

**Heartland Region Pesticides
Best Management Practices Workshop
June 6, 2006**

**Understanding Pesticide
Leaching and Runoff**

Patrick J. Shea
School of Natural resources
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln



Pesticide Losses to the Environment

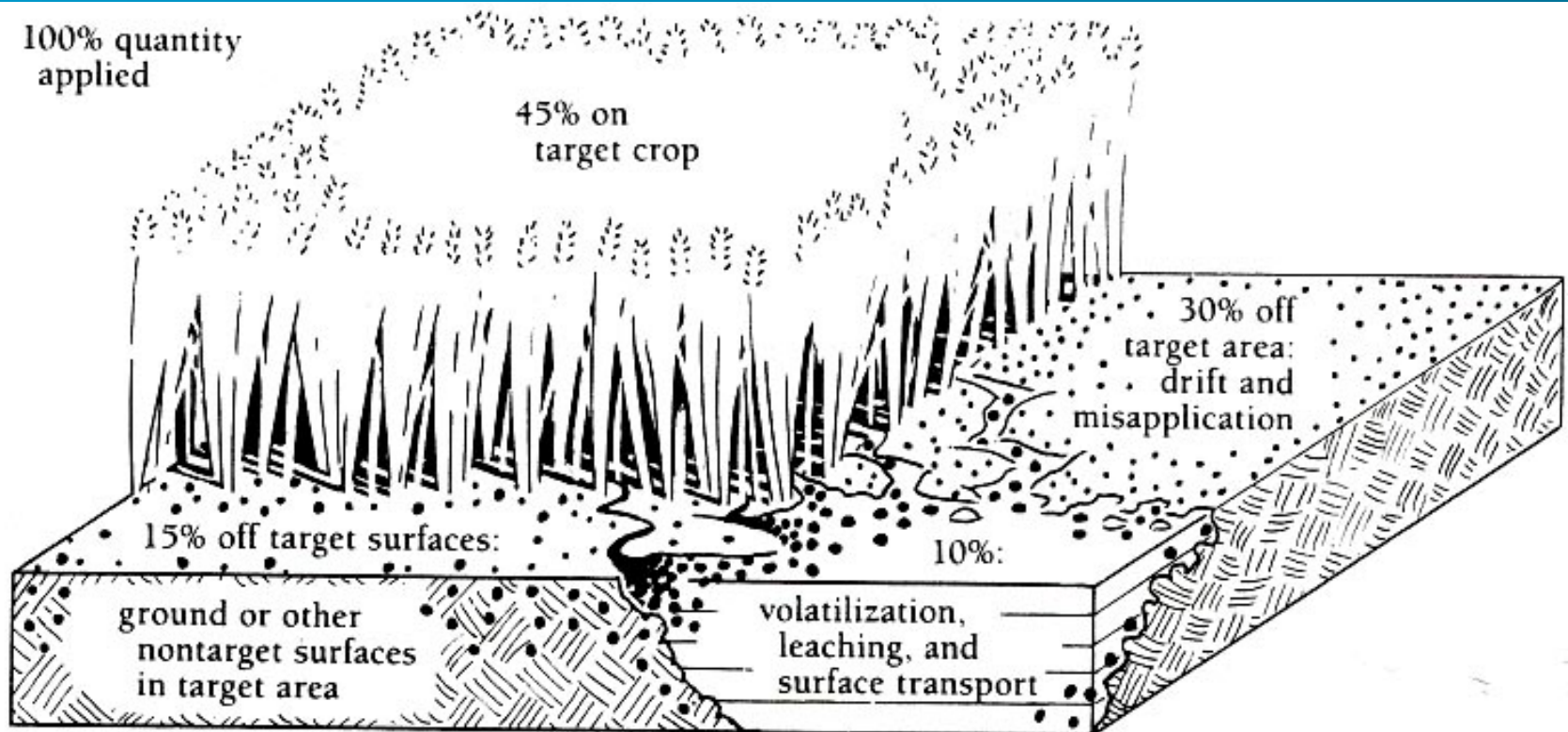
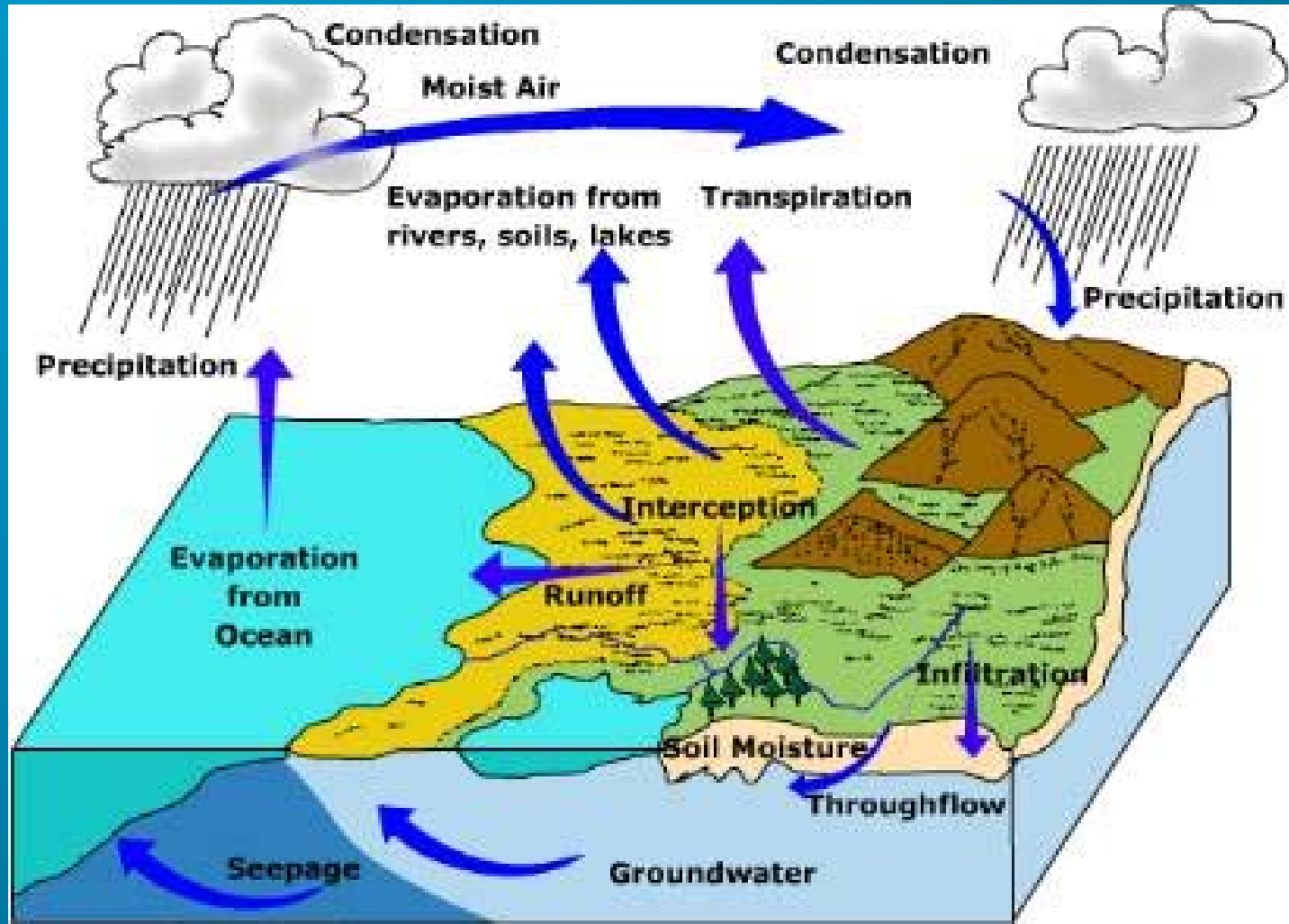


FIGURE 6-9.

As much as 55% of an applied pesticide may leave the application site due to spray drift, volatilization, leaching, runoff, and soil erosion.

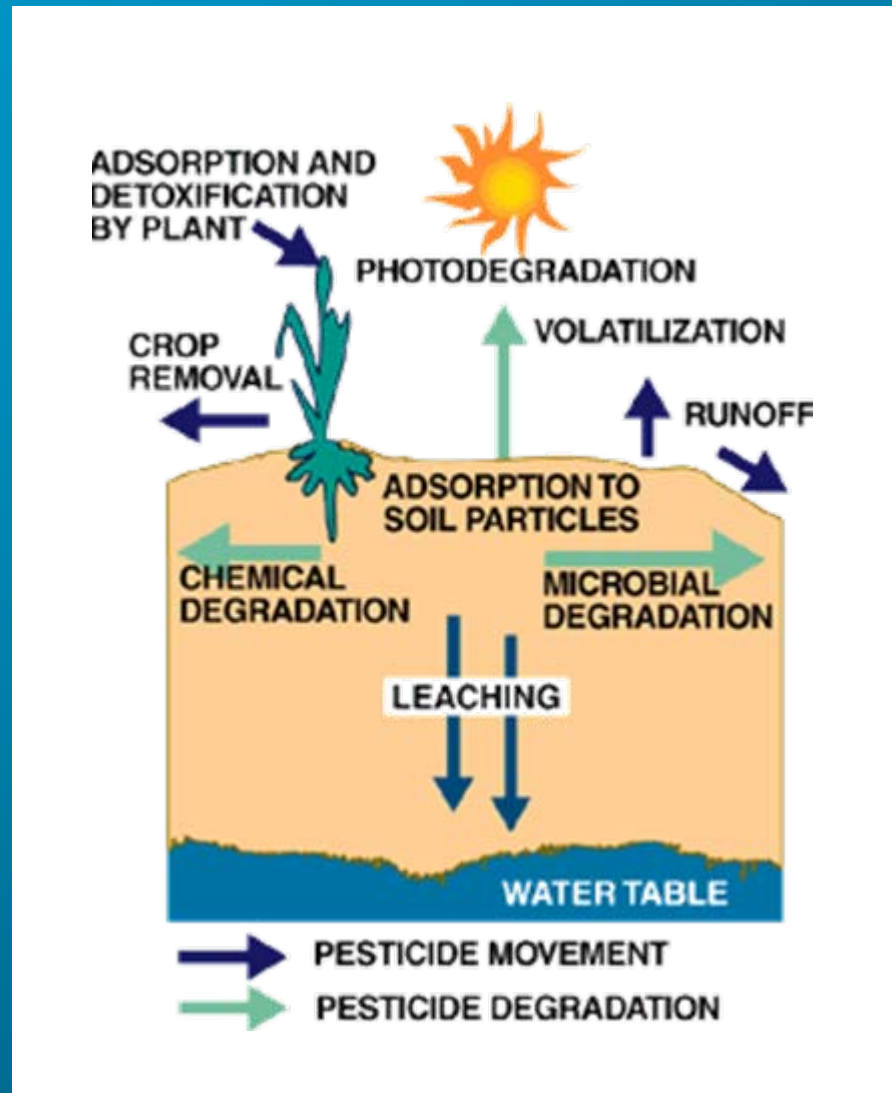
Hydrologic Cycle



Effective and profitable pest management and environmental sustainability requires understanding pesticides, soils, and landscape characteristics

- Challenged to **predict fate** under diverse environments and scales.
- Increasingly **rely on models** because measurements are not possible at every site.
- Models must include **critical variables** affecting activity and fate.

Environmental Considerations



Contamination Risk

- **pesticide properties**
- **soil properties**
- **landscape characteristics**
- **climatic conditions**
- **management practices**

Pesticide Properties

- **retention by soil**
- **persistence**

Retention by Soil

- **pesticide polarity (solubility)**
- **organic matter and clay contents**

Solubilities of Some Pesticides

- Tordon (picloram) = 430 ppm
- 2,4-D = 890
- Assert (imazamethabenz) = 1,370
- Ally/Escort ← **solubility is pH-sensitive**
(metsulfuron)
 - 1,750 (pH 5)
 - 2,790 (pH 7)
 - 213,000 (pH 9)
- Roundup (glyphosate) = 15,700 (pH 7)
(pH-sensitive; salt forms are more soluble)
- Paraquat = 620,000 (salt of cation)

Retention by Soil

- Adsorption partition coefficient (K_d)

$$K_d = \frac{\text{pesticide concentration in soil}}{\text{pesticide concentration in solution}}$$

- Organic carbon partition coefficient (K_{oc})

$$K_{oc} = \frac{K_d}{\text{percent soil organic carbon}} \times 100$$

Pesticide Retention in Soil



**Organic Matter
(highly retentive)**



**Sand
(no retention)**

Koc of Common Pesticides (weakly retained)

- Banvel (dicamba)= 2
- Stinger (clopyralid)= 6
- Pursuit (imazethapyr)= 10
- Tordon (picloram) = 16
- 2,4-D = 20
- Assert (imazamethabenz) = 50

Koc of Common Pesticides (strongly retained)

- Python (flumetsulam) = 700
- Methyl Parathion = 5,100
- Lorsban (chlorpyrifos) = 6,070
- Treflan (trifluralin) = 7,000
- Roundup (glyphosate) = 24,000 *
- Buctril (bromoxynil) = 10,000
- Capture (bifenthrin) = 216,500
- Paraquat = 1,000,000 *

* Strongly bound but also highly water soluble

Pesticide Persistence

- relative longevity
- based on half-life ($t_{1/2}$)
or “time for 50% disappearance” (DT_{50})
- inherent degradability of pesticide
- microbial degradation decreases with increasing soil depth
- actual persistence may be highly variable

Half-lives of some common pesticides (in days)

- Malathion = 1
- 2,4-D = 10
- Banvel/Clarity (dicamba) = 14
- Ally (metsulfuron) = 30
- Stinger (clopyralid) = 40
- Assert (imazamethabenz) = 45
- Roundup (glyphosate) = 47
- Tordon (picloram) = 90
- Spike (tebuthiuron) = 360
- Paraquat = 1,000

Soil Characteristics

- **texture**
- **organic matter content**
- **structure and macropores**
- **antecedent moisture content**
- **pH**

Site and Landscape Features

- **depth to groundwater**
- **proximity to surface water**
- **topography**
- **slope**
- **rainfall and irrigation**
- **drainage ways and buffers**

Factors that increase pesticide leaching potential

Factor

Guideline

Pesticide properties

long half-life

greater than 21 days

low-moderate adsorption

Koc less than 500

Kd less than 10

high solubility

greater than 30 ppm

Soil characteristics

sandy soil, low organic matter

less than ~1% OM

Site features

shallow groundwater

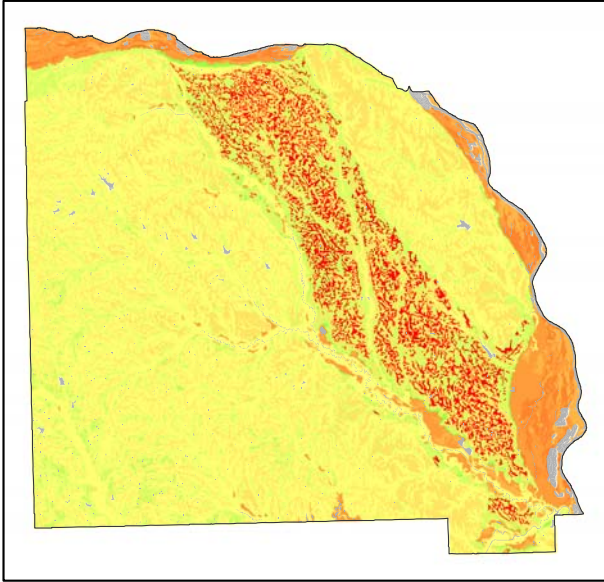
less than 30 feet deep

permeable overburden

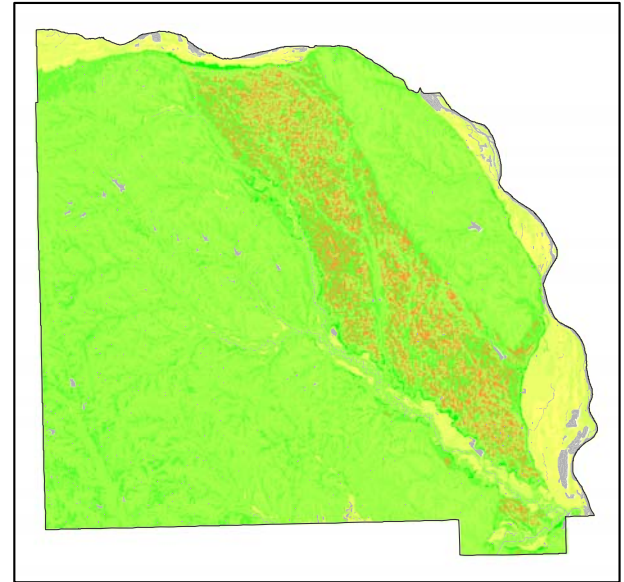
excess irrigation

Pesticide Leaching Risk

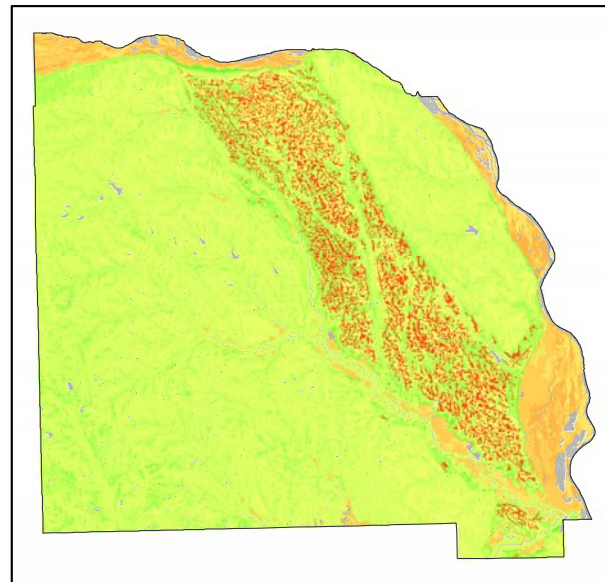
Combined Chemical and Landscape Perspective



Small Koc / Long Half-Life




Large Koc / Short Half-Life



Intermediate Koc and Half-Life

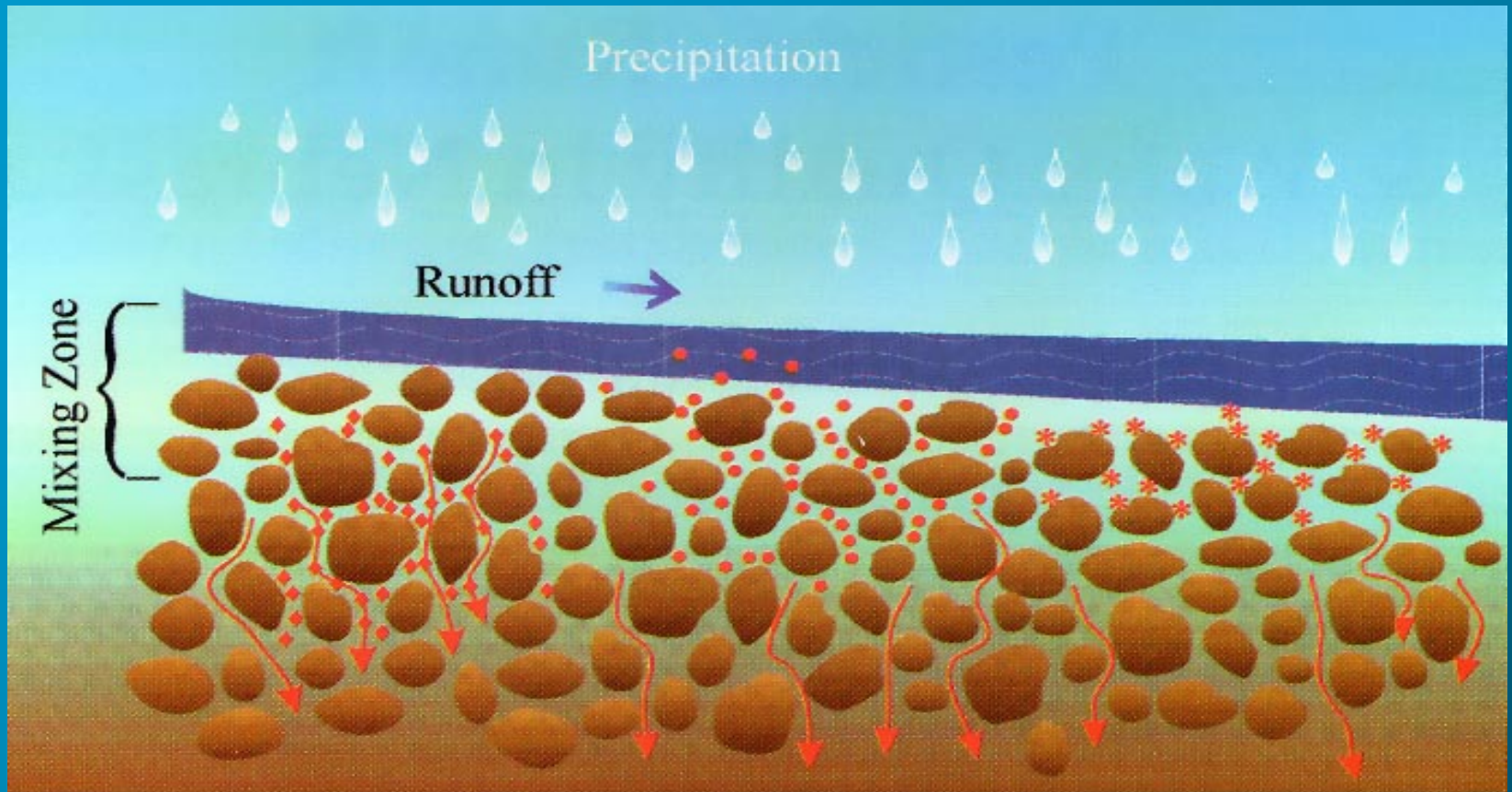
Data Inputs

Organic Matter, Clay Content, pH, Free Water, Index Surface Runoff, Koc and Half-Life

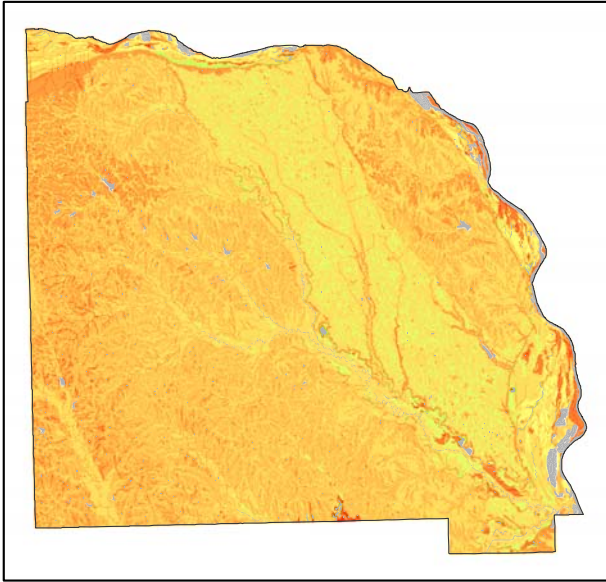
High  Low
Dams, Fluvaquents, Gravel Pits and Water

Factors that increase pesticide runoff potential

Factor	Guideline
Pesticide properties	
moderate adsorption (solution runoff)	Koc 50 to 5,000
strong adsorption (particle-ads runoff)	Koc > 5,000
Soil characteristics	
soil compaction and poor structure	low permeability
high antecedent moisture	
Site and landscape features	
slope	
surface waterways	
Climatic variables	
rainfall causing runoff event	within ~15 d of app.



◆	●	✱
Weakly Adsorbed	Moderately Adsorbed	Strongly Adsorbed
<hr style="border: 1px solid red;"/> <ul style="list-style-type: none"> ● $K_{oc} < 50$ ● may leach or runoff 	<hr style="border: 1px solid red;"/> <ul style="list-style-type: none"> ● $50 < K_{oc} < 5000$ ● high potential for runoff 	<hr style="border: 1px solid red;"/> <ul style="list-style-type: none"> ● $K_{oc} > 5000$ ● runoff loss with sediment

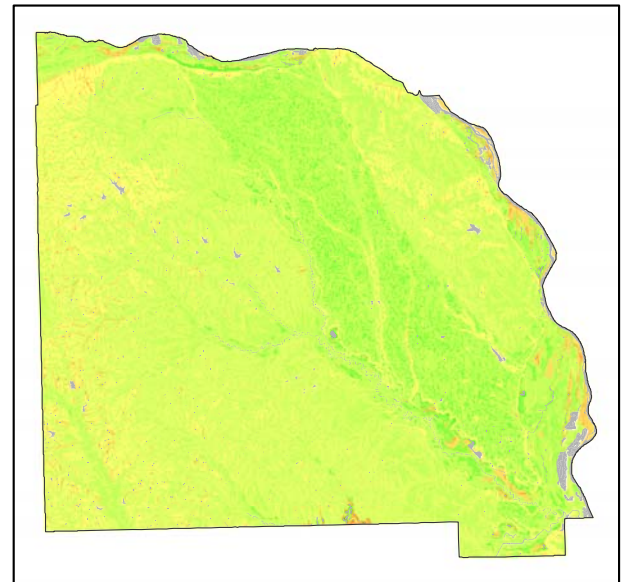


Small Koc

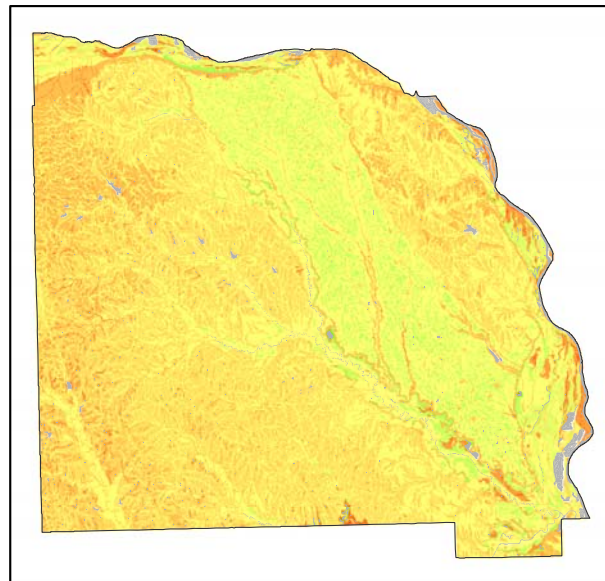
Pesticide Runoff Risk

Combined Chemical
and Landscape
Perspective

Loss in Solution



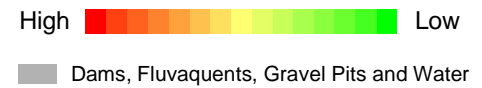
Large Koc



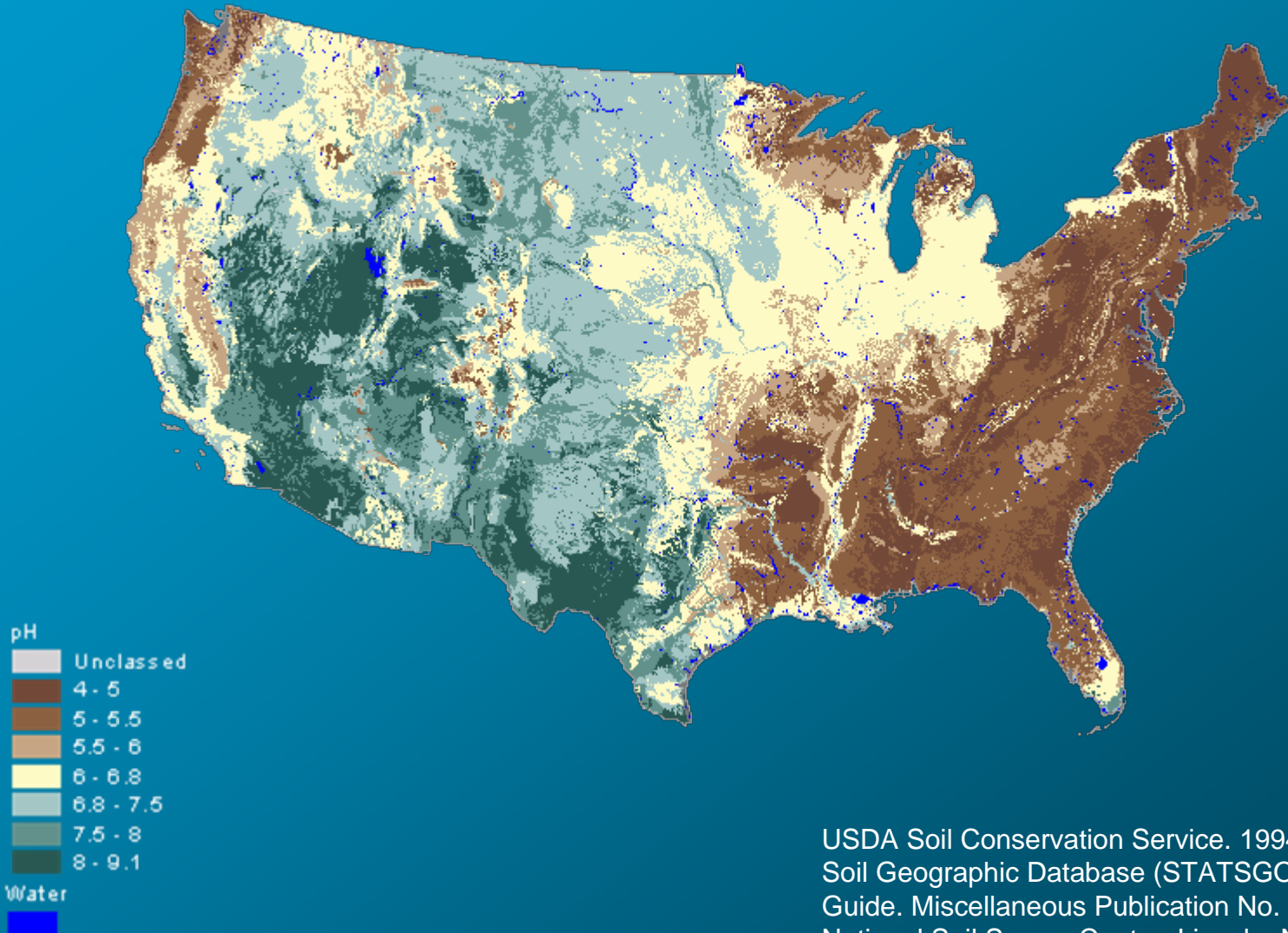
Intermediate Koc

Data Inputs

Organic Matter, Clay Content,
Index Surface Runoff, Water
Buffers / Flooding, and Koc



pH (0 – 2 inches)



USDA Soil Conservation Service. 1994. State Soil Geographic Database (STATSGO), User's Guide. Miscellaneous Publication No. 1492, National Soil Survey Center, Lincoln, NE.

Pesticides are affected by soil pH

- acids or bases (pKa)
- affects soil retention, availability, mobility
- persistence (biotic and abiotic degradation)
- activity (soil residual, plant uptake and hydrolysis of ester formulations)

Acidic Herbicides form anions:



Anions are weakly held by soil.

Basic Herbicides form cations:



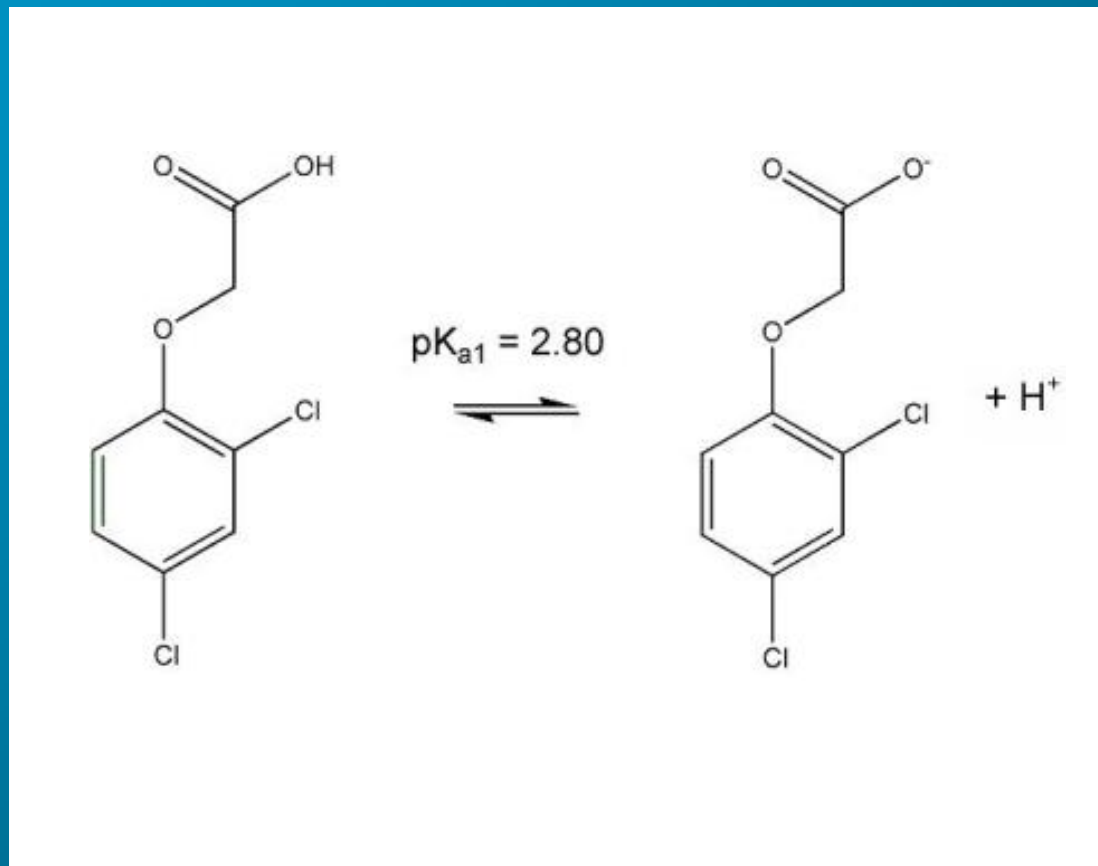
Cations are strongly held by soil.

**Speciation is determined by pH
in relation to **pKa****

What is pKa?

The ***pKa*** is the pH at which half of the molecules are neutral and half are negatively charged (acidic herbicides) or positively charged (basic herbicides).

Acidic Herbicide Example: 2,4-D



Herbicides Affected by pH

(45+ products in total)

- Atrazine (base, pKa = 1.7)
- Bladex (cyanazine, base, pKa = 1.1)
- Sencor/Lexone (metribuzin, base, pKa = 1.0)
- Accent (nicosulfuron, acid, pKa = 4.3)
- Banvel/Clarity (dicamba, acid, pKa = 1.9)
- Beacon (primisulfuron, acid, pKa = 5.1)
- Curtail/Stinger (clopyralid, acid, pKa = 2.3)
- Permit/Battalion (halosulfuron, acid, pKa = 3.4)
- Pursuit (imazethapyr, acid, pKa = 3.9)
- 2,4-D (acid, pKa = 2.8)

Effect of pH on Retention

(acids and bases)

strongly
adsorbed

K_d

weakly
adsorbed

5.5

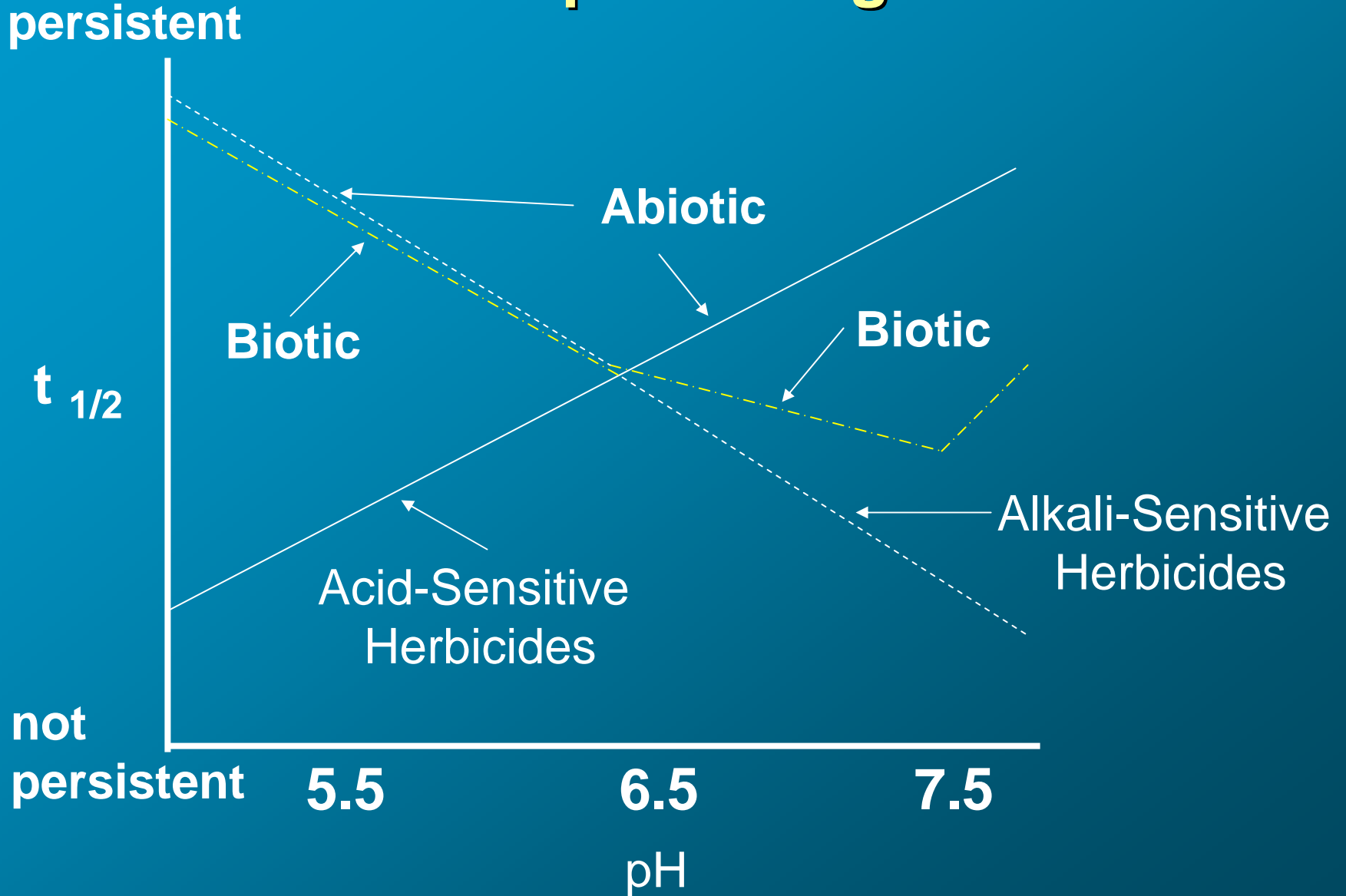
6.5

7.5

pH



Effect of pH on Degradation



Effect of Soil pH on Herbicide Activity and Environmental Risk

Herbicide	pH	Influence	Result
Atrazine Simazine	>7.0	Slow degradation	Increased carryover Greater risk
Atrazine Simazine	<5.5	Increased retention More hydrolysis	Reduced weed control Decreased risk
Clorimuron	>7.0	Slowed hydrolysis	Increased carryover Greater risk
Imazethapyr	<5.5	Increased retention Slow degradation	Increased carryover Greater risk

Management Practices

- **Pesticide Load**
 - application rate
 - percent of soil treated
(band vs broadcast)
- **Residue Cover**
 - percent of surface and amount
- **Method of Application**
 - soil surface, incorporated, canopy
- **Precipitation/Irrigation Timing**
 - intensity, duration, amount
- **Soil Surface Roughness**
 - tillage operation and timing



www.sare.org

Management and Fate Predictive Models and Tools

WIN-PST

(Windows Pesticide Screening Tool)
USDA-NRCS

University of Nebraska Models

(later presentation at this workshop,
M. Milner et al.)

Effective Modeling

Best spatial data – Integrate terrain-based landscape, hydrology, SSURGO and climate data with chemical properties and management practices

Thank You

Questions?

pshea1@unl.edu

402-472-1533