Integrated Analysis of Weed Management Practices to Reduce Atrazine Contamination in a Missouri Watershed

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Acknowledgement

The project was supported by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service (CSREES), grant number 2003-35101-13823.

Problem

- Atrazine is the most widely used herbicide in corn and soybean production, and has been detected in more than 90 percent of raw drinking water samples collected in northern Missouri.

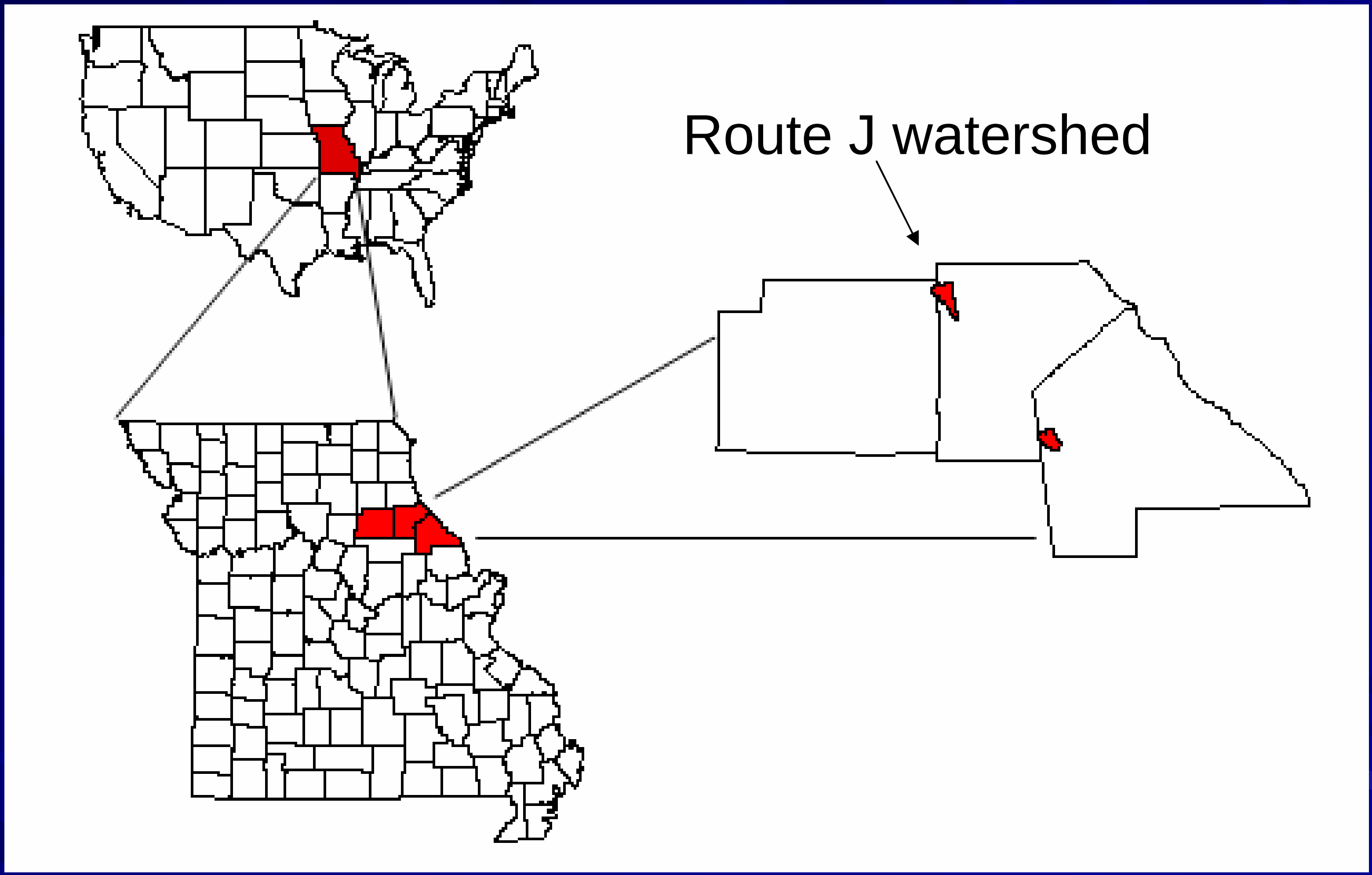
- Half the samples had atrazine concentrations that exceeded the maximum contaminant level (MCL) of 3 ppb.

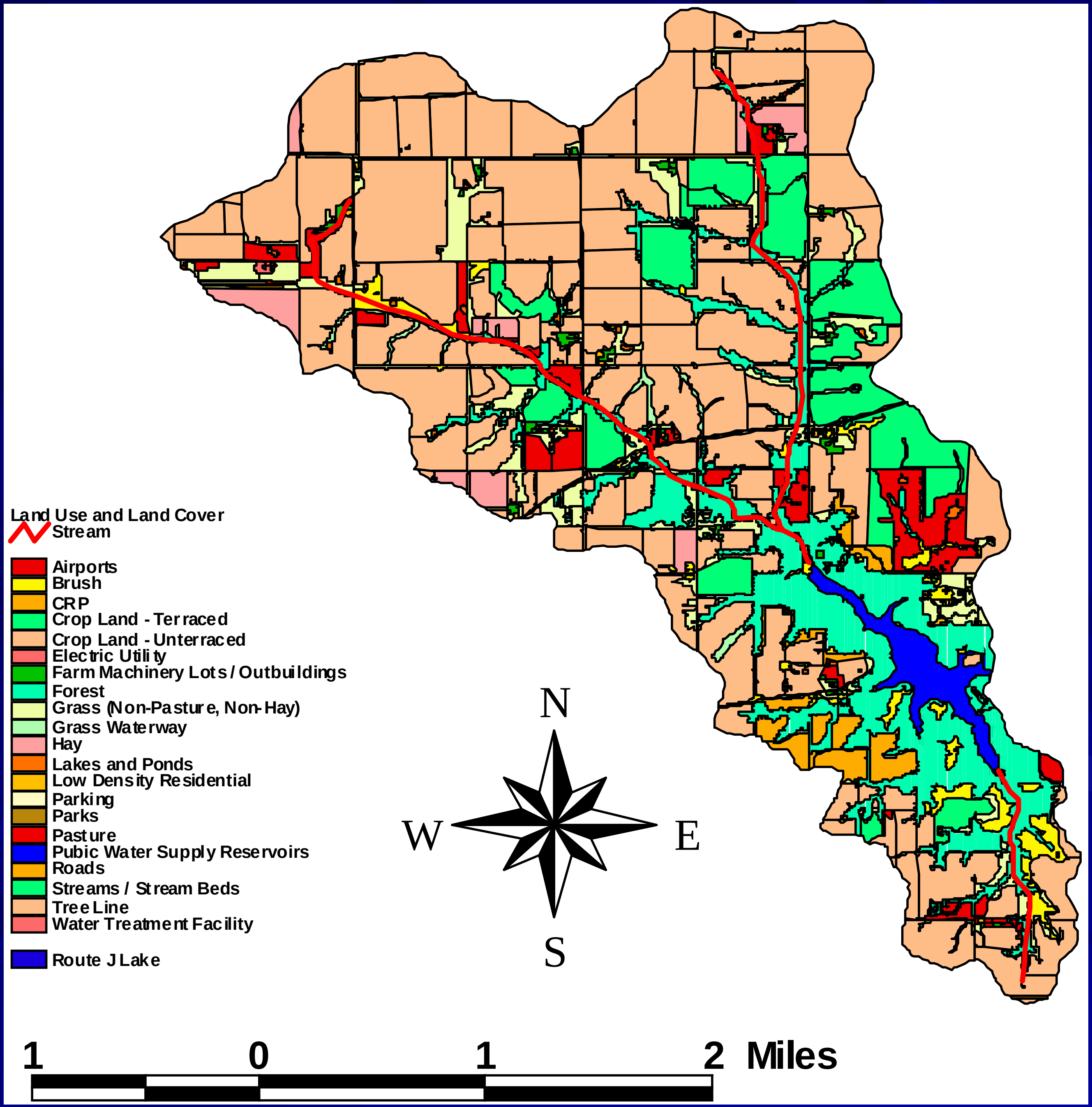
Objective of Study

To develop an integrated model that identifies profitable and effective weed management practices for reducing atrazine contamination of a drinking water supply in northwest Missouri.

Study Area

Route J watershed is in Monroe City, Missouri in the northwest corner of Monroe County, approximately 20 miles west of Hannibal.


Route J watershed



Route J watershed

Total land = 5,155 acres

Cropland = 3,376 acres (65% of total land area)

Reservoir = 96 acres

- In 1994, quarterly average concentrations of atrazine in treated water samples from the Route J reservoir, which is the secondary drinking water supply for Monroe City, exceeded the MCL of 3 ppb established by EPA.
- Route J watershed is on Missouri’s 303(d) list of impaired water bodies.

- Herbicides were custom applied to 73% of the corn acreage in 2001.
- Most producers in the watershed use a two-pass system of weed control that combines pre-emergence and post-emergence herbicide application.
- The main soil type in the watershed is claypan, which has a clay horizon 6 to 9 inches below the soil surface.

- The claypan limits infiltration and crop root growth, and contributes to high rates of soil erosion and runoff.

Other Studies

- Johnson et al. (1996) stated that reducing the rates of post-emergence or two-pass atrazine application can reduce atrazine in surface runoff in Missouri.
- Most previous studies that address the impact of herbicides on water quality fail to account for crop yield responses to herbicides for different weed varieties and weed populations (i.e., crop-weed competition), and the lifecycle of crops and weeds.

- Integrated pest management incorporates the economic threshold (ET) concept, which is useful in achieving effective weed management (Coble and Mortensen 1992; Black and Dyson 1993; Zanin et al. 1993; Sartorato et al. 1996).

- Weed management based on a bioeconomic model that incorporates the ET concept can reduce environmental damages caused by herbicides and maintain farm profitability (Marra and Carlson 1983, Marra et al. 1989, and Deen et al. 1993).
- Few economic studies use a bioeconomic model based on the ET concept (Saphores 2000).

- WeedSOFT® is a useful bioeconomic model for simulating the long-term environmental impacts of alternative weed management practices (Park et al. 2003).

Overview of Method

- A bioeconomic model (WeedSOFT®) is used to simulate net returns per acre in corn production for alternative weed varieties and management practices that utilize atrazine and other herbicides.

- A biophysical model (Soil and Water Assessment Tool or SWAT) is used to simulate atrazine concentrations in surface runoff in the watershed for alternative weed management practices.

Bioeconomic Model

- WeedSOFT® was used to simulate crop yield losses for corn based on specified weed and crop conditions.
- Weed-crop conditions refer to weed species and populations, crop production stage, and possible maximum yield (PMY) for crops under weed-free conditions.
- PMY for corn was set at 100 bu/acre.

- Since data were not available for weed species and weed populations, 10 weed species were selected for evaluation.
- It was assumed that weed species were uniformly distributed over all cropland in the watershed.

- The 10 weed species were classified into two groups: Group A having a high competitive index (CI) and Group B having a low CI.

Competitive indices for two weed groups used in WeedSOFT® Simulations

Group	Weed	Competitive Index
A	Giant Ragweed	4.0
	Velvetleaf	4.2
	Common Cocklebur	5.5
	Morning Glory	5.5
	Sunflower	10.0
B	Hempdogbane	1.0
	Common Ragweed	1.5
	Fall Panicum	1.5
	Common Waterhemp	2.5
	Giant Foxtail	3.0

Source: Johnson et al. (2001).

- Nine scenarios were simulated comprising different combinations of low, intermediate, or high weed populations for groups A and B, as follows:

Weed population scenarios used in WeedSOFT® simulations

Scenario	Weed Population of Group A (High CI)	Weed Population of Group B (Low CI)
1	Low	Low
2	Low	Intermediate
3	Low	High
4	Intermediate	Low
5	Intermediate	Intermediate
6	Intermediate	High
7	High	Low
8	High	Intermediate
9	High	High

Biophysical Model

- SWAT was used to simulate atrazine concentrations in surface runoff entering Route J watershed for various weed management practices.

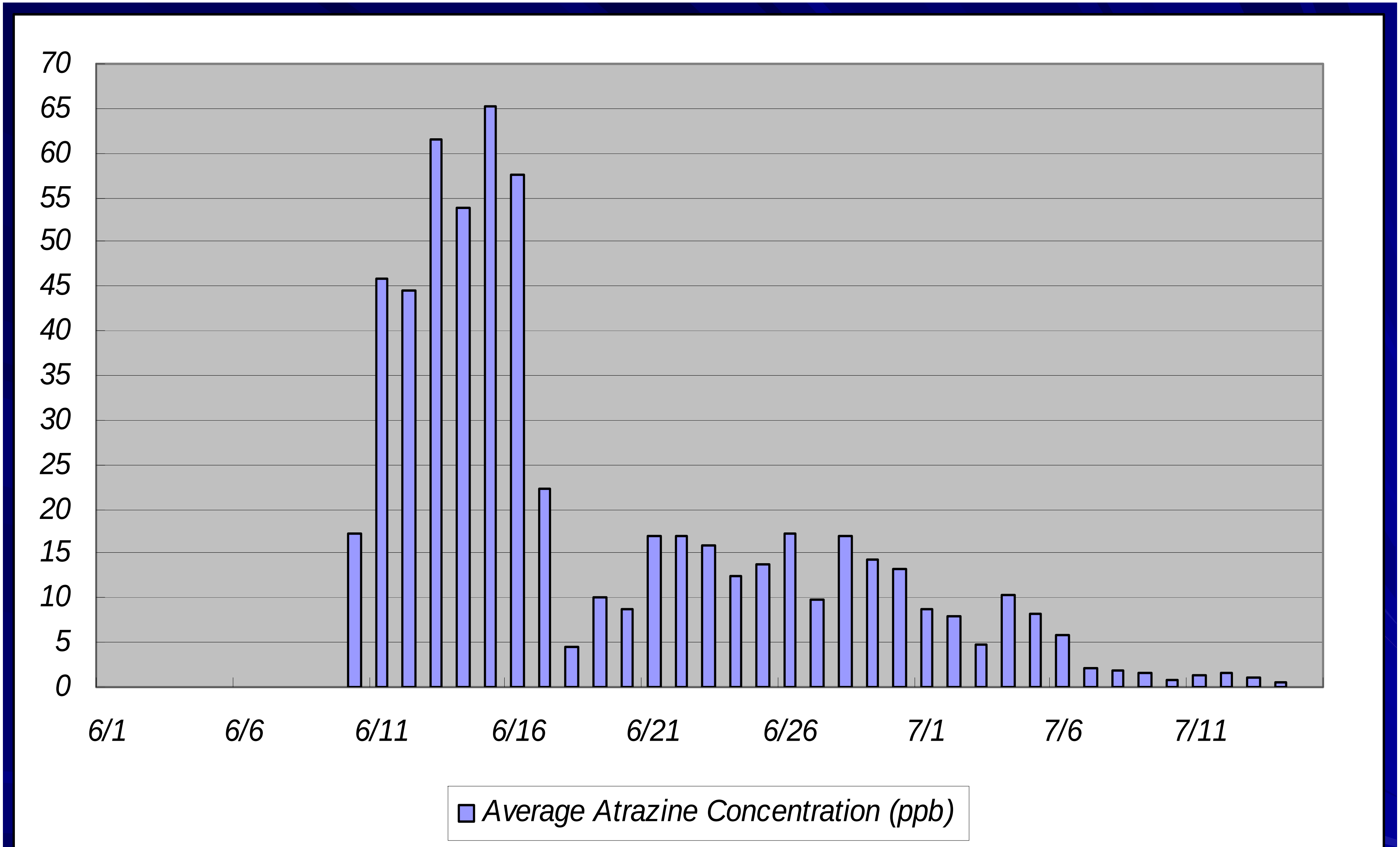
- For modeling purposes, the Route J watershed was divided into nine sub-basins and 28 hydrologic response units based on stream flow patterns and soil types.

Baseline SWAT Simulation

- A baseline simulation was used to validate the SWAT model for the Route J watershed.

- The baseline simulation assumed a corn-soybean-wheat rotation with minimum tillage and application of atrazine on June 10^{th} as a post-emergence weed treatment at a rate of 1 lb a.i./acre.

- Baseline simulated runoff volume as a percent of annual precipitation was reasonable.
- Baseline simulated average annual atrazine loss for the watershed was 5.4% of the total amount applied.



Baseline simulated June-July average atrazine concen. in runoff for Route J watershed, 1990-2003

Evaluation of Alternative Weed Management Practices

- The bioeconomic model was used to evaluate a two-pass weed treatment system in which corn is planted May 1 and harvested October 20, and pre-emergence and post-emergence herbicides are applied May 8 and June 10, respectively.
- No tillage was assumed.

- WeedSOFT® was used to evaluate every possible herbicide combination for the pre-selected weed species and their populations.

- The price of corn was set equal to \$2.32/bu, which was the forecasted corn price in Missouri for 2004.

Pre-emergence Results

- 46 possible pre-emergence herbicide treatments were simulated; 12 do not use and 34 do use atrazine.
- Scenarios 1, 4, and 7, which have relatively low weed populations, had the highest number of treatments with positive net returns.

- All high weed population scenarios and most intermediate weed population scenarios required atrazine to achieve positive net returns.
- Pre-emergence + Cultivation (at post-emergence) treatments rely less on atrazine application to achieve positive net returns.

- The additional cost of cultivation makes this treatment less profitable than the pre-emergence-only treatment.
- In summary, pre-emergence use of atrazine was profitable, but resulted in very high concentrations of atrazine in surface runoff; an unfavorable tradeoff.

Post-emergence Results

- 67 possible post-emergence herbicide treatments were simulated; 47 did not use and 20 did use atrazine.

- Post-emergence was more effective than pre-emergence weed treatments in reducing corn yield losses due to weed competition.

- The rate of post-emergence weed treatments with positive net returns was almost twice what it was for pre-emergence weed treatments.
- Except for scenarios 1, 4, and 7, which have low weed populations for weeds and low CI, post-emergence treatments that did not use atrazine were more profitable than treatments that used atrazine.

- In most cases, average annual atrazine concentrations in runoff were below 3 ppb for post-emergence treatments that utilized atrazine.
- A two-pass system that used only post-emergence application of atrazine was found to be effective in reducing atrazine concentrations in surface runoff.

- Post-emergence weed control was more profitable and resulted in less atrazine contamination of surface water than pre-emergence weed control.

- Finally, timely mechanical and cultural weed management was effective and profitable in some situations.

Conclusions

For corn production in Route J watershed:

- Applying atrazine at the pre-emergence stage is profitable only when weed populations are high.
- The most profitable weed management practices for post-emergence and two-pass systems do not use atrazine.

Implications

There exists:

(1) a significant potential to reduce atrazine contamination of surface waters in watersheds for which corn is a major crop; and

(2) a significant role for new herbicide mixes that do not use atrazine or substitute cultural practices for herbicides.

Questions and Comments