Report for 2005AL36B: Spatial Dynamics of Runoff-Contributing Areas for Effective Management of Phosphorus from Land-Applied Poultry Litter

Publications

- Conference Proceedings:
    - Sen, S.; P. Srivastave, K. Yoo, P. Clement, 2005, Hydrologically Active Areas for Effective Management of Phosphorus From Land-applied Poultry Litter in 2005 Annual Alabama Water Resources Conference Proceedings, Alabama Water Resources Research Institute, Auburn, AL.
    - Sen, S.; P. Srivastava, K. Yoo, J. Shaw, and M. Kang, 2006, Characterizing Hydrologically Active Areas for Effective Management of Phosphorus Loss in Surface Runoff in Annual International Meeting of the American Society of Agricultural and Biological Engineers, American Society of Agricultural and Biological Engineers, Portland, OR.

Report Follows

Project Synopsis
for the
Water Resources Research Institute Program
under
Section 104, Water Resources Research Act of 1984
to the
Alabama Water Resources Research Institute

Project Title

SPATIAL DYNAMICS OF RUNOFF-CONTRIBUTING AREAS FOR EFFECTIVE MANAGEMENT OF PHOSPHORUS FROM LAND-APPLIED POULTRY LITTER

by

Puneet Srivastava (Principal Investigator, Biosystems Engineering)
Kyung Yoo (Co-PI, Biosystems Engineering)
Prabhakar T. Clement (Co-PI, Civil Engineering)

College of Agriculture
College of Engineering
Auburn University
(334) 844-7426
srivapu@auburn.edu

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Statement of Problem and Research Objectives

Alabama's agricultural economy depends on poultry production. Confined poultry production, however, results in massive amounts of litter and associated phosphorus (P). Land application of litter to pastures, as a cheap alternative to commercial fertilizer, has resulted in excessive buildup of P in soils of major poultry producing counties (e.g., Cullman, Marshall, Dekalb, and Blount) of Alabama. While P is an essential nutrient for plant growth, runoff of P can accelerate eutrophication resulting in severe impairment of waterbodies that support aquatic, recreational and drinking water uses. Because of excessive buildup of P in soils and the resulting threat to our water quality, recent years have seen the development of a P-index in major poultry producing states of the country. Alabama's P-index suggests applying litter based on agronomic P requirement rather than agronomic nitrogen (N) requirement to those fields that have mid- or higher-field vulnerability ratings. Since poultry litter has a high P to N ratio, this recommendation has resulted in a great imbalance in the amount of poultry litter produced and the area available for litter application.

Current P management practices, however, treat an entire field as one homogeneous unit. The underlying assumption is that an entire field contributes to overland flow. Several studies have shown that overland flow is generated from well-defined and often identifiable portions of a watershed. Extrapolating based on the results of these studies, we contend that areas within those fields might be suitable for poultry litter application at a higher rate because probability of these areas generating runoff is extremely low. Through an intensively-instrumented field study we are identifying those areas (i.e., hydrologically active areas (HAAs)) in the Sand Mountain region of Alabama where major Poultry producing counties are located. Since the primary mechanism of P transport is overland flow, we believe that consideration of hydrologic controls and identification of HAAs are critical for effective management of P. Also, since most of the litter management occurs at a hillslope scale, understanding the hydrologic controls at that scale is fundamental to reducing water quality impacts. Specific objectives of our proposed research were to:

1. Delineate spatial and temporal distribution of HAAs and identify surface runoff generation mechanism (infiltration excess vs. saturation excess) using distributed sensors., and
2. Relate the spatial and temporal variability of HAAs and runoff generation mechanism to static and dynamic watershed hydrologic characteristics.

Methodology

The study is being conducted on a 0.3 ha hillslope at the Sand Mountain Research and Extension Station, DeKalb County, Alabama. The Sand Mountain Research and Extension Center is one of the outlying units of Alabama Agricultural Experiment Stations. The hillslope represents a typical pasture in the Sand Mountain Region of Northern Alabama. The site was extensively surveyed using a Real-Time Kinematic GPS unit to generate detailed topography data. The study is on a Hartsells soil (fine-loamy, siliceous, subactive, thermic Typic Hapludults). The Hartsells series consists of moderately deep, well-drained, moderately permeable soils that are formed of loamy material from acid sandstone containing thin strata of shale or siltstone. These soils are on nearly level to moderately steep ridges and upper slopes of hills and mountains. The hillslope was intensively instrumented using surface and subsurface sensors, rain gage, H-flume and shallow wells. In particular, surface and subsurface runoff sensors (Figure 1) at 27 points were installed. The surface runoff sensors are miniature v-notch weir made of 2-mm thick galvanized sheet metal with a sensor pin and ground pin set 2 cm apart and 3 cm away from the v-notch and located on the upslope side of the sensor. The subsurface sensors, installed up to 60 cm depth, record the fluctuation in water table near the surface. The subsurface and surface sensors are powered using 12-volt DC batteries. All sensors are connected to a series of multiplexers and dataloggers (model CR10X Campbell Scientific, Inc.). A tipping bucket rain gage measures the rainfall intensity at 5-min intervals. Two shallow water wells were installed to monitor the depth of water table. One well is located near the upslope end

Figure 1. Instrumented hillslope with surface and subsurface sensors (detailed view on the right), H-flume, rain gage, and shallow wells at the Sand Mountain Research and Extension Center, Crossville, Dekalb County, Alabama.

of the hillslope, while the other is located near the downslope end of the hillslope. The site was instrumented such that the hillslope drains to a point where an H-flume records the overland flow from the entire instrumented hillslope. All 27 surface and subsurface sensors were installed in pair to study the interaction between the water table and overland flow for the characterization of HAAs and runoff generation mechanisms.

Rain gage triggers surface and subsurface sensors and pressure transducers (in shallow wells and H-flume) and prompts data collection during rainfall event and two hours after rainfall event has seized. Rainfall, water table level, and occurrence of overland flow at surface and subsurface sensors are collected at 5-min interval. The data collection began in January 2006 and so far data for more than 5 rainfall events have been collected. Since we are still in the process of collecting data to meet our objectives, we present results from a rainfall event to demonstrate the kinds of data we are collecting. In addition, we describe our plan for relate the spatial and temporal variability of HAAs and runoff generation mechanism to static and dynamic watershed hydrologic characteristics. Even though the project period ended in April of 2006, we are continuing our project with support from other sources to meet our objectives.

Results

Figure 2 below shows an example of the kinds of data we are collecting. As an example, the figure shows a rainfall event that started at 11:30 PM on January 28, 2006 and continued for over 4 hrs. The top figure shows three distinct HAAs (detected by surface sensors) after 3 hr 20 min of rainfall; the subsurface sensors suggested that the water table was below the surface at that time. After 3 hr 35 min of rainfall, the mechanism of overland flow appears to have changed from infiltration excess flow to saturation excess overland flow at some HAAs. Note that the overland generated at these locations did not reach the outlet of the sub-watershed where an H-flume has been installed to estimate the amount of overland flow. The cumulative rainfall for this event was more than 0.5 in. The preliminary data collected for 5 storm events suggest that the mechanism of runoff generation at this site is mostly infiltration excess. Also, it appears that the HAAs start from the same locations for every storm event and expand depending on the characteristics of the rainfall event. Even though the Hartsells series soil, on which this watershed is located, is moderately deep and well-drained, it appears that there are locations within the hillslope where the hydraulic conductivity is low. This difference in hydraulic conductivity might be the reason that some areas on the hillslope generate infiltration access runoff where as other areas do not generate any runoff. We plan to confirm this observation by collecting soil hydraulic conductivity data using an air permeameter. In addition, we plan to use EM38 to characterize the spatial variability in soils characteristics. These two datasets together will help explain the reason for infiltration excess runoff from a few locations.

The approximate average depth of sandstone layer at the site is about 100 cm and the sandstone layer seems to be a bit porous. Because of this characteristic, it also appears that there is quite a bit of subsurface flow at the site. We plan to install moisture sensors and continue to collect data from this site for at least one and a half more years. In addition, we also plan to instrument another sub-watershed next to this watershed. Once sufficient field data has been collected, we will confirm these preliminary observations. If these preliminary observations are found to be true, the study would suggest that (1) the mechanism of runoff generation at Sand Mountain pastures are mostly infiltration excess, (2) the location of HAAs can be identified using air permeameter and EM38, and (3) subsurface flows are significant part of total flow out of a hillslope.

We will attempt to generalize the findings of the field data through HYDRUS 2D or 3D modeling and geostatistics (to meet objective 2 of this study). Also, once we understand the hydrologic and geomorphic characteristics of these two sub-watersheds, we will test various litter management prescriptions and determine a prescription that lets a farmer maximize the amount of applied-litter, while providing the best water quality protection possible. This kind of detailed data collection is crucial for science-based decision making and for increasing the acceptability of Federal and State regulations.

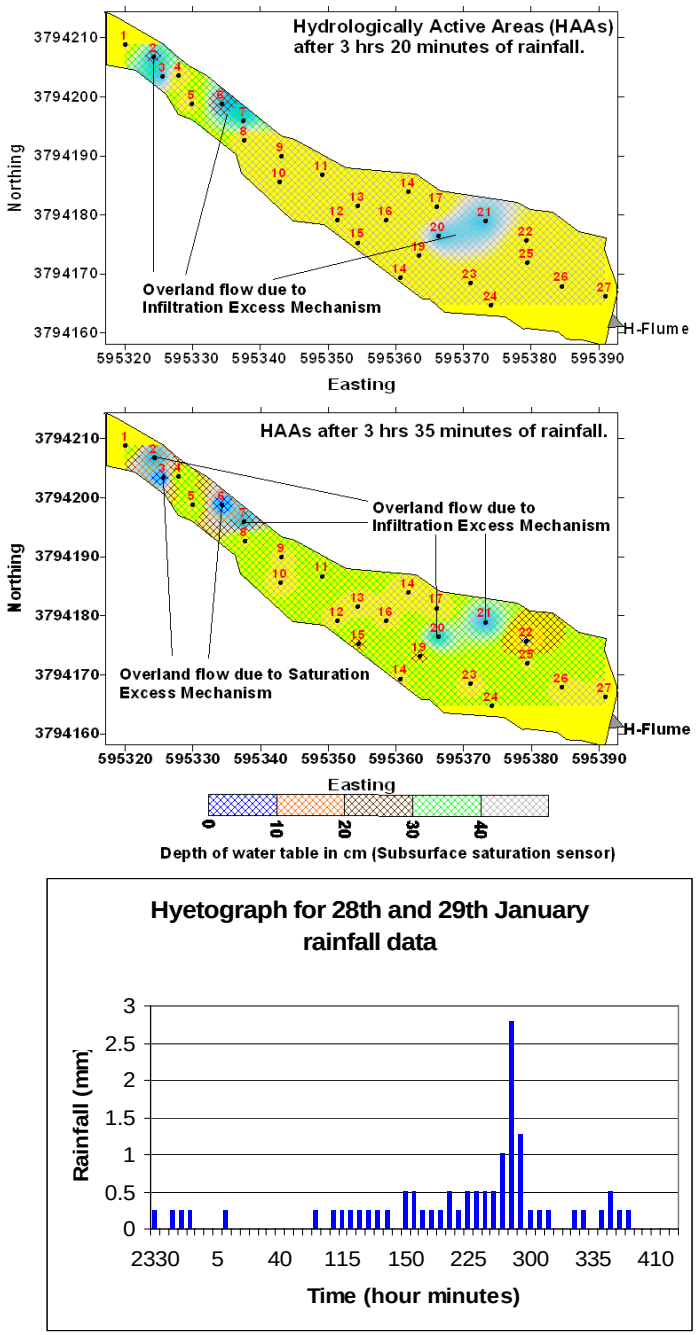

Figure 2. Hydrologically Active Areas (HAAs) as determined by surface and subsurface sensors in a sub-watershed located at the Sand Mountain Research and Extension Center, Crossville, DeKalb County, Alabama. The top and the middle figures were generated for two different times (3 hr 20 min and 3 hr 35 min) after the rainfall began. Note that both infiltration excess and saturation excess overland flow generation mechanisms appear to be present during this storm event.