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Project Summary

Preliminary Testing, Evaluation and Sensitivity Analysis for the Terrestrial Ecosystem Exposure Assessment Model (TEEAM)

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This report documents an initial testing and sensitivity analysis of the Terrestrial Ecosystem Exposure Assessment Model (TEEAM). TEEAM calculates the exposure concentrations of plants and animals to contaminants in terrestrial ecosystems.

This project was performed in two phases. First, a sensitivity analysis was performed using a simple system--an American robin inhabiting a typical peanut field in Georgia that had been treated with diazinon. The primary food source for the robin was the earthworms living in the pesticide-contaminated soil. Second, an intensive model testing and evaluation effort was undertaken to examine each major model component. Results of the testing suggest that continued model development should focus on better simulation of surface ponding, plant transport, and uptake by soil dweller and aboveground insect populations.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Understanding the impacts of pesticides and other toxic substances on wildlife is a significant environmental concern. The Terrestrial Ecosystem Exposure Assessment Model (TEEAM) was developed to allow the environmental analyst to compute the level of wildlife exposure in evaluating the registration or regulation of specific pesticides. TEEAM is a logical extension of the Pesticide Root Zone Model (PRZM), which estimates pesticide leaching and runoff from agricultural watersheds. TEEAM couples the physical transport processes represented in PRZM with transport into plants, soil-dwelling organisms, and wildlife. It is a short-term exposure model with a weekly to seasonal time frame with particular emphasis on 30-day exposure scenarios.

This report documents the initial testing, debugging, and sensitivity analysis for the TEEAM model. The analysis was performed in two phases. First, under contract to USEPA's Woodward-Clyde, the developer of the original model, performed a sensitivity analysis on the model for a simple ecosystem, i.e., an American robin inhabiting a typical commerical peanut production field in Georgia that had been treated with diazinon. The primary food source for the robin was earthworms living in the treated soil. Second, an intensive model testing and evaluation effort was undertaken by the Assessment Branch, Environmental Research Laboratory, Athens, GA.

Model Overview

The TEEAM model simulates (1) toxicant application/deposition; (2) soil and atmospheric transport and transformation; (3) plant growth, uptake, translocation, and fate; and (4) terrestrial food chain bioaccumulation and biomagnification processes. Calculations are made in a time-variable mode and temporal resolution is on a daily basis. A schematic of

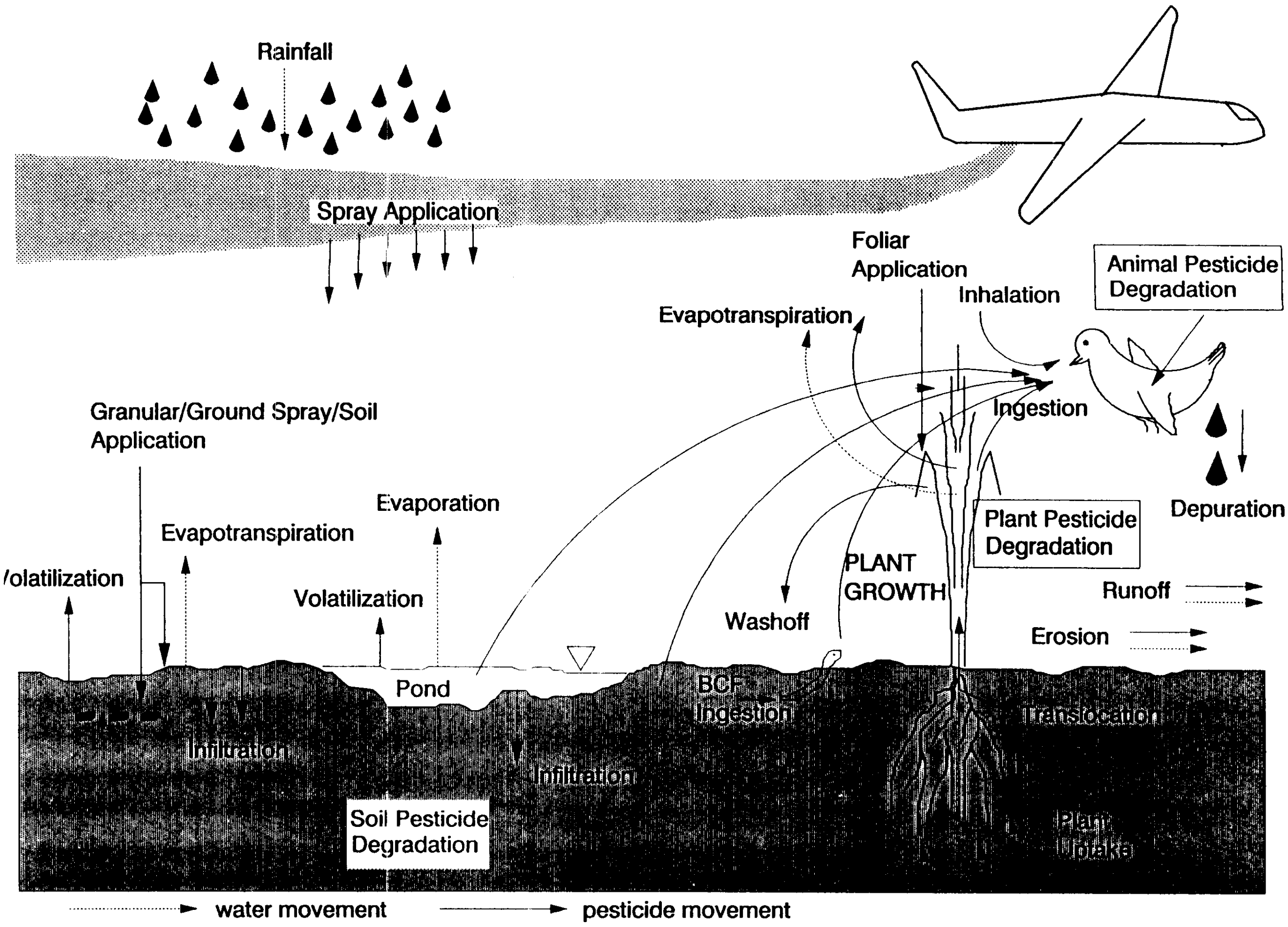

Figure 1. Processes represented in TEEAM.

processes represented in the model is shown in Figure 1.

Simulation of the principal model processes are handled by five computational subprograms. A toxicant application/ deposition submodel calculates a spatial distribution of a pesticide based on meteorological factors and application techniques. This submodel contains FSCBG, a model developed by the USDA's Forest Service to compute spray drift from aerial applications, that includes options for simulating the direct application of chemical to foliage, soil surfaces or subsurfaces, and for evaluating a time release granular formulation.

A terrestrial fate subprogram (TFAT) calculates the system water balance; movement of contaminant in the soil root zone; and loss of contaminant from the soil through degradation, volatilization, plant uptake, runoff and erosion. TFAT is based on the PRZM model with enhancements to calculate volatilization and losses through surface pond formation.

Plant growth is simulated to predict the deposition of contaminant on the canopy and soil and the uptake and translocation of contaminants from the soil into the plant either to estimate animal exposure, to predict direct effects on plants themselves, or to adjust the total mass balance. The plant growth model in TEEAM was adapted from the USDA's Erosion Productivity Calculator (EPIC).

The plant contaminant transport module calculates the amount of contaminant that enters the plant and the concentration of contaminant within and on the plant biomass. Plant transport is simulated as a two-compartment model, i.e., aboveground plant parts and below-ground roots. No distinction is made at present between different above-ground plant parts.

The animal pesticide uptake module calculates dosage to, and concentration of, pesticides in soil-dwelling organisms and above-ground habitat-mobile organisms. Calculations made in previous modules provide concentrations of toxicant in the medium that the animal ingests. In addition, food chains may be specified, and animal exposure may occur by ingestion of prey animals. Aboveground animals may move between habitats, and media concentrations are calculated in each of these habitats as described above.

Results of Sensitivity Study

A sensitivity analysis for a robin living in a single habitat eating earthworms in a diazinon-treated field was performed allowing variation of 19 input variables with 500 Monte Carlo simulations. Parameters that were allowed to vary include: soil bulk density, adsorption partition coefficient, wilting point water content, field capacity water content, soil hydraulic conductivity, decay rate in soil, decay rate on foliage, Henry's Law constant, pesticide application rate, root reflection coefficient, decay rate in plants, octanol water partition coefficient, runoff curve number, bioconcentration factor for earthworms, metabolic degradation rate in target species, total feeding rate, soil preference factor, pond water ingestion rate, and air inhalation rate.

For this simple example, the most important parameters controlling dosage to and concentration within the robin was total application mass, bioconcentration factor for earthworms, total feeding rate, soil bulk density, decay rate in soil, soil preference factor, and soil pesticide partition coefficient. However, these results are for a very simple system and are specific to the particular system. Chemical properties and specifics of the organisms would greatly alter the parameters to which the system is sensitive.

Module Testing

Response of each transport function in TEEAM was tested and evaluated separately. First, the TFAT portion of TEEAM was compared to PRZM results for a nonvolatile pesticide under conditions where ponding did not occur, i.e., conditions where TEEAM results should replicate PRZM results. TEEAM performance was satisfactory in this basic comparison to PRZM.

Next, TFAT performance for the two major modifications to PRZM, i.e., pond formation and chemical volatilization were evaluated by (1) examining the response of pond formation with respect to soil characteristics and meteorological conditions and (2) examining the response of volatilization flux to Henry's Law constant for the chemical and meteorological conditions.

The ponding formulation in TEEAM must be parameterized in a counterintuitive way in order for ponds to form; i.e., ponding occurs only when SCS curve number values are set at values for a soil with a large infiltration capacity. This approach is not satisfactory for development of a model with a prior predictive capability. Volatilization fluxes increased proportionally to an increase in Henry's Law constant as expected. Volatilization fluxes decreased during rainfall events. For some chemicals, volatilization losses from soil have been shown to be lowest under drought conditions indicating that TEEAM's volatilization algorithm may need some modification.

Total uptake of pesticide by plants was somewhat different for PRZM and TEEAM. PRZM does not allow uptake of pesticide by the plant from the surface layer whereas TEEAM does. The presence of roots near the soil surface is dependent on the species of plant and seasonal moisture patterns. TEEAM calculates the concentration of pesticide within the plant in addition to uptake of pesticide by the plant. Response of concentration in the plant as a function of soil K_d, chemical K_{ow}, and plant type was evaluated. Two limitations were identified in the plant transport module. First, the formulation does not allow for calculation of differential above-ground plant part, e.g., stems and leaves, concentrations. Second, the formulation does not calculate loss from the leaf surface as a function of a chemical characteristic, i.e., Henry's Law constant, reducing the potential predictive capability of the approach.

Response of concentrations in soil-dwelling organisms and above-ground habitat-mobile organisms to biocon–centration factors, metabolic degradation rates, Henry's Law constant, and assimilation efficiency were evaluated. Improvements to the animal uptake module that should be performed fall into three categories. First, uptake of pesticide for all organisms should be based on formulations using chemical properties and biological characteristics of the organism. Currently, assimilation of contaminant by the animals is an empirical factor specific for a given chemical, organism, and chemical concentration. Second, soil dwelling organism uptake should be formulated based on soil ingestion rates. Finally, formulations specifically for aboveground insects, ingestion of which can be a major exposure route for birds, should be included in the model.

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The complete report, entitled "Preliminary Testing, Evaluation and Sensitivity Analysis for the Terrestrial Exposure Assessment Model (TEEAM)," (Order No. PB91-161 711/AS; Cost: $23.00 subject to change) will be available only from:

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