# Management Practices to Keep Nutrient out of Air and Water (and put them into crops)

MSU Extension Annual Conference Nov 8, 2011

by Clain Jones, Extension Soil Fertility Specialist
and Kathrin Olson-Rutz, Research Associate
clainj@montana.edu; 994-6076

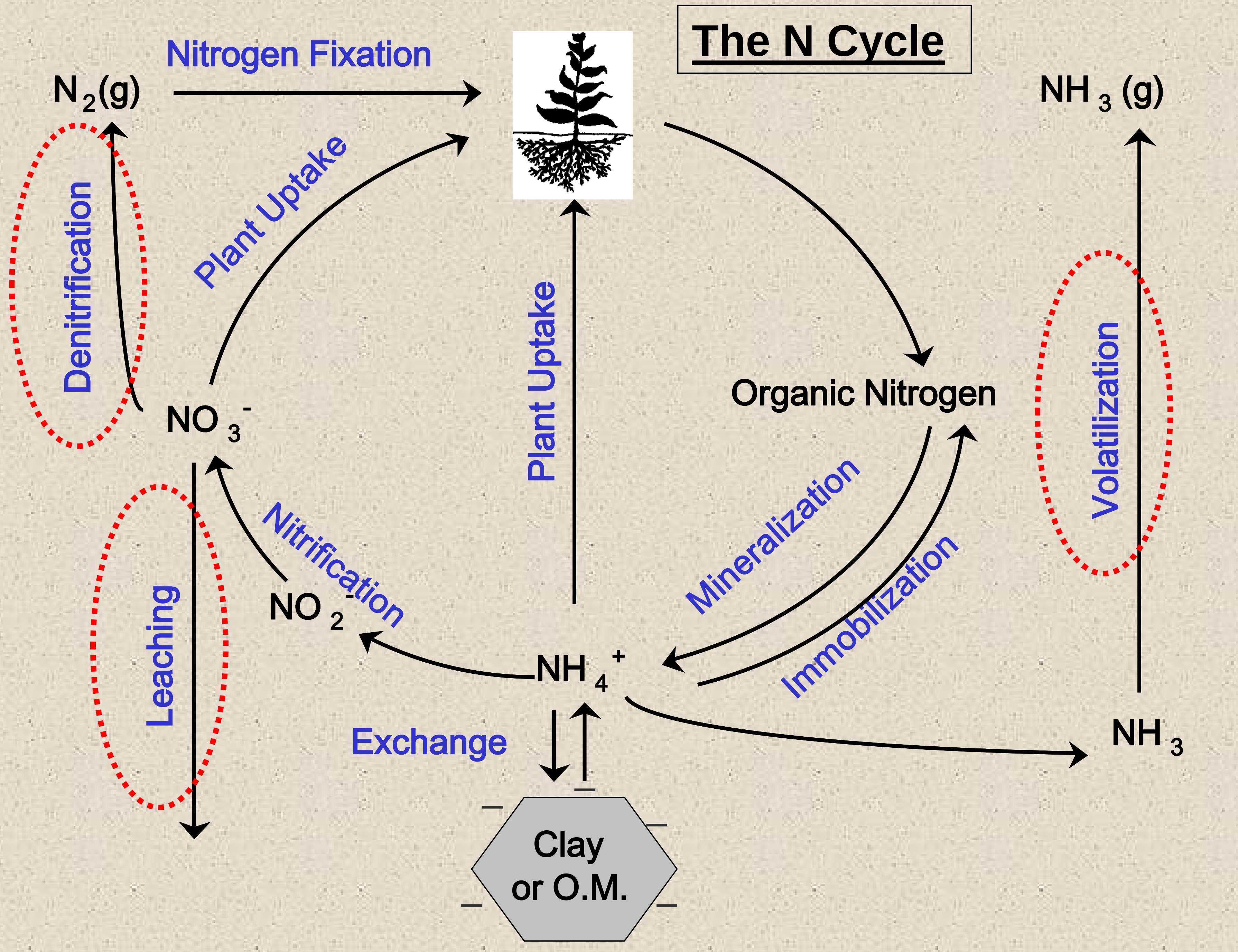
MONTANA STATE UNIVERSITY EXTENSION

AGRICULTURE

MAKING A DIFFERENCE IN MONTANA COMMUNITIES

# Today's Goals

- Discuss processes and factors that affect nutrient losses to water and air with focus on nitrogen and phosphorus
- Discuss crop and fertilizer management practices to minimize losses


The N Cycle
Nitrogen Fixation
N 2 (g)
NH 3 (g)
Denitrification
Plant Uptake
Plant Uptake
NO 3 -
Organic Nitrogen
Volatilization
Mineralization
Immobilization
Nitrification
NO 2 -
Leaching
NH 4 +
Exchange
NH 3
Clay
or O.M.

# Crop management factors that decrease N leaching

- Carefully manage irrigation, especially on coarse soils
- Recrop rather than fallow
- Reduce tillage
- Diversify to include perennial and/or deep rooted crops
- Consider legumes since don’t need to fertilize w/ N
- Space crops for optimal yields to optimize resource use; ex. SW in 6” rows and 30 plants/$ft^2$ – Fertilizer Fact # 37

# Long-term effect of cropping system on soil fertility

- 1983 to 2004 near Culbertson, MT
- Comparing tillage and crop
- Small-plot field trial
- Soil samples:
  - Collected in October 2004, 4-6 weeks after fall tillage
  - Taken to 8 inch depth

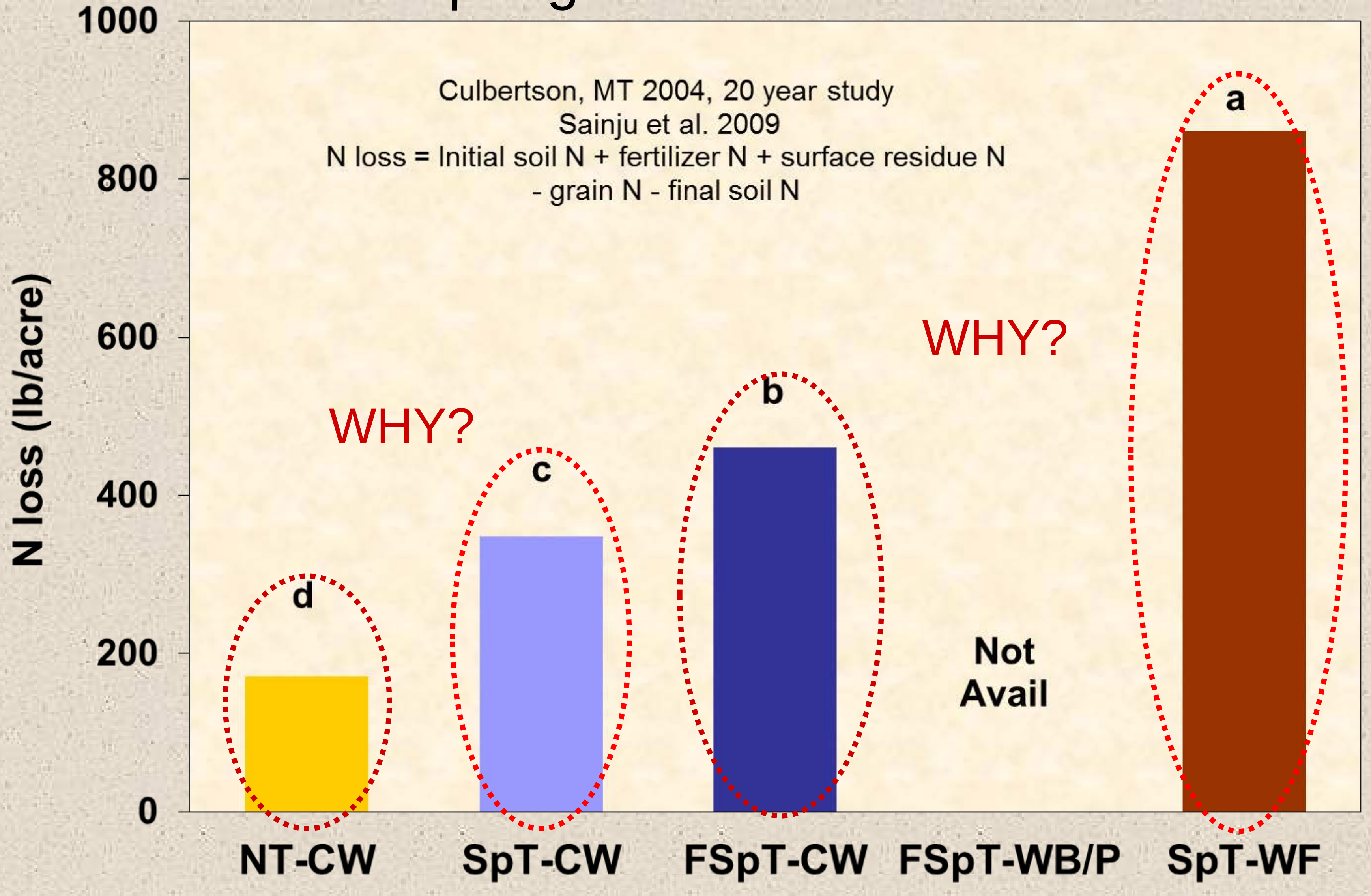
# Tillage and crop combinations

- NT-CW : No Till-Continuous Spring Wheat
- SpT-CW: Spring Till-Continuous Sp. Wheat
- FSpT-CW:
  Fall & Spring Till – Continuous Sp. Wheat
- FSpT-WB/P: Fall & Spring Till – Wheat/Barley (17 years), Wheat/Pea (4 years)
- SpT-WF: Spring Till – Sp. Wheat/Fallow

All residue was left on the field

# Estimated N loss

## Spring 1983 to Fall 2004




Economics?

# Nitrogen management practices that decrease nitrate leaching

- Apply N in spring according to soil test ESPECIALLY if have greater than 50 lb N/acre in fall AND soils less than 2 ft deep.
- Split N application to match plant needs or use slow release N fertilizer
- Consider applying less N in areas that yield less or have shallower soils (variable rate application)

# Conditions that increase denitrification (nitrate → nitrogen gas)

- Wet
- High organic matter
- High levels of nitrate
  - urea can take ~ 1 to 5 weeks to get converted to ammonium
  - ammonium can take ~1 to 3 weeks to get converted to nitrate
- WARMTH

Note: Can lose 1 to 5% of soil nitrate *per day* from saturated soils (Ransom, NDSU).

What time of year would you expect denitrification rates to be highest?

Mid spring, possibly mid fall if rains after fertilization

What types of farming practices would increase rates?

Irrigated, fall N application, high rates of N fertilization, warm season crops

# Management practices to decrease denitrification losses:

1. Don't apply N in fall or winter in areas that frequently pond or become saturated.
2. Consider applying a slow release product (e.g. ESN) or nitrification inhibitor (e.g. DCD which is in SuperU and Agrotain®Plus) if conditions are good for denitrification.
3. On irrigated fields, especially those with fine soils, monitor soil water closely to keep near field capacity (~15 to 20% by mass) to minimize anaerobic conditions.

# Ammonia Volatilization

I've shown Rick Engel's results at the past two spring ag agent updates so won't repeat here (take home: urea volatilization losses ranged from 3 to 44% when broadcast on cold soils)

Will describe volatilization process and factors affecting volatilization plus other research results from region

READY FOR SOME CHEMISTRY??

# Ammonia Volatilization

$$NH_4^+ + OH^- \longrightarrow NH_{3\ (gas)} + H_2O$$

- **<u>Can occur with urea and all ammonia or ammonium based fertilizers</u>**
- **Losses vary with environment and are difficult to predict.**

Looking at above equation, what is 1 factor that increases volatilization? **High pH**

# N fertilizer can increase pH during hydrolysis

## Ex: Urea

Urease
Enzyme (found naturally in soil)

$$CO(NH_2)_2 + 2H_2O \xrightarrow{\text{Urease}} 2NH_4^+ + HCO_3^{2-} + OH^-$$

**Effect on pH?** Increases *temporarily*. Why?

**Good or bad?** Bad: ↑ pH, ↑ volatilization

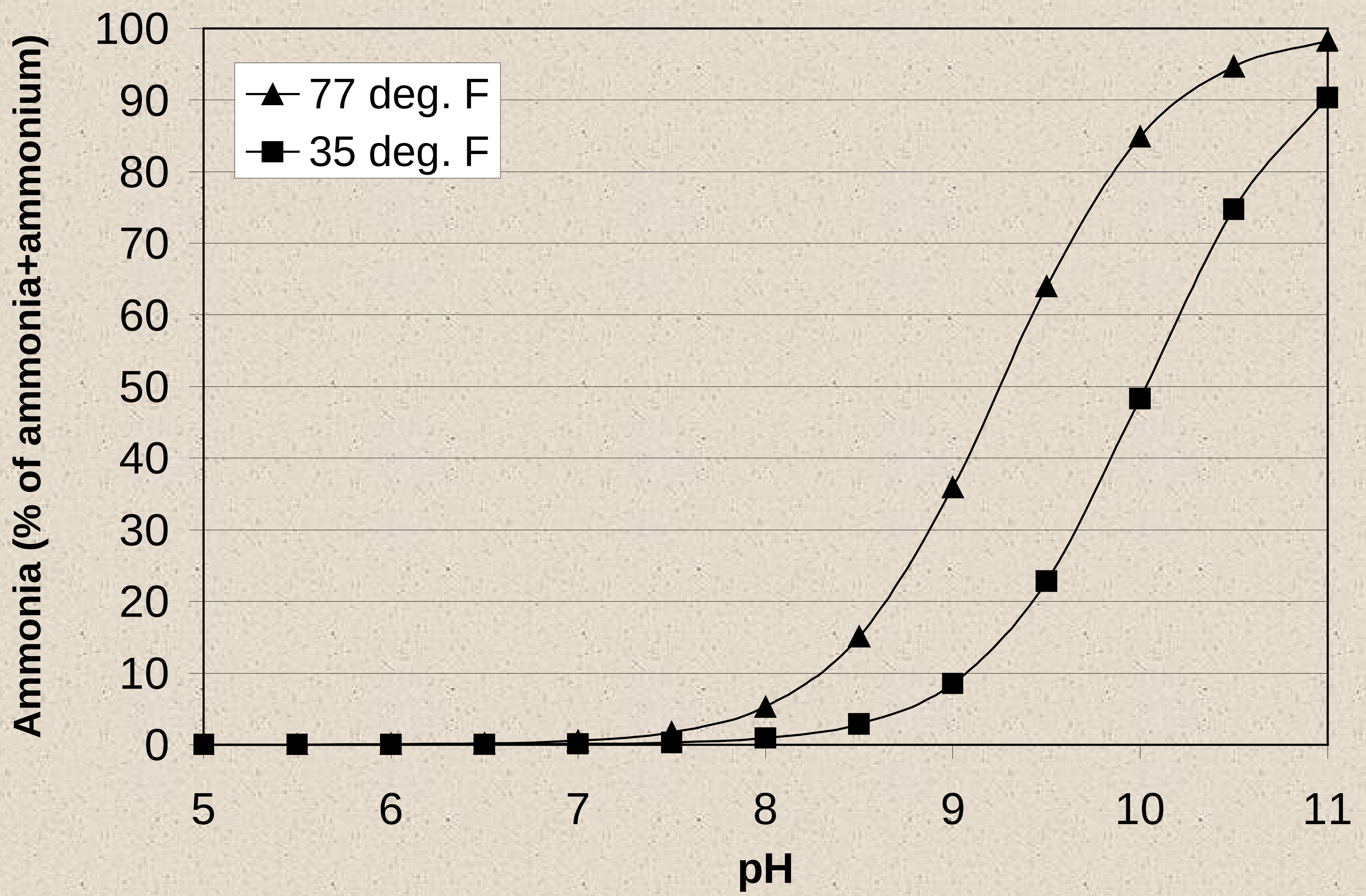
$$(NH_4^+ + OH^- \longrightarrow NH_{3\ (gas)} + H_2O)$$

# Factors affecting volatilization

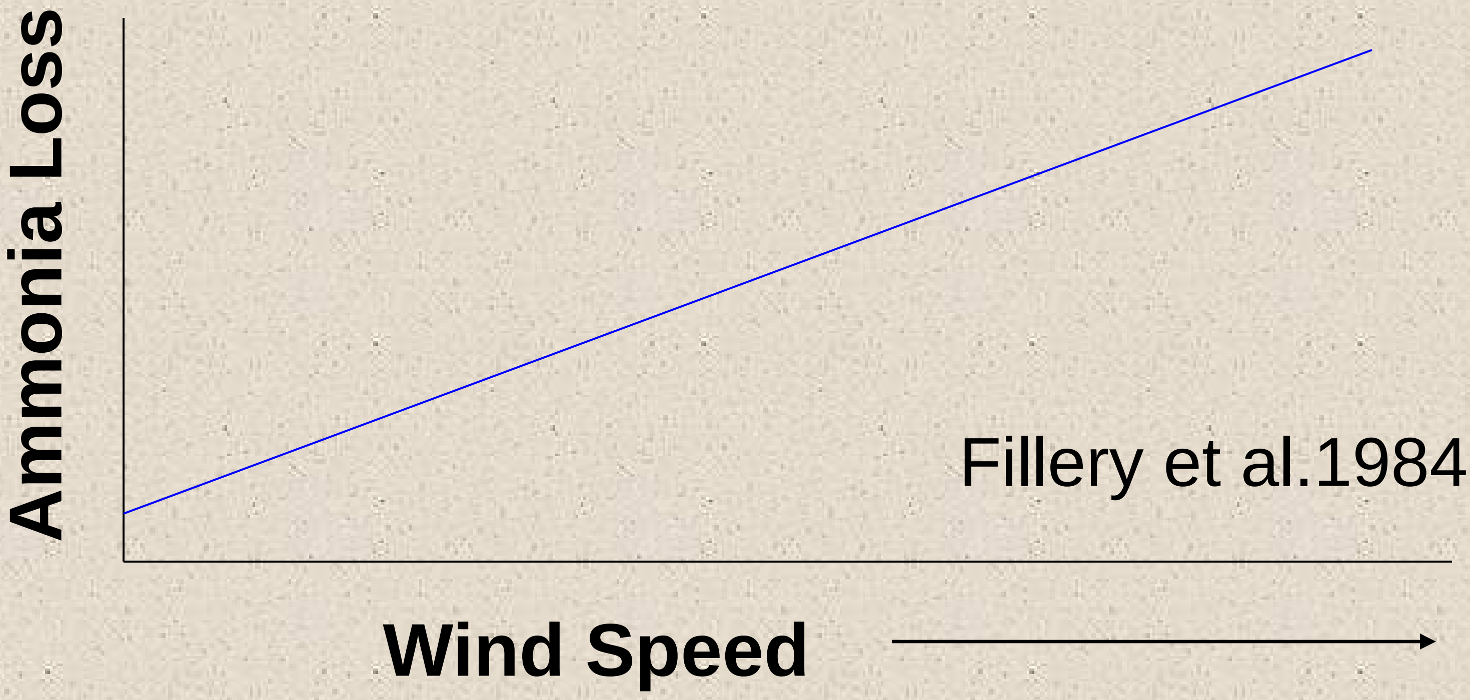
1. Soil pH and temperature
2. Wind
3. Cation Exchange Capacity (CEC). WHY?
4. Buffering capacity (resistance to pH change)
5. Soil moisture/humidity
6. Rainfall/irrigation following fertilization (depth in soil)
7. Ground cover/vegetation/residue. WHY?
8. Soluble and exchangeable calcium

**Bottom line: Large number of factors make volatilization amounts VARIABLE and difficult to predict.**

# 1. Soil pH and Temperature: effects on relative amount of ammonia in soil solution



# 2. Wind




- SO, don’t apply on windy day or with high winds in short term forecast.

# 3. Cation Exchange Capacity

- As CEC increases, volatilization rates generally decrease (Fenn and Kissel, 1976). Why?

  1. Less $NH_4^+$ in solution to volatilize

  2. Increased pH buffering capacity (next slide)

# 4. Buffering capacity

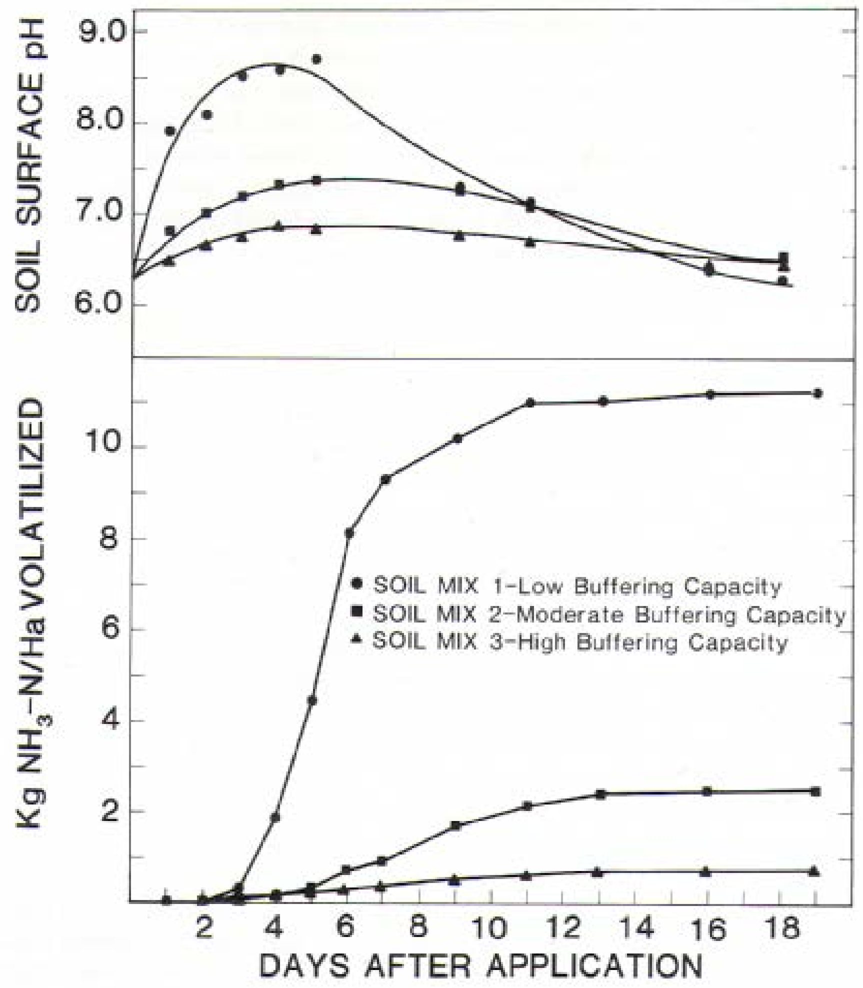
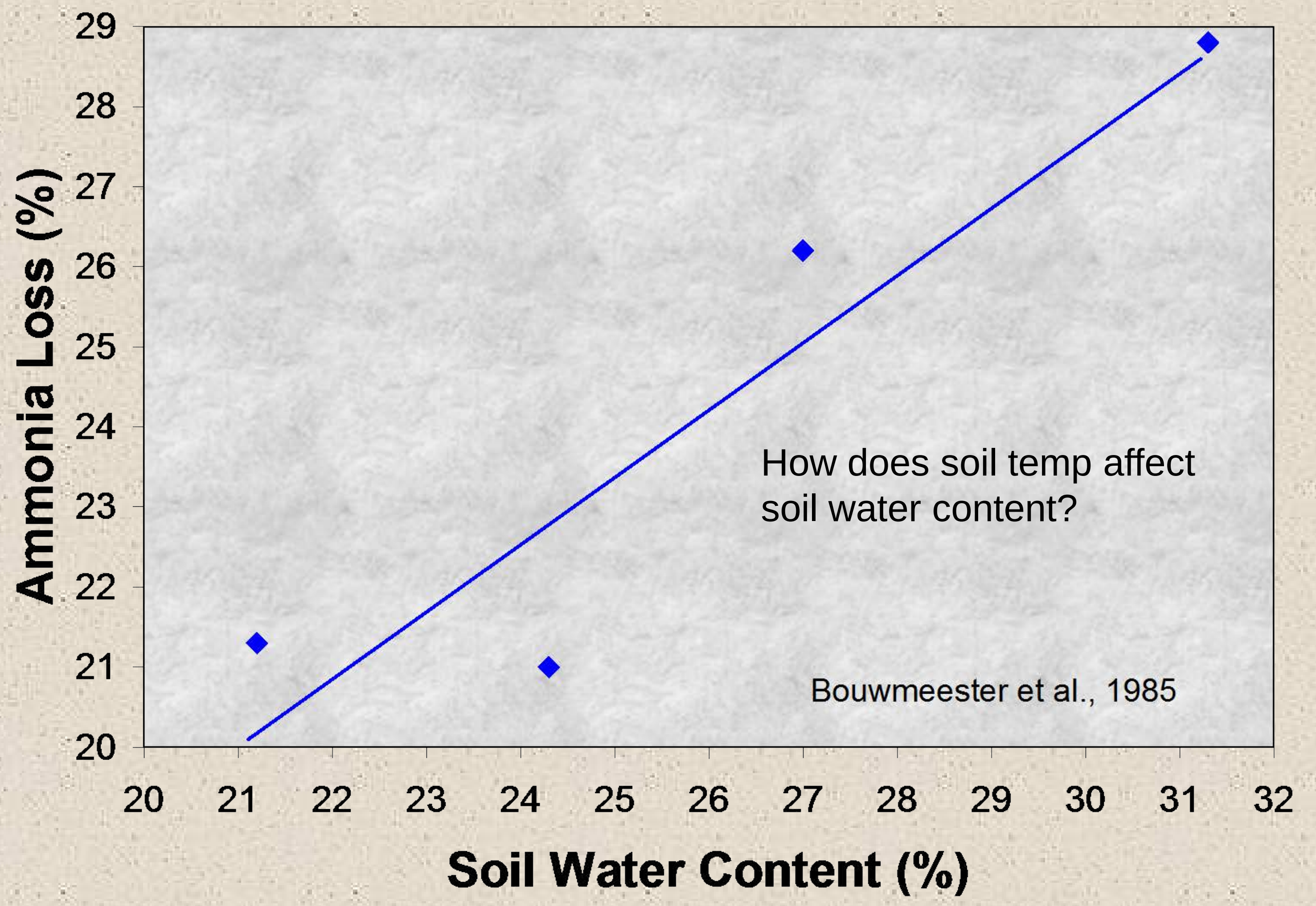



**Figure 1.** **Soil surface pH and cumulative $NH_3$ loss as influenced by pH buffering capacity. (from Ferguson et al., 1984).**

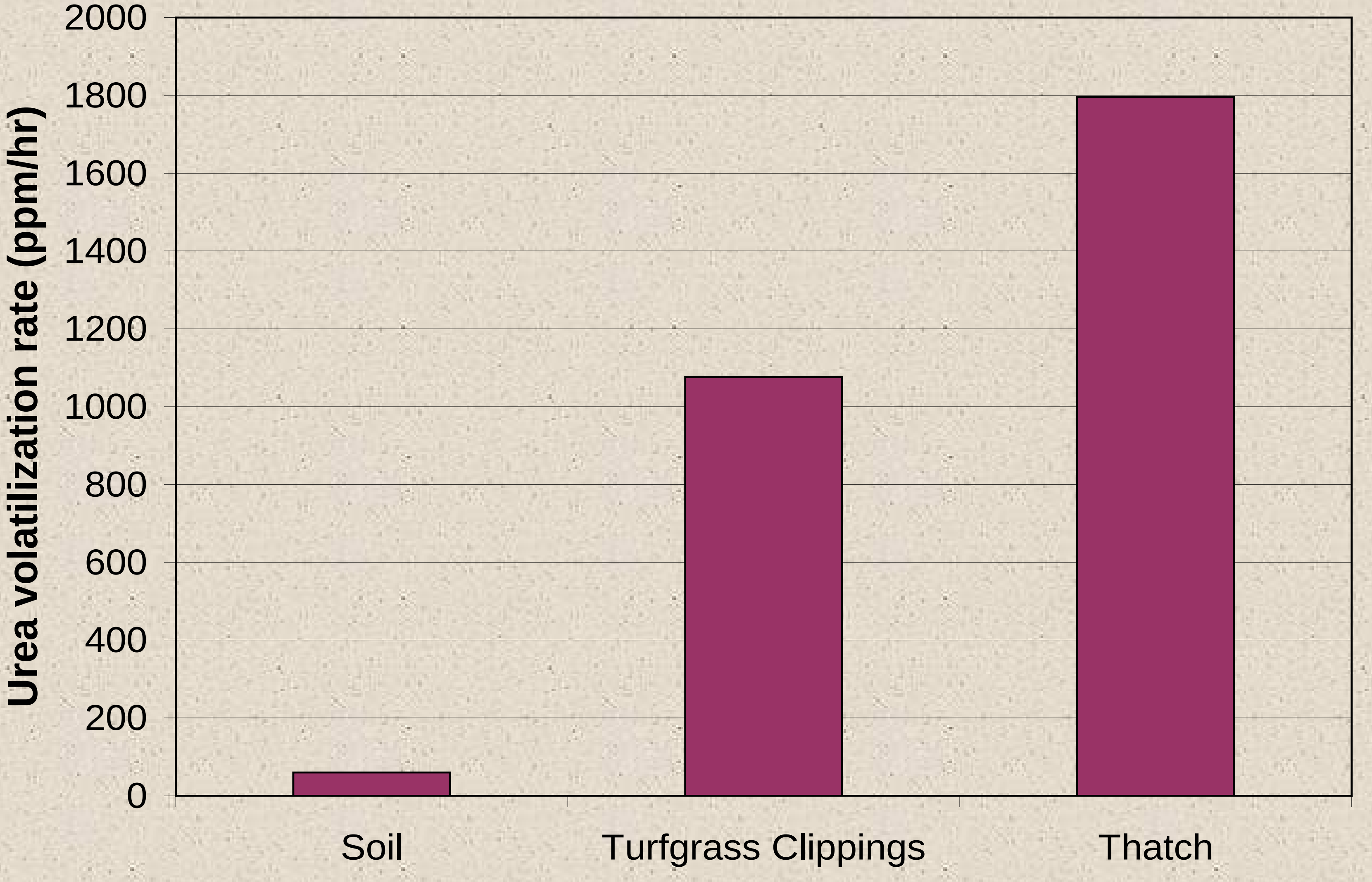
# 5. Effect of soil water content



# 6. Rainfall/irrigation

- 1/5 inch of rain/irrigation dissolves fertilizer, allowing volatilization (Engel et al. 2011).
- 1/2 inch of rain/irrigation pushes dissolved fertilizer about 2 in. into soil, essentially stopping volatilization if within about 2 days of fertilization (Meyer et al., 1961; Lloyd, 1992)

# 7. Effect of grass residue




Dick 1984

# Effect of residue, cont'd

- Volatilization was found to be approximately 2 times higher in the upper 1.5 inches under no-till than under conventional tilled systems (Dick, 1984).

# 8. Exchangeable $Ca^{2+}$ decreases volatilization (Fenn and Kissel,1976)

Exchangeable Ca minimizes pH rise.

**Implication**: Less concern with volatilization on soils with high exchangeable Ca levels (generally indicated by high CEC). Doesn’t matter though if urea doesn’t reach soil.

**Unanswered question**: with long-term no-till, have exchangeable Ca levels decreased at soil surface due to leaching?

# QUESTIONS?

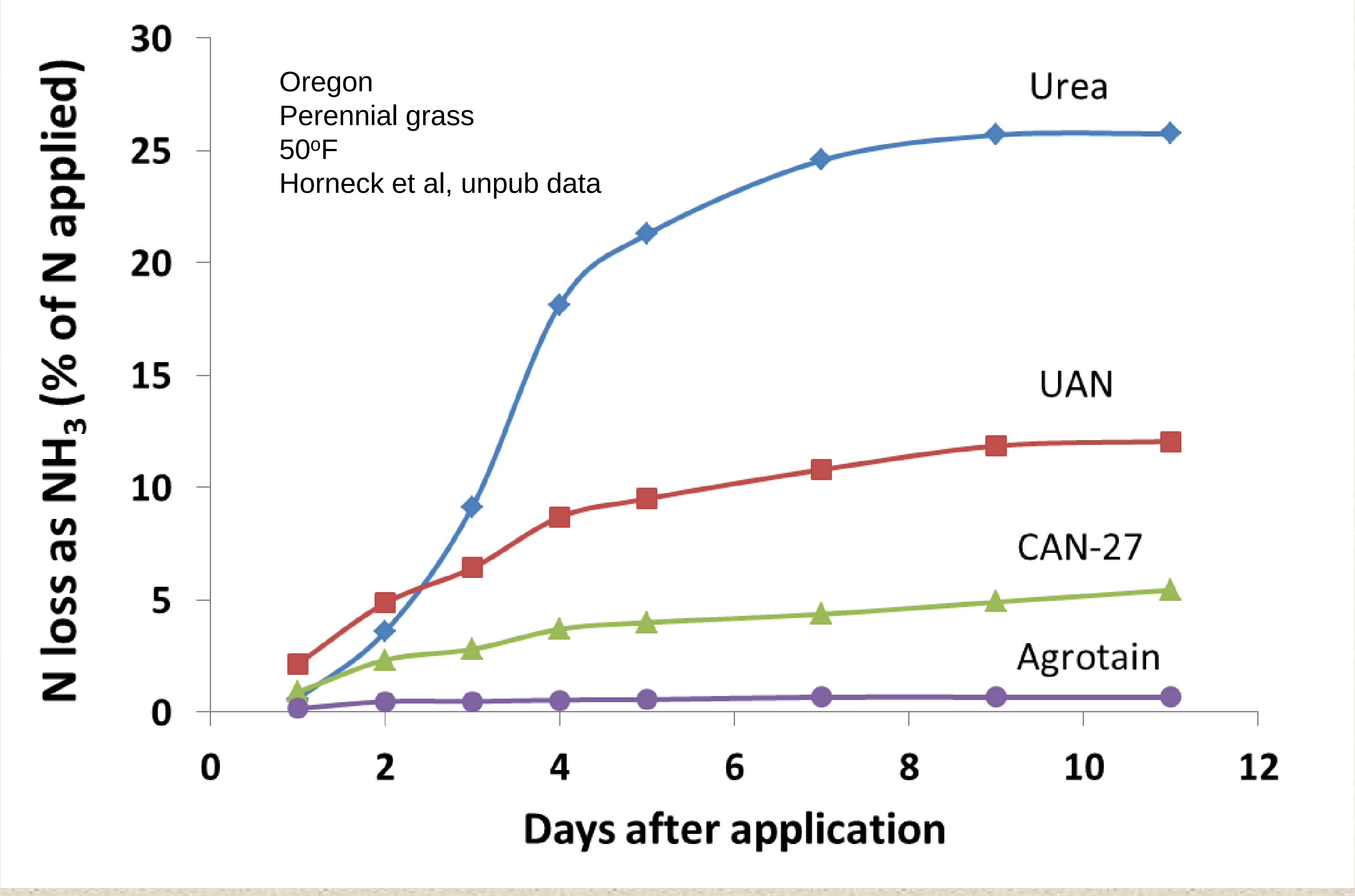
# Demonstration

| Treatment (175 lb N/ac) | Ammonia test in air (ppm) |
|---|---|
| Control | |
| Urea - broadcast | |
| Urea - incorporated | |
| Urea - NBPT (Agrotain®) | |

# N Management

- Source
- Placement
- Timing

# Effect of N source on volatilization loss



# Why differences in volatilization?

- Urea and UAN cause larger pH increases than calcium ammonium nitrate (CAN-27).
- UAN is only ½ urea; the AN doesn't volatilize much.
- Agrotain® dampens pH increase, though volatilization can occur well after application.

# Urease Inhibitors

- Agrotain® (NBPT) is main product. Delays hydrolysis by up to 14 days

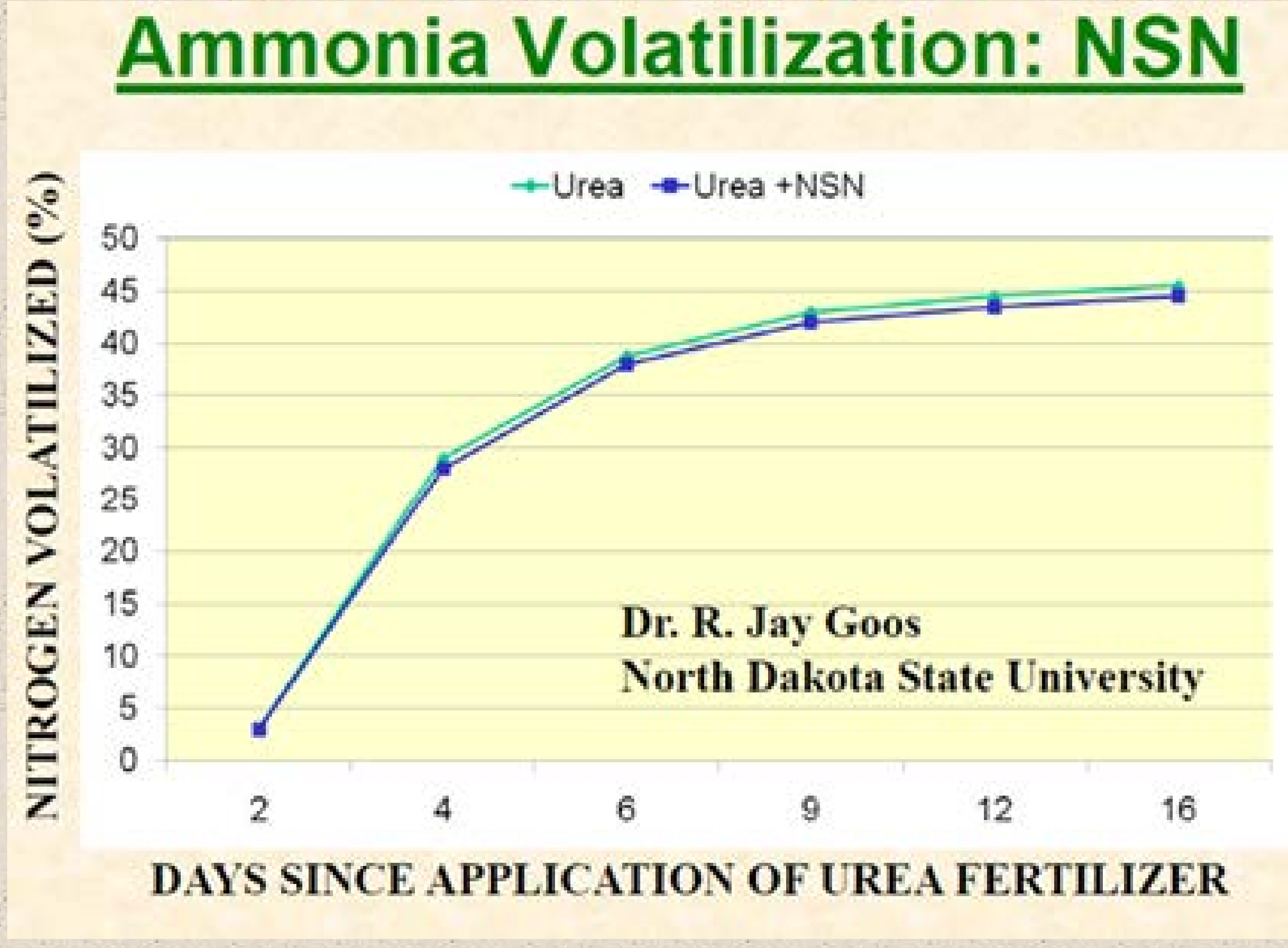
  -advantage: allows more chance for rain or irrigation to push N into ground

  -disadvantage: will delay time to become available, volatilization can still occur, and cost (adds ~$50/t-urea).

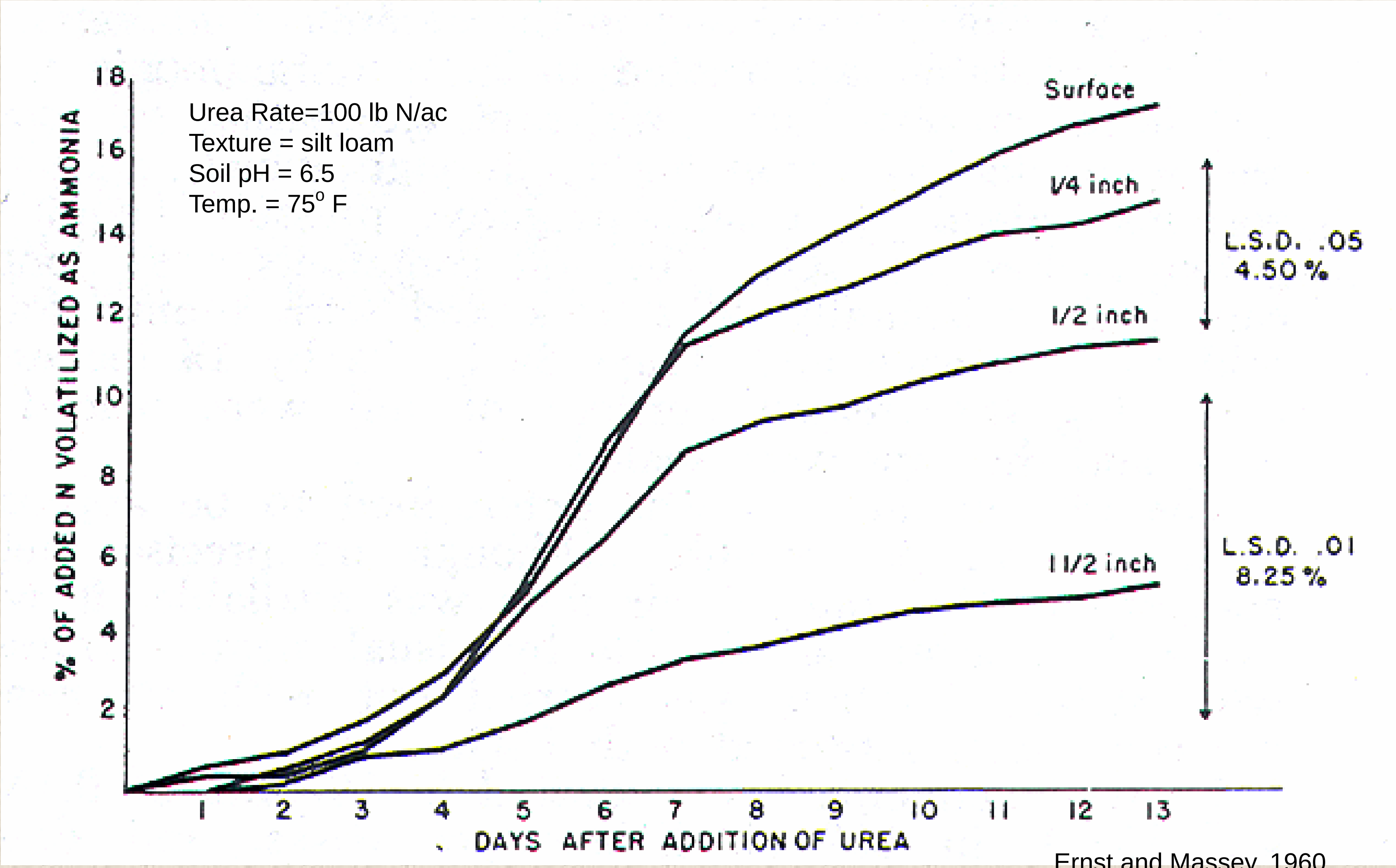
# Effect of polymer coated urea (PCU, e.g. ESN) on volatilization

- ESN decreased volatilization in UT by 40 to 51% compared to urea in a field study (Story et al. 2011).
- ESN decreased volatilization in WA by ~75 to 95% over urea in a lab study over 15 days (Koenig, unpub. data).

# Effect of NSN on volatilization



# Placement: Effect of incorporation depth




Ernst and Massey, 1960

# Timing: Effect of temperature on UAN volatilization with and without NBPT

| **% of surface applied N volatilized over 7 days** | | | |
|---|---|---|---|
| | Check | UAN | UAN+NBPT |
| May (74°F) | 0 | 7 | 1 |
| July (86°F) | 0.6 | 50 | 16 |

Grant et al., 1996, Manitoba

# Timing: Effect of moisture

- Engel et al. (2011) in MT found that worst-case conditions for volatilization were when urea was:

  -applied to moist soil surface

  -w/ no more than ¼ in. of total precip in next 2 weeks

- Engel et al. found that lowest volatilization amounts occurred when urea was:

  -applied to a dry soil surface

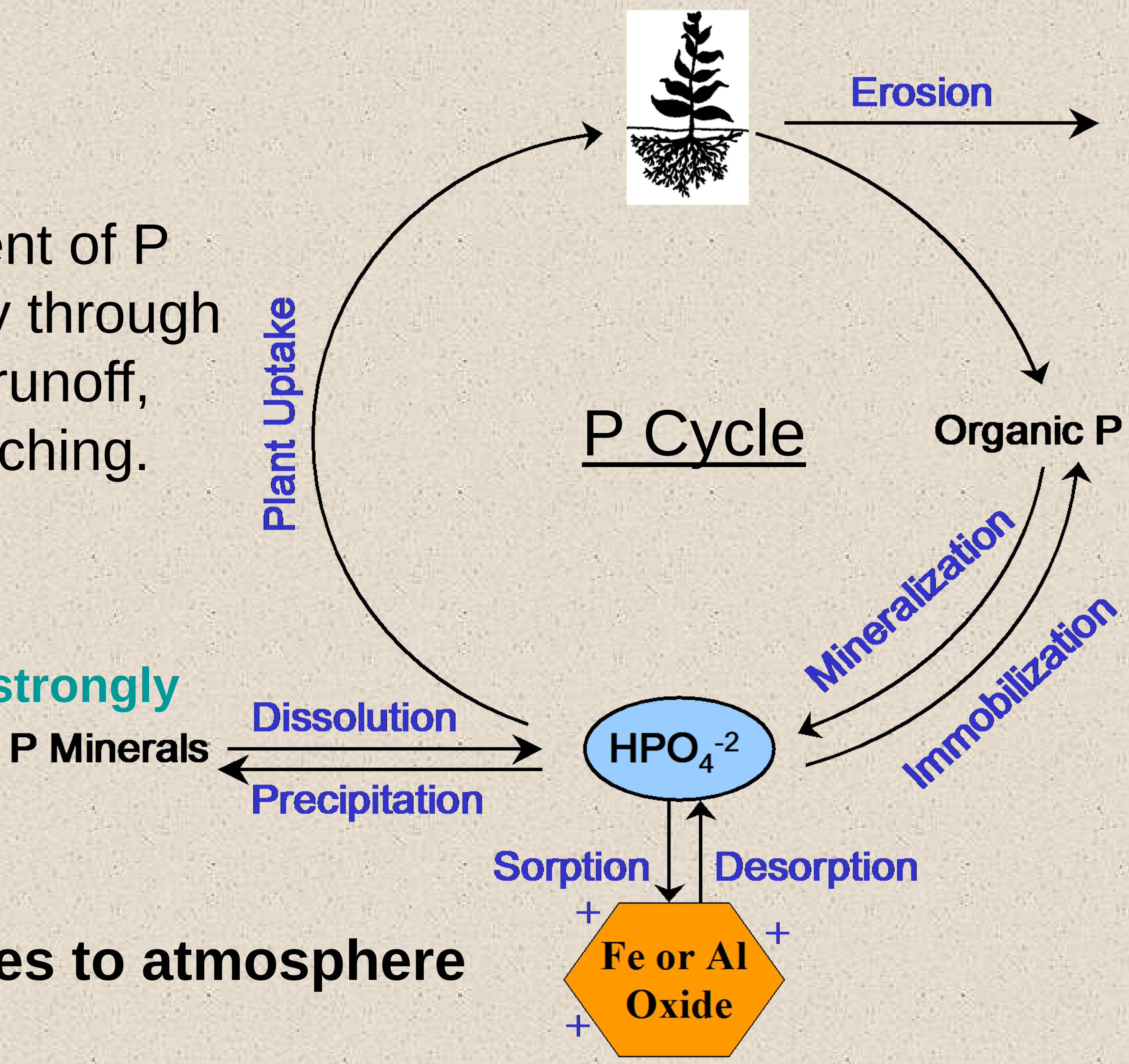
  -first precip event after application was >3/4 in.

# What should growers do to minimize volatilization?

1. Do not apply urea on moist ground UNLESS a snow or rainstorm is forecast to drop at least ½ inch of moisture in a day, preferably more (unlikely unfortunately!)
2. If irrigate, apply at least ½ inch of irrigation water after urea application
3. Apply urea below the surface – either in a mid-row band, 2 inches from the seed or with the seed with a ‘protected’ product
4. Consider using Agrotain®, UAN, or ammonium nitrate (if available) if can’t apply during a low risk time

# Questions on nitrogen losses?

Movement of P is largely through erosion/runoff, NOT leaching. Why?




**P binds strongly to soil**

**No losses to atmosphere**

If erosion and runoff are minimized, P movement is also minimized. How?

1. Reduce tillage, leave stubble tall
2. Carefully manage irrigation
3. Avoid annual cropping on slopes where gullies can form
4. Reduce fallow
5. Increase perennial crops

# Other Resources

- Soil Fertility information: http://landresources.montana.edu/soilfertility
- Western Nutrient Digest – look for it as an email attachment in 3 – 4 weeks. The fall issue will have 2 articles on volatilization (MT, OR research) and 1 related to leaching (MT research).

# Questions?