Runoff and Sediment Yield Modelling
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SIMULATING EFFECTS OF FOREST MANAGEMENT PRACTICES ON PESTICIDE LOSSES WITH GLEAMS[1]

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The GLEAMS model pesticide component was modified to simulate up to 245 pesticides simultaneously, and the revised model was used to simulate pesticide application windows for forest site preparation and pine release. Fifty-year simulations were made for soils representing four hydrologic soil groups in four climatic regions of the southeastern United States. Five herbicides commonly used in the region to control competing vegetation were represented in the model study. Within the application windows for each herbicide, the best application dates, or "environmental" windows were determined to minimize environmental effects for each location. Results of the simulation study are tabulated in the paper for use in the forest industry.

INTRODUCTION

The forest industry in the southeastern United States has successfully used herbicides during the last 10 years to control competing grass and herbaceous vegetation in site preparation for pine (Pinus sp.) plantings and in pine release (Michael et al., 1990). Vegetation control alone and in combination with fertilization has resulted in significant increased pine growth (Neary et al., 1990). Runoff studies have been conducted at a number of locations to measure losses of herbicides to streamflow following site treatments (Michael and Neary, 1993). Field studies of herbicide fate cannot be replicated on the same site in successive years. Efficacy studies have been made to determine the best time period for herbicide application for vegetation control. Results of these studies have been used to estimate the "best" interval within the longer time interval (Miller and Bishop, 1989). The one-time herbicide application on a specific field site does not allow evaluation of climatic and environmental consequences of variable application dates.

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A mathematical model called GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) was developed by Leonard et al. (1987) to assess the complex interactions of soil-climate-management for field-size areas on a long-term basis. Although GLEAMS was developed primarily for crop and pasture lands, Nutter et al. (1993a) added an option to consider application on forest sites as well. GLEAMS model applications have been made to assess the long-term environmental impact of insecticide use in Southeastern forests (Nutter et al., 1993b).

GLEAMS was validated for agricultural crops (Leonard et al., 1987), and for forested areas (Nutter et al., 1993). A study is currently underway to evaluate forest streamside management zones at the locations included in this paper. Although the results have not been published, the model simulations made thus far compare favorably with observed measurements of runoff and pesticide losses.

Leonard et al. (1992) made 50-year GLEAMS simulations to examine the probabilities of year-to-year pesticide losses for a 20-day planting window for corn (Zea maize, L.). These were compared with 50-year means and standard deviations to consider potential for extreme or "worst case" situations.

The purpose of this paper is to demonstrate the use of the GLEAMS model to determine the best herbicide application periods to minimize potential environmental impacts. Four locations with different soils were selected for simulation with herbicides using a 50-year climatic record at each site. The "environmental" window is compared with the "application" window for management recommendations.

METHODS OF ANALYSES

The GLEAMS model was developed to assess edge-of-field and bottom-of-root-zone loadings of water, sediment, and chemicals for comparing alternate management strategies using long-term simulation results. GLEAMS is a continuous simulation model with a daily time step, and consists of hydrology, erosion, pesticide, and plant nutrient components. The hydrology component uses daily climatic data and simulates the water balance components including surface runoff and percolation below the root zone. The erosion component computes soil detachment and sediment transport to the edge of the field. The pesticide and plant nutrient components compute pesticide, nitrogen, and phosphorous transformations, and calculates their transport in the solution and adsorbed phases. Up to 10 pesticides can be represented in a single simulation. Comparisons of long-term simulation results enable the user to make sound management decisions based upon relative loadings. Alternatives that can be evaluated include selection of herbicides and dates of application. GLEAMS model version 2.03 was modified to consider up to 245 pesticides simultaneously in a single computer run. This modification made it possible to consider 1 pesticide applied on as many as 245 days by naming the pesticide with successive numbers and using the same pesticide characteristics for all applications. For example, Roundup was applied on day 1 of the application window as Roundup 1, Roundup 2 was applied on day 2 of the window, and so on to Roundup 245, each with the same characteristics. It is recognized that herbicide half-life may change due to climatic differences within the application window, but the same values were used throughout the window. Losses for each herbicide were kept separate in the simulation and reported separately. Model output includes annual losses and the final total losses in runoff, adsorbed onto sediment, and in percolation.

Herbicide applications are not made each year, but climate is different every year. The model was applied for 50 consecutive years of observed climate, but the same cover (canopy) was assumed for each year. In essence, this gives one treatment and 50 replications in time. The final results represent a significant sample of year-to-year changes in climate.

The USDA-Forest Service conducted herbicide efficacy and fate studies at sites in Alabama, Florida, and Mississippi in the southeastern United States. Four locations were selected for this study to provide a range of soils and surface slopes as shown in Table 1. Fifty-year climatic records at nearby locations were obtained for model simulations. The 50-year mean annual rainfall is shown in Table 1 for each site.

Table 1. Location, site characteristics, and soils for GLEAMS model simulation.

County	State	Annual Rainfall	Soil Series Soil Texture	Soil Order	Hydrologic Soil Group	Drainage Area	Average Slope
		mm				ha	%
Coosa	Alabama	1346	Tallapoosa sandy loam	Ultisol	C	71	4.6
Fayette	Alabama	1423	Ruston fine sandy loam	Ultisol	B	42	5.9
Alachua	Florida	1303	Pomona fine sand	Spodosol	A	4	0.6
Noxubee	Mississippi	1325	Wilcox silty clay loam	Alfisol	D	11	3.1

Herbicides commonly used by the forest industry for site preparation for pine plantings in the Southeastern U.S. were considered in this study. The 5 compounds, their characteristics, the application windows, and application rates are shown in Table 2. The half-life data are representative for the climatic and soil region. The application windows and rates are for site preparation rather than for pine release. Although the differences are minor in most cases, only the site preparation application is considered here due to the space limitation for the paper.

Table 2. Herbicide characteristics and application windows for GLEAMS model simulation.

Herbicide Trade Name COMMON NAME	Water Solu-bility	KOC	Half-Life Soil	Half-Life Foliage	Wash-off Fract.	Application Window	Application Rate*
	ppm	l/g	days	days			kg/ha
Arsenal IMAZAPYR	11,000	100	65	30	0.90	5/1 - 10/31	2.24
Oust SULFOMETURON METHYL	70	78	20	10	0.65	2/1 - 05/31	0.42
Roundup GLYPHOSATE AMINE	900,000	24,000	47	3	0.60	8/1 - 10/31	5.60
Velpar-Liquid HEXAZINONE	33,000	54	77	30	0.90	3/1 - 05/31	2.24#
Velpar-Granules HEXAZINONE	33,000	54	77	@	@	2/1 - 04/30	1.68

* Application rate of active ingredient for site preparation
# Not applied on sandy soil
@ Not applied on foliage

RESULTS AND DISCUSSION

Fifty-year simulations were made for each of the four sites listed in Table 1 for each herbicide listed in Table 2 except Velpar-liquid which was not modeled on the Spodosol at Alachua County, Florida, due to label restrictions. Since GLEAMS does not consider pesticide toxicity and the health advisory levels do not apply at field's edge or bottom of root zone, only herbicide losses can be examined in this study. Losses with runoff, sediment, and percolation are expressed as percentage of application rate, and are therefore unitized.

A 3-D plot was made for each herbicide and each site to show year-by-year losses as a function of application date. Rainfall distribution within the year was reflected in the graphs. Only a simple example with a 2-D graph is shown here to illustrate the procedure. The 50-yr percolation losses of Oust and Velpar granules are shown in Figure 1 since the application window for both herbicides begins on February 1 with 120 and 89 days in the window, respectively.

Figure 1 indicates that Oust may be the preferred herbicide to minimize potential groundwater quality impact. Oust is applied at one-fourth the rate of Velpar granules (Table 2), and the percent percolation loss of Oust is less than one-fourth that for Velpar granules (Figure 1). Figure 1 shows that leaching losses of both herbicides decline with time in the window. This is due to high soil water conditions on February 1 with increasing evapotranspiration and decreased leaching later in the application window.

Similar comparisons of simulation results were performed for all locations and herbicides. Runoff, sediment, and percolation losses were examined, and the results are summarized in Table 3.

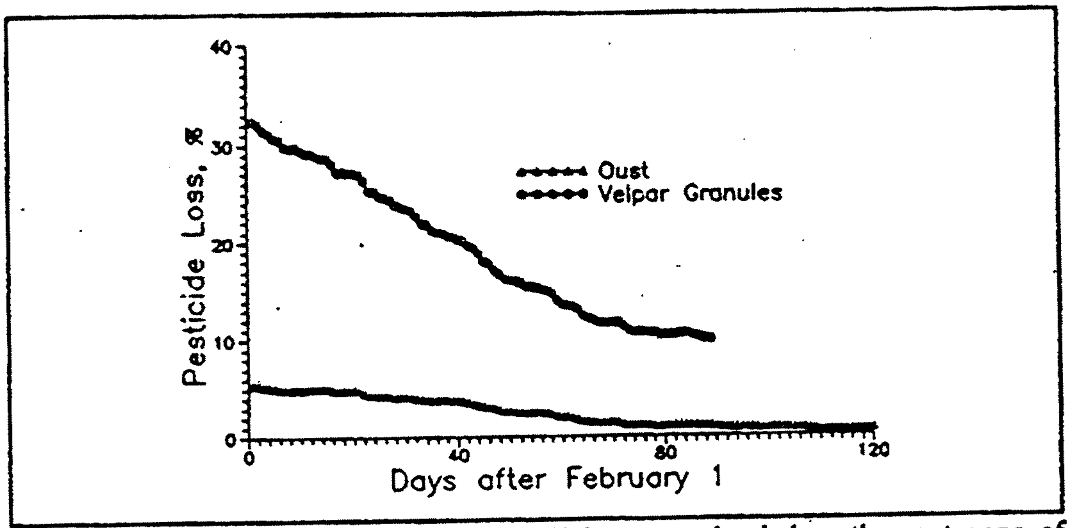

Figure 1. Leaching losses of Oust and Velpar granules below the root zone of Tallapoosa micaceous sandy loam, Coosa County, Alabama

Table 3. Herbicide application windows based upon 50-year average runoff, sediment, and percolation losses compared with "best" window for vegetation control.

	Herbicide				
	Arsenal	Oust	Roundup	Velpar Liq.	Velpar Gran.
Application Window	5/01-10/31	2/01-5/31	8/01-10/31	3/01-5/31	2/01-4/30
Best for Control	7/01-09/30	3/05-4/10	8/01-10/20	3/05-4/25	N/A
Environmental Window					
Coosa Co., AL	5/01-06/25	4/01-4/30	8/01-08/28	4/05-5/31	4/08-4/30
Fayette Co., AL	5/01-06/25	5/01-5/31	8/01-08/31	5/09-5/31	4/15-4/30
Alachua Co., FL	9/24-10/31	2/01-5/31	8/01-10/31	—	4/05-4/17
Noxubee Co., MS	5/01-06/25	5/20-5/31	8/01-09/10	4/25-5/31	4/14-4/30

The influence of climate can be seen among the locations for Arsenal, Oust, and Velpar. The best "environmental" window in Table 3 is based upon the 50-year averages. Year-to-year climatic affects are masked, but the window selection is valid. The environmental windows may differ significantly from the best window for vegetative control.

Roundup and Oust are of least environmental concerns at the Florida site since runoff and sediment yield were not predicted. Although this study does not consider toxicity, Oust appears to be "environmentally kinder" at all locations because of the relatively low application rate and the relatively low percentages of losses among runoff, sediment, and percolation. The long application window for Arsenal extends through the high evapotranspiration season into the late summer/early autumn rainy season of Alabama and Mississippi. Thus, the environmental window occurs in the early part of the application period at those locations. However, the summer rainy season and fall dry season in Florida results in the late environmental window for Arsenal. Due to space limitations, simulated runoff, sediment yield, percolation, and associated herbicide losses are not shown.

SUMMARY

Model simulations in this study show how forest herbicide management alternatives can be assessed with the GLEAMS model. Alternate herbicide selection and recommended application dates were analyzed for different climatic and soil regions. The study indicates that blanket geographical recommendations should be avoided without similar long-term model analyses. Interactions of soils, slope, climate, and pesticide characteristics affect the environmental window.

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