INSTRUMENTATION TO QUANTIFY AND SAMPLE SURFACE RUNOFF AND SHALLOW GROUND WATER

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Introduction

Ground water contamination by chemical fertilizers and pesticides has been documented by various federal and state agencies in the United States (Canter 1987). Ground water pollution continues to be a major concern in the United States because over half of the drinking water is from this natural resource. Various studies have found water pollution to be the most damaging and wide spread environmental effect of agricultural production (Brinsfield *et al.* 1987; Kanwar 1990). Ground water contamination by pesticides and nitrogen fertilizers have been cited in 32 states and Europe from agricultural-related enterprises (National Research Council 1989; Oakes *et al.* 1981; Gast *et al.* 1978; Hall *et al.* 1989; Kanwar *et al.* 1988). Over 800 of 1437 counties in the U.S. have reported ground water pesticide contamination. One billion kg of more than 400 different types of pesticide chemicals are sprayed each year on America's cropland (National Research Council 1989).

In Mississippi, ground water constitutes 54 percent of all the freshwater and is the water supply of 93 percent of the population (Mississippi Ground-Water Quality 1986). Due to Mississippi's sparsely populated agricultural areas, ground water contamination has not been considered a major problem. However, Mississippi's ground water is susceptible to contamination due to the very permeable soils, shallow depth to ground water, heavy clay subsoil, and large annual rainfall. Data is lacking on any potential agrichemical contamination of ground water underlying the agricultural areas of Mississippi, particularly the Delta along the Mississippi River and the Uplands to the north (Mississippi Ground-Water Quality 1986).

Agricultural land areas have varying degrees of potentials for ground water pollution depending on the type of soils, climate, geology, and the agricultural management practices. The use of conservation tillage for production of agriculture may help in developing the Best Management Practices in reducing the ground water pollution problems. Conservation tillage, such as a no tillage practice, is an effective practice for conserving energy and soil. Conservation tillage reduces surface water pollution by contaminants attached to the sediment particles since erosion is significantly reduced. However, conservation tillage may increase the risk of ground water pollution of soluble contaminants because these tillage systems have been found to increase infiltration and subsequently ground water recharge (Kanwar *et al.* 1988). Conservational tillage (minimum to no tillage) practices leave the structure of surface soil largely intact, which may cause faster movement of pesticides and nitrates due to reduced soil residence time. In contrast, the conventional tillage practices, which include plowing, disking, and harrowing, destroy all the preferential paths which result in reducing the movement of chemical pollutants to the ground water. The combination of mobility and persistence of a chemical pollutant determines whether a compound will be degraded to a harmless form during its residence time in the biologically active vadose zone.

Research is needed to determine the extent of chemical leaching to ground water as a function of tillage practices. Therefore, a field study was started to understand the relationships among agricultural practices (tillage and chemical application), surface runoff (soil erosion), and ground water pollution. The overall objectives of this study were to determine the role of macropore flow under three different tillage systems (conventional, conservational or minimum, and no tillage) on corn and to quantify the concentrations of pesticides and nitrate found in shallow ground water and in surface runoff so that practices could be developed to improve both ground water quality and surface runoff. The methods used to establish these objectives are discussed below.

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Design

The experimental site for this study was located at the North Mississippi Branch of the Mississippi Agricultural and Forestry Experiment Station at Holly Springs, Mississippi. This study site was on a predominantly Loring silt loam soil (*Typic Fragiudalf)* formed from loess material on sloping uplands. A fragipan occurred 50 to

60 cm under the soil surface that restricted the downward movement of water and caused an intermittent perched water table during months of high rainfall. This fragipan is a naturally occurring subsurface horizon generally characterized by high bulk density, very low hydraulic conductivity, brittleness, and the absence of fine feeder roots in the brittle portion. This site was planted to corn by conventional tillage for several years prior to 1990. In 1990, the site was mechanically fallowed while construction occurred.

The experimental design will consist of growing corn on a randomized block design with three treatments (no-till, minimum till, conventional till) with two replications. Plots were constructed and installed during the summer of 1990 with 1991 being the first cropping year. Each plot was 8.1 m x 38.1 m (0.03 ha) with slopes averaging 2.8 and 4.0% for replications 1 and 2, respectively. Runoff and ground water samples were taken from a subarea of 4.0 m x 22.1 m (0.01 ha) within each 0.03 ha plot (Figure 1).

Ground Water Design

In 1990, six field plots (0.03 ha) were established to obtain shallow ground water and runoff samples from the corn study. These plots were hydrologically isolated by making a 20-cm wide and 122-cm deep trench around three sides (the above-slope side and the two parallel-slope sides) of each plot using a small chain-type trencher. After trenching, a 0.38-mm thick plastic barrier was placed in the trench from the surface to a depth of 122 cm to ensure outside subsurface water from entering into the test plots. The depth of the plastic barrier was approximately 0.61 m into the fragipan to prevent the lateral movement of the perched ground water from the plot and ensure its collection.

Within each plot, a 4.1 m x 22.1 m (USLE plot) (Mutchler *et al.* 1988) subplot was constructed for sampling runoff and ground water quality (Figure 1). Separation of the USLE plot was achieved by enclosing three sides (above-slope and two parallel-slope) with a 10-cm PVC pipe entrenched 5 cm into the soil. For ground water collection, three 5-cm PVC pipes (Schedule 40), 4.1-m long, were horizontally placed on top of the fragipan (approximately 50 cm below soil surface) perpendicular to the slope (dashed lines in Figure 1). Each lateral was placed 7.31 m apart beginning at 3.65 m from the lowest side of plot. These laterals were installed by horizontally drilling 5.0-cm holes 4.57 m starting 90 cm from the side of plot. The laterals were perforated along the upper two-thirds of the pipe's circumference and 3.65-m length by drilling 0.635-cm holes 5-cm apart. Five lines spaced 2.54 cm along the circumference possessed these perforations with adjacent lines having holes offset by 2.54 cm. Each lateral was plugged with a PVC end cap and was inserted into the 5-cm holes with the center line of perforations toward the soil surface and all the perforated length (3.65 m) within the plot allowing for the remaining 0.45 m to tie into the main. No traffic was allowed on the plots which would alter infiltration and hydraulic conductivities due to compaction. Quantities of runoff and ground water would be more representative of true values than would conventional drainage installation techniques. Nylon stockings were placed around the pipes to prevent plugging the drainage system. Each lateral was connected into a main, and adjacent mains from adjacent plots were routed with outlets into a concrete sump. A 37.8-L stainless-steel container was positioned under each outlet to collect the ground water sample. Three sumps were constructed with concrete floors, block walls, and aluminum roofs to prevent rainfall contamination into the ground water samples. Inside each sump, the two outlets were draped with a plastic shroud that covered the sampling container to further prevent sample contamination. After major rainfall events that produced ground water samples, the containers were removed and taken to the National Sedimentation Laboratory for water quality measurements. Clean containers were repositioned inside each sump.

Runoff Design

The equipment used for measuring runoff and soil loss for each of the six USLE plots included collectors, approaches, end plates, 0.15-m H-flumes, FW-1 water-level recorders with potentiometers, runoff splitters, Isco composite water samplers, and dataloggers. Collectors, approaches, end plates, flumes, and water-level recorders were constructed according to procedures in Agricultural Handbook 224 (Brakensiek *et al.* 1979) (Figure 2). Due to the advances in microprocessor and electronic controls within the past five years, this manual was unable to provide adequate information to automate this system. Information from Grissinger and Murphree (1991) of using commercially-available dataloggers in runoff and erosion studies was used to automate this design. The runoff splitter, which was initially constructed and described as a modified slotted sampler/turbulence box by Murphree (Grissinger and Murphree 1991), was used for collecting runoff outflow from the H-flume. The intake port for the composite pump sampler was mounted on this box.

A datalogger (Omnidata 516C Polycorder equipped with an analog/digital interface card) was used to collect rainfall and runoff data and to independently control pump sampling equipment. One datalogger was used to collect data from two runoff plots and a tipping-bucket rain gauge. Two Isco (Model 2710) composite water samplers and two potentiometers from the FW-1 water-level recorders were wired into the analog/digital interface card of the datalogger. The datalogger and water samplers were placed in a grounded, insulated instrument shelter positioned at the lower end between the plots (Figure 3). Power for the datalogger and the pumps on the water samplers was supplied from 12-V DC battery which was kept recharged by 12-V solar panels mounted to the roof of the shelter. The rain gauge was wired into an accumulator that was wired into each of the digital inputs of the datalogger's interface card. Two other shelters with duplicate equipment were used for the remaining four plots, except no rain gauge was required.

One datalogger was programmed to continuously monitor the rain gauge. When rainfall was detected, the datalogger recorded the count and processed the count into the converted measurement (1 count = 0.25 mm) and stored for later retrieval.

At the lower end of each plot, an H-flume and stilling well were mounted onto a collector and approach. Inside the stilling well, a potentiometric float and pulley were installed for measuring the water level. The potentiometric output from the FW-1 water-level recorder is proportional to the stage or height of the float in the stilling well. As a backup, the float height was also recorded on the strip chart. The potentiometer was wired to the analog and excitation port of the analog/digital datalogger (Omnidata 516C Polycorder). An Isco composite water sampler was wired to the digital output of the datalogger.

A complete description of the programming of the dataloggers was provided by Grissinger and Murphree (1991). Using a modified version of their program, the three dataloggers read the voltages of the potentiometers every 30 seconds. When runoff was detected, the dataloggers calculated discharge rates using appropriate equations to convert potentiometric voltages to flow depths and flow depths to discharge rates. For each time interval, discharge volumes were calculated. These incremental discharge volumes were summed and compared to a predefined flow limit. When the cumulative discharges (summation of incremental discharges over 30 second intervals) equaled or exceeded the flow limit, a pulse from the dataloggers activated the water samplers that took a preprogrammed quantity of water from the runoff splitter. The cumulative discharge was reset to zero. As the runoff event continued, the incremental discharges were again summed until the cumulative discharges equaled or exceeded the flow limits that again triggered the water samplers and allowed another incremental quantity of water from the runoff splitter into the water samplers. This cycle continued until runoff ceased. The collection of the discharge-weighted composite samples was necessary to reduce the sample analysis load to levels realistic to available resources. The dataloggers stored the incremental discharge rates and cumulative discharge volumes for each runoff event. During post-storm plot servicing, the data was downloaded from the dataloggers into a Polycorder 600 digital unit (from Omnidata) for transfer to the computers at the National Sedimentation Laboratory for further analyses.

Water samples from the Isco samplers were collected in 37.8-L stainless-steel containers positioned under the inflow of the Isco sampler. These containers were removed with the composite water samples and transported to the lab for sediment load and water quality analyses. The number of pumps, which represented the number of times the cumulative discharge equaled the flow limit during the runoff event, was recorded from the LED display of the Isco sampler. The sampler was reset to zero and clean containers were repositioned under the inflow for preparation of the next runoff event.

Further Installation

Outside the USLE plot, but inside the isolated 0.03 ha area, a series of piezometers, suction tubes, tensiometers, and wave guides for time domain reflectometry will be installed near the center of each plot after the 1991 harvest. The devices will be installed at 0.15, 0.30, 0.46, 0.61, 0.91, 1.22 and 1.52-m depths into the soil profile and 0.91 m spacing within the crop rows. Piezometers will be used to measure hydraulic head gradients and obtain water samples for nitrate, pesticide, and other major plant nutrient analysis. Soil suction cups will be used to collect ground water samples when piezometers remain dry after storm event. Tensiometers will be used to determine unsaturated moisture condition and develop soil matrix potential. Time domain reflectometry will be used to measure unsaturated volumetric water contents and composite dielectric constants.

Recommendations

Several modifications of commercially available equipment were necessary for the use of the dataloggers in this study. The analog/digital interface board did not provide continuous pulse counting that was necessary for the tipping-bucket rain gauge. An accumulator to interface the rain gauge to the datalogger was developed and supplied by Omnidata for this purpose. Also, the dataloggers' power was modified to accept 12-V DC to extend unattended operation in the field. Various dataloggers such as the Basic Data Recorders (BDR) used by U.S. Geological Survey, or the CR10 and 21X from Campbell Scientific (CR10 and 21X) need no modification and provide many of these same capabilities.

A minor problem with the dataloggers was the periodically random renaming of subroutines with an extended character that caused the incomplete performance of the program. Either static electricity or power drain using the same power source for the two

Isco pumps and datalogger was suspected to cause the hardware errors. Since this renaming appeared at random among the subroutines, the programming was not a problem. Dataloggers were wrapped in static-free towels as a possible remedy. A separate power source may eventually be necessary to separate the datalogger from the pumps.

Summary

A field acquisition system was developed and constructed to sample and quantify both surface runoff and shallow ground water from erosion plots of a conservation tillage study. Advantages of this system included minimum labor requirements for data reduction due to taking composite water samples, continuous automation of water sampling during runoff events, and uniform time base for all plots. Although not completely satisfactory due to the periodic erroneous renaming of subroutines, the acquisition system provided accurate and reliable results.

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