RELATING AGRICHEMICAL RUNOFF AND LEACHING TO SOIL TAXONOMY: A GLEAMS MODEL ANALYSES

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INTRODUCTION

The presence of pesticide residues in surface water and in ground water is cause for increasing public concern for nonpoint-source pollution. Pesticides have tremendous economic importance in helping to provide reliable supplies of food and fiber at reasonable cost. Numerous agencies are developing strategies to reduce risks to water quality associated with pesticide use. For example, the USDA-Soil Conservation Service has been mandated to include water quality goals in development of farm resource management systems. The SCS, in cooperation with the USDA-Cooperative Extension Service and others, will develop plans to reduce loads of sediment and/or agrichemicals reaching the nation's water supplies.

Interaction of agrichemical properties and processes, farm management practices, and soils as a function of climatic factors and their effects on agrichemicals moving through the soil root zone are extremely complex. Decisions by management and regulatory agencies need to consider all these factors. Research data are limited to a few chemicals for a few practices on a limited number of soils under short-term climatic conditions. The only feasible way to extend these limited results to other systems is by use of mathematical models formulated to represent the multiplicity of interactions. Even for model simulation, the number of possible combinations of soils, pesticides, climates, and management is practically infinite. For general planning purposes, an alternative is to group soils and pesticides in some scheme to represent broad behavioral classes and then test the validity of the classification and establish limits using data from simulation analyses. Such groupings have been made for the Georgia Coastal Plain, and this paper describes the concepts and summarizes simulation results to convey the first steps of such a process. The Groundwater Loading Effects of Agricultural Management Systems Model (GLEAMS) (Leonard et. al., 1987) was selected for the simulations.

THE GLEAMS MODEL

GLEAMS consists of three major components: hydrology, erosion/sediment yield, and pesticides. Detailed descriptions were given previously (Leonard et. al. 1987, Leonard et. al. 1988). The GLEAMS model is an extension of the CREAMS model (Knisel, 1980) and retains the daily hydrology/soil-water-balance features, and the rill-interill soil erosion/sediment transport features along with the pesticide components for simulating degradation, foliar washoff and partitioning of pesticide between surface runoff and infiltration. The GLEAMS model additionally routes pesticides within and through the specified soil root zone depth. Several other features have also been added such as irrigation options, pesticide metabolite tracking, and software to facilitate model implementation and output data analysis. To accomplish the objectives of this application the model was modified to consider up to 12 computational soil layers instead of the original seven as in CREAMS.

To run the model, input requirements includes daily rainfall volumes for the period of simulation, crop and management parameters, soil and physical parameters for soil detachment and transport, pesticide property data such as solubility, expected half-life in soil and/or on foliage, and adsorptivity, and soil physical data by horizon to route water and chemicals. Output data includes, but not limited to, water, sediment, and pesticide masses in runoff, volumes of water percolated through the root zone, masses of pesticide percolated, and irrigation volumes required. Output frequency can be by day, month, or year. Daily or storm outputs also provide data on distribution of pesticide within the root zone.

SOIL AND PESTICIDE CLASSIFICATION

Leonard and Knisel (1988) demonstrated that a useful index for pesticide leaching potential is the pesticide half-life:pesticide adsorption constant ratio, $t_{1/2}$/Koc. Pesticide leaching potential increases as this ratio increases. For this study we placed pesticides into three classes using this ratio: I<0.1, nearly immobile;

II 0.1 to 1.0, moderately mobile; III > 1.0, very mobile. Actual pesticide movement is also strongly dependent on soil properties.

For soils of the Georgia Coastal Plain we suggest a two-level classification system as follows. At level 1, three separations are made based on texture of the surface 50 cm: A. Sandy (sands, loamy sands and coarse sandy loams); B. Loamy (fine-loamy families); C. Clayey (clayey and fine families). The 0-50 cm depth increment was chosen to differentiate the soil subgroup and to some degree the soil family classification (U. S Department of Agriculture, 1975). At level 2, the separations are based on soil characteristics of the 50-130 cm depth increment. These are: 1) sandy; 2) coarse-loamy or sandy argillic, 3) fine-loamy or clayey argillic without plinthite; 4) fine-loamy or clayey argillic with plinthite; 5) perched or natural water table; 6) genetic pan features (fragic properties); and 7) expanding lattice clays resulting in moderate to high shrink-swell potential.

The classification system proposed is illustrated in Table 1. Only series names are provided. Complete taxonomy can be obtained from Perkins (1987). In Table 1, soils grouped 1A have the greatest potential for pesticide leaching with leaching potential decreasing from 1 to 7. Leaching potential also decreases from A to C. Movement of water and chemicals through soils of groups 5, 6, and 7 will be limited by high water tables and/or subsoils with limited permeability. In these soils, shallow subsurface flows may occur and deliver water and chemicals to surface-water bodies, particularly by artificial drainage systems.

TABLE 1. GROUPING OF SELECTED SOILS AS TO INFERRED POTENTIAL FOR PESTICIDE TRANSPORT BELOW THE PLANT-ROOT ZONE (> 130 cm).

Level 2, 50-130 cm	Level 1, 0-50 cm A	B	C
1	Lakeland, Kershaw, Troup		
2	Americus, Eustis		
3	Lucy, Wagram	Goldsboro Norfolk Orangeburg	Faceville Greenville Marlboro
4	Fuquay, Leefield	Tifton Dothan	Carnegie
5	Alapaha Pelham		
6		Cowarts Irvington	
7			Duplin Sunsweet Susquehanna

MODEL SIMULATION RESULTS

Fifty-year simulations were performed using rainfall data from Tifton, Georgia, for years 1936-85. Ten hypothetical pesticides ranging in half-life from 5 to 60 days and K_{oc} from 50 to 5,000 were assumed applied to the soil surface when corn (Zea Mays) was planted on April 1 each year. Results averaged by pesticide class for three soils, Lakeland, Tifton, and Greenville are given in Table 2 for illustration. The values provide a basis for separation by soil and pesticide class. Additional simulation results would further illustrate the utility of the proposed classification system. The surface pesticide losses have an approximate inverse relation with percolation losses. However, separation of surface losses into solution phases and sediment phases will provide better correlations with soil and pesticide properties. Also, indices other than $t_{1/2}/K_{oc}$ give better correlation when considering surface losses. These aspects and a more detailed analysis of the proposed system will be provided later.

TABLE 2. SIMULATED MASSES OF PESTICIDE BY CLASS TRANSPORTED FROM SELECTED SOILS. MEANS OF 50 YEARS, 1936-85.

Soil and Pesticide Class	Losses in Surface Runoff	Losses to Percolation
	Percent of Application	
Lakeland sand		
I (<0.1)	0.07	0.11
II (0.1 - 1.0)	< 0.005	2.6
III (>1)	< 0.0001	12.2
Tifton loamy sand		
I (<0.1)	0.71	<0.005
II (0.1 - 1.0)	0.22	0.14
III (>1)	< 0.01	1.5
Greenville sandy clay loam		
I (< 0.1)	2.6	<0.0001
II (0.1 - 1.0)	1.2	0.001
III (> 1)	0.20	0.17

SUMMARY AND CONCLUSIONS

We have grouped soils and pesticides into behavioral classes based on physical and chemical properties. Potential loadings of pesticides by group in relation to soil class have been demonstrated using model simulation results. Based on this preliminary analysis, we believe that the proposed classification scheme will provide useful grouping for planners and water quality managers. In this short communication, we present only the basic concept and techniques for implementation. A classification scheme may need to be developed for each major land resource area (MLRA).

LITERATURE CITED

Knisel, W. G. (Ed.), 1980. CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. U. S. Department of Agriculture, Science and Education Administration, Conservation Research Report No. 26. 643 pp.

Leonard, R. A. and W. G. Knisel, 1988. Evaluating Ground Water Contamination Potential from Herbicide Use. Weed Tech. 2:207-216.

Leonard, R. A., W. G. Knisel, F. M. Davis, and A. W. Johnson, 1988. Modeling Pesticide Metabolite Transport with GLEAMS. Proceedings, American Society of Civil Engineers, Irrigation & Drainage National Conference, "Planning Now for Irrigation and Drainage in the 21st Century", Lincoln, Nebraska, July 18-21, pp. 255-262.

Leonard, R. A., W. G. Knisel, and D. A. Still, 1987. GLEAMS: Groundwater Loading Effects of Agricultural Management Systems. Transactions of the American Society of Agricultural Engineers. 30(5):1403-1418.

Perkins, H. F., 1987. Characterization Data for Selected Georgia Soils. Georgia Agricultural Experiment Stations, College of Agriculture, The University of Georgia. Athens. Spec. Pub. 43, 545 pp.

U. S. Department of Agriculture, 1975. Soil Taxonomy. Agriculture Handbook No. 436. U.S. Gov. Printing Office, Washington, DC, 754 pp.