MODELING SPRAY DRIFT AND RUNOFF RELATED INPUTS OF PESTICIDES TO RECEIVING WATER

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Background and study objectives

- Various pathways for pesticide transport
- Surface runoff is known as the most prevalent; spray drift is also significant
- Relative significance of different pathways is not well studied
- Limited literature on drift contribution: 0.3-59%
- Mitigation requires knowledge on the contribution of each route

Objective: develop a modeling framework for evaluating significance of pesticide spray drift within watersheds
Modeling framework

**Input data**
- Pesticide use (PUR)
- Weather (CIMIS)
- Drainage (NHD)
- Soil (SSURG)
- Land use (NLULC)

**Models**

1. **Identification of drift potential**
   - Field location
   - Wind direction

2. **AgDRIFT**
   - Application method
   - Deposition curve
   - Area receiving deposition

3. **SWAT**
   - Landscape hydrology
   - Surface runoff
   - Spray drift input as point source
   - Pesticide use & irrigation
   - Channel routing

**Outputs**

- Identified application events with drift potential
- Drift fraction
- Drift mass
- Daily pesticide loading

**Observation**
(Monitoring data)
Case study: Orestimba Creek Watershed

- Tributary to SJQ River
- Area: 513 sq. km
- Ag in lower basin
- Highly managed hydro.
- Daily water samples for chlorpyrifos in 1996-1997
Analysis of monitoring data: calculation of pesticide loading

\[ L_i = C_i \times F_i \times 0.0864 \]

\[ L_{dr} = \sum_{i=m}^{n} L_i \]

- \( L_i \): pesticide loading on day \( i \) (kg)
- \( C_i \): Concentration on day \( i \) (µg/L)
- \( F_i \): flow on day \( i \) (cms)
- \( L_{dr} \): total loading for a drift event
- \( L_i \): pesticide loading on day \( i \)
- \( m \): the day drift begins
- \( n \): the day drift event ends
**Identification of drift potential**

- Drift potential =
  - use &
  - within 400 m &
  - wind direction
**Determination of drift amount**

\[ M_d = R_p \times A \times F_d \]

- **\( M_d \)**: mass of pesticides drifted and deposited to the receiving water (kg);
- **\( R_p \)**: pesticide application rate (kg/ha);
- **\( A \)**: surface area of the creek that captures drifted droplets (ha);
- **\( F_d \)**: fraction derived from the AgDRIFT deposition curve at downwind distance \( d \).
AgDRIFT spray drift deposition model

- AgDRIFT® version 2.0: curves for aerial, ground and orchard/airblast
SWAT: Soil and Water Assessment Tool

- SWAT2012: by USDA, widely used, physically based; simulate flow, sediment, nutrients and pesticides

- Management:
  - Planting/harvesting
  - Pesticide use
  - Irrigation
  - BMPs

Schematic from Arnold et al., 2012
SWAT model set up

- Watershed delineation
- Hydrological response unit (HRU) = Land use + soil + slope
- Calibration: auto and manual

Objective functions

1. NSE: Nash-Sutcliffe efficiency
2. RSR: RMSE-observations standard deviation ratio
3. PBIAS: Percent bias
<table>
<thead>
<tr>
<th>Field ID</th>
<th>Crop</th>
<th>Spray date</th>
<th>Method</th>
<th>Treated area (acre)</th>
<th>Wind direction</th>
<th>Applied rate $R_p$ (kg/ha)</th>
<th>Distance $d$ (m)</th>
<th>Drift fraction $F_d$</th>
<th>Deposition area $A$ (ha)</th>
<th>Drift mass (kg)</th>
<th>Drift/total applied (%)</th>
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</table>

*This application was excluded from model inputs as the field was located downstream of the sampling sites; and the impacts of spray drift from this field were not captured by the measured dataset.
Results: analysis of monitoring data

- 67-70% were detections (> 0.001 µg/L)
- Max concentration: 2.3 µg/L
- 25 independent peaks at L1
- 8 correspond to spray events
- Mean concentration higher in runoff samples but not statistically significant (P=0.42)
- Drift loading: 24%
- Runoff loading: 76%
Results: flow calibration at L1 site

<table>
<thead>
<tr>
<th></th>
<th>NSE</th>
<th>RSR</th>
<th>PBIAS(%)</th>
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Rainfall (mm) vs. Flow (cms) plot showing observed and simulated data. The plot includes a 1:1 line for comparison.

- **Rainfall**
- **Observed**
- **Simulated**
Results: chlorpyrifos simulation

- Drift contribution: Sim. 19%; Obs. 24%
- During summer, 54% of the loading from spray drift
- Total predicted loading: 1.32 kg/yr; Obs: 1.29 kg/yr

Rainfall (mm)

Chlorpyrifos loading (kg)

Rainfall
- Observed
- Simulated

NS = 0.18
RSR=0.9
PBIAS=-1.6%
Results: about drift contribution

- The concentration of pesticides resulting from runoff is much higher than those from spray drift (Schulz 2001).

- Relative contribution of the drift and runoff is dependent on two main factors:
  1. Pesticide concentrations from runoff and drift events
  2. Number of runoff and drift events occurring within a temporal cycle

- The results may vary significantly depending on the study area (Schulz et. al. 2001; Raupach et. al., 2001)
The modeling framework simulated daily flow (NSE = 0.74) and pesticide loading (NSE = 0.18) with satisfactory results.

Deposition on the OCW ranged from 0.08 to 6.09% of applied.

Surface runoff was the major pathway in OCW, accounting for 76% of the annual loading; the rest 24% from spray drift.

Modeling showed 81 and 19%, respectively, for runoff and drift.

Spray drift contributed over half of the loading during summer.

The modeling framework could have many uses including design and implementation of mitigation practices.

Next step: will apply to more watersheds in CA; probabilistic approach to consider uncertainties in model inputs.
Thank you!

Questions?

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