Auburn University
Southern Forest
Nursery Management
Cooperative

# RESEARCH REPORT 00-7

## USING THE GLEAMS MODEL TO SIMULATE NITRATE NITROGEN AND PESTICIDE LEACHING FROM FOREST TREE NURSERIES

by
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**INTRODUCTION**

Forest tree nurseries in the South are frequently located on sandy soils. As a result, soil moisture retention is relatively low and water generally moves easily through the soil profile. At the same time, nursery culture requires the use of both fertilizers and pesticides. A common fertilizer application rate for the southern pine species is 168 kg of N/ha split into 5 or 6 equal applications. Hardwoods often receive amounts from 358 and 440 kg of N/ha split into 8-12 increasingly larger applications. It is estimated that 50 to 70 % of the N applied is taken up by the pine crop (May 1985). The 30 to 50 % not taken up can be immobilized, lost as runoff, lost in volatilization, or leached. The nitrate anion ($NO_3^-$) is very soluble in water and moves with the wetting front of infiltrating rainfall and irrigation. Groundwater contamination from fertilizers used in nursery production is therefore an area of concern. Similarly, some pesticides also leach depending on solubility. Some, like oxyflourfen are highly insoluble, whereas others, like dacthal are much more mobile in the soil.

The GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) model was developed by the Agricultural Research Service (USDA) to predict the potential loss of fertilizers and pesticides through leaching. It has the potential to be a useful tool for selecting management options. However, it was developed specifically for agricultural crops, and consequently, values for many of the model variables are not available for forest seedlings. The objective of this project was to use the GLEAMS model to calculate the potential leaching from forest tree nurseries and to compare several management scenarios.

**METHODOLOGY**

The GLEAMS model involved several steps:

1) The variables in the model (over 200) were reviewed to determine if crop specific (field) data would be necessary. Most of the variables, such as climate data, soil data, nursery management practices were obtained in the GLEAMS manual, weather records, and nursery personnel.
2) The model was run to simulate a 48 year period for the following management scenarios;
    a. 1:1, 2:2, and 2:1 pine seedling and cover crop rotations.
        A "standard" fertilization regime for pine included 168 kg/ha of N applied as ammonium nitrate and 166.5 kg/ha applied to cover crops.
    b. 1:1, 2:2, and 2:1 hardwood seedling and cover crop rotations.
        A "standard" fertilization regime for sweetgum included 440.5 kg/ha of N applied as ammonium nitrate and 166.5 kg/ha applied to the cover crop.
    c. five application rates of nitrogen in both pine and hardwood culture:
        112, 168, 224, 280, and 335 kg/ha of nitrogen.
    d. Different application timings for pine seedling fertilization.
3) The GLEAMS model was also used to simulate pesticide leaching. Table 1 provides a list of chemicals that were included in the models.

**Table 1.** Pesticides used in GLEAMS simulations, application rates and predicted movement out of the root zone.

| Trade Name | Common Name | Class | Application Rate (kg/ha) | Number of Applications | Movement out of Root Zone (%) |
|---|---|---|---|---|---|
| Goal | oxyfluorfen | herbicide | 0.448 | 4 | 0 |
| Reflex | fomesafen | herbicide | 0.280 | 1 | 0 |
| Cobra | lactofen | herbicide | 0.112 | 2 | 0 |
| Vantage | sethoxydim | herbicide | 0.140 | 3 | 0 |
| Asana | esfenvalerate | insecticide | 0.038 | 4 | 0 |
| Bayleton | triadimefon | fungicide | 0.280 | 4 | 0 |

## RESULTS

### Pesticide Movement

The results of using the GLEAMS model for simulating pesticide movement indicated that none of the pesticides modeled showed any movement out of the root zone.

### Nitrate Movement

The predicted amount of nitrate nitrogen leached under the three different pine crop rotation systems was less for the 1:1 and 2:2 rotations than for the 2:1 rotation (Table 2). Over a 48 year modeling period, 2:1 rotations averaged 26% more nitrate leaching than the 2:2 rotation system (86 vs 68 kg/ha/yr, respectively). Interestingly, both cover crops and seedling crops had similar amounts of leaching loss in the 2:1 system. This was not true for the 1:1 and 2:2 rotations, however, as the 1:1 averaged a higher nitrate loss from the cover crops than from the seedlings. The opposite was true for the 2:2 rotations.

**Table 2.** Predicted amount of $NO_3$-N leached annually from loblolly pine, sweetgum, and cover crops grown under three different rotation systems for 48 years.

| | Seedling/Cover Crop Rotation | | |
|---|---|---|---|
| | 1:1 | 2:2 | 2:1 |
| Loblolly Pine | | kg/ha/yr | |
| $NO_3$-N Leached During Simulation | 65 | 68 | 86 |
| $NO_3$-N Leached From Seedling Crop | 53 | 92 | 87 |
| $NO_3$-N Leached From Cover Crops | 78 | 44 | 82 |
| Sweetgum | | | |
| $NO_3$-N Leached During Simulation | 163 | 164 | 216 |
| $NO_3$-N Leached From Seedling Crop | 112 | 193 | 202 |
| $NO_3$-N Leached From Cover Crops | 214 | 134 | 244 |

As expected, the amount of nitrate nitrogen lost in sweetgum management was considerably more than pine. The rotation systems behaved the same as the pine. The 2:1 system resulted in increased leaching potential. The 1:1 system resulted in comparatively more leaching from the cover crops while the 2:2 rotation had more losses from the seedling crops. Field sampling in the two modeled nurseries and subsequent tissue analysis indicated that 63% and 36% of applied nitrogen was actually taken up by pine and sweetgum, respectively. Apparently, the cover crops are acting as an uptake mechanism for the extra nitrogen applied to both the pine and sweetgum seedling crops. The amount leached over the 48 year modeling period is closely tied to the ability of cover crops to use this extra nitrogen.

**Table 3.** Percent of applied nitrogen predicted to leach over 48 years from a 2:2 rotation of loblolly pine and cover crop when fertilized with ammonium nitrate at five different levels.

| | N Application Rate (kg/ha/yr) for Pine Crop† | | | | |
|---|---|---|---|---|---|
| | 112 | 168 | 224 | 280 | 336 |
| | | | percent of nitrogen leached | | |
| $NO_3$-N leached during simulation | 37 | 41 | 45 | 48 | 48 |
| $NO_3$-N leached from seedling crop | 64 | 55 | 51 | 49 | 46 |
| $NO_3$-N leached from cover crops | 19 | 27 | 35 | 46 | 53 |

† 111 kg N/ha to millet and 55.5 kg N/ha for winter rye in any given cover crop year.

Table 3 presents the predicted nitrogen leached by a 2:2 pine rotation when different amounts of ammonium nitrate are used for pine cultivation. As expected the percent of nitrogen applied that is lost through leaching increases with the amount applied. Interestingly, however, the percent of nitrogen lost in the pine crop decreases with increasing fertilization levels, while the percentage lost from the cover crop (whose fertilization rates are held constant) gradually increases. One can speculate that as more nitrogen is applied, seedlings are responding by getting larger and utilizing more nitrogen. The cover crops, on the other hand are not able to uptake both the fertilizer applied for cover crop cultivation as well as the carryover from the pine seedling crop. This further indicates the importance of cover crops in overall nursery fertilization management.

Table 4 presents the predicted amount of nitrate nitrogen leached from loblolly pine and cover crops for different application regimes. A single bulk application of ammonium nitrate at the beginning of the pine growing season resulted in a predicted seedling crop leaching potential of 63 kg/ha/yr, while 10 applications over 12 weeks resulted in only 51 kg/ha/yr for a 1:1 rotation. By spreading out the nitrogen applications to the pine crop, the amount of nitrogen leached decreased by 20%. The 2:2 rotation reduced nitrate nitrogen loss by 11% by spreading out the applications. In both cases, there was very little effect on leaching when spreading from 5 applications to 10. In both cases, leaching from cover crops increased when going from one bulk application (to the pine crop) to 10 applications.

**Table 4.** Amount of nitrogen predicted to leach over 48 years from loblolly pine and cover crops when fertilized with ammonium nitrate at three different fertilization regimes.

| | $NO_3$-N Leached by Rotation Type (kg/ha/yr) | | |
|---|---|---|---|
| | 1:1 | 2:2 | 2:1 |
| Single Bulk Application | | | |
| Seedlings (168 kg/ha rate) | 63 | 102 | 95 |
| Cover Crop (166.5 kg/ha rate)† | 71 | 36 | 71 |
| Five Applications Over 8 Weeks | | | |
| Seedlings (5 x 33.6 kg/ha) | 53 | 92 | 87 |
| Cover Crop (166.5 kg/ha)† | 78 | 44 | 82 |
| Ten Applications Over 12 weeks | | | |
| Seedlings (10 x 16.8 kg/ha) | 51 | 91 | 86 |
| Cover Crop (166.5 kg/ha)† | 80 | 46 | 85 |

† 111 kg N/ha to millet and 55.5 kg N/ha for winter rye in any given cover crop year.

## MANAGEMENT IMPLICATIONS

The GLEAMS model output should not be used for quantitative assessment of leaching potentials. In other words, the 53 kg/ha/yr that the model predicts as the amount leached by pine seedling crops in a 1:1 rotation, may or may not be correct. The fact the model under-predicts pine seedling uptake at only 51 kg/ha/yr (30% of applied N) indicates the model still needs to be refined for forest tree nursery crops. We know from tissue analysis the correct number os closer to 60% of applied N.

The GLEAMS model can be expected, however, to provide a relative comparison between management options. First, the 2:1 rotation system results in more leaching loss than either 1:1 or 2:2 systems. Second, the cover crop is an important and integral part of fertilizer management. Leaching losses should not be evaluated on a single crop basis, but on a multiple year basis and within a rotation system. Third, the importance of cover crops in nitrogen uptake and maintenance increases as pine fertilization levels increase. Fourth, the typical application scenario of spreading pine N applications over 5 applications is quite efficient in terms of nitrogen loss, and the model predicts little gain from spreading it out further. Finally, as has been indicated by earlier Coop studies where pesticide leaching was actually measured, applications of forest tree nursery pesticides commonly used in the South should not result in groundwater contamination through leaching.