroporosity. We compared measurements of runoff, soil moisture and ground water depth to predicted runoff, soil moisture and deep seepage (below 3 meters in the soil profile) during 2000 and 2001 to estimate the amount of rainfall required to recharge ground water. The cropping systems used were no-till millet and sorghum crops and rye and wheat winter cover crops. The simulation was begun on 11/1/1999 and run through 12/31/2001. The area had been in an ongoing drought since June 1998.

GROUND WATER RESPONSE

Ground water measurements from a well at the outlet point of the watershed instrumented with a flume and pressure transducer for automatic data logging were begun on August 1, 2000. Measurements were output at 15' intervals and daily average ground water depth was calculated along with daily measured rainfall at a rain gage at the bottom of the watershed to look at response patterns of ground water levels to rainfall. Ground water remained at a depth of 7.3 meters for 139 days despite a near continuous series of small intermittent rain events of less than 7 cm (Figure 2). Ground water began to rise and continued to recharge for a period of 66 days after the depth began to change. Though 27 more cm of rainfall occurred over the next 82 days, the water table had begun to drop again.

The model predicted positive seepage below the root zone from March 26, 2000 until December 19, 2000, a total of 334 consecutive days, but ground water depth was not effected according to measured rainfall and water table levels until 53 days after predicted deep seepage had stopped. Though the volume of cumulative predicted deep seepage (12.4 cm) since the beginning of the simulation period did not equal the change in ground water depth after ground water depth began rising, the fact that

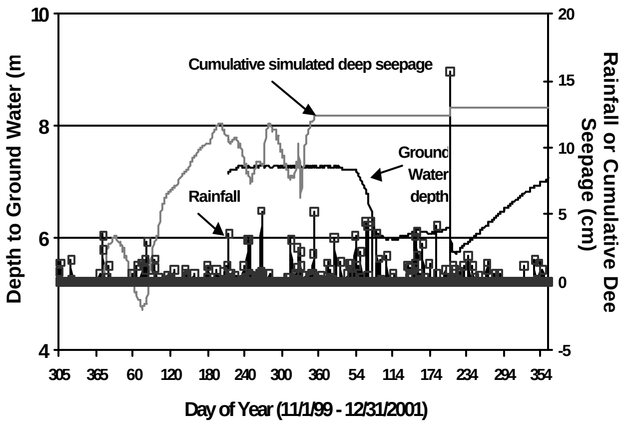

Figure 2. Measured rainfall and ground water depth, and simulated cumulative deep seepage, P1 watershed, 11/1/99 - 12/31/01.

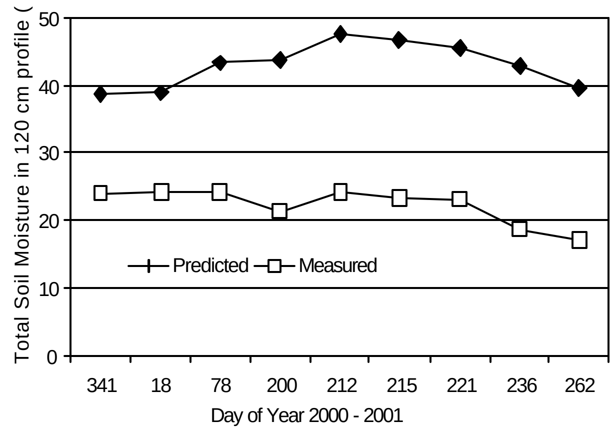

Figure 3. Measured and predicted soil moisture in a 120 cm profile, P1 watershed, 12/6/00 - 9/19/01.

the ground water level did not respond to rainfall for 190 days from the middle of August 2000 until the end of January 2001 indicates that the high water-holding capacity of the soil as well as losses due to evapotranspiration dominate the rate at which ground water recharges under this agricultural scenario. The soil profile, particularly at depths of 1-3 meters where infiltration slows to less than 1 cm hr^{-1} also plays an important role in the rate at which seepage reaches ground water levels.

After the water table began to drop again, a rain event of 16.7 cm over a 30-hour time period caused a 10.9 cm rise in ground water over a period of just 4 hours. The model predicted a deep seepage total of 0.56 cm on the second day of this rainfall event. In this case, the ground water level responded almost immediately to rainfall even though measured soil moisture was near field capacity (0.19 volumetric in a 120 cm profile, Figure 3) and the weather was typical for July when temperatures and evapotranspiration rates are high. Previous runs of the model for other cropping scenarios revealed that the model is not sensitive to macroporosity though it is set up by the user as an option. Apparently though, from the rapid ground water response to this particular rain event, bypass flow seemed to occur. As the rain events decreased in size and number over the next several days, the ground water level dropped rapidly again, an indication that evapotranspiration rates and soil water storage were again dominating the water balance.

Simulated runoff for the rain event of 16.7 cm was 7.2 cm and measured runoff was 5.2 cm. This indicates that the model in its current state, using the simple growth and yield model, may be useful for predicting runoff and patterns of deep seepage relative to ground water recharge. Before a thorough water balance could be completed and be relied on to predict seepage volume and soil moisture accurately, the crops used in this study would need to be calibrated using the generic plant production model available in the model to effect the soil moisture storage and resulting partitioning of root zone soil moisture to evapotranspiration and seepage below the root zone. Previous testing of the generic model has given excellent results for production of corn and cotton at the research location.

SUMMARY

Based on measured rainfall rates and changes in ground water levels, and simulated patterns of soil moisture and deep seepage below the rooting zone, the RZWQM, with proper crop calibration, should be able to accurately simulate the impact of current agricultural management practices on small Piedmont watersheds and the way these management practices will effect the ground and surface water supplies in the future.

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