Enhanced Efficiency Fertilizers:
Why is Efficiency Important?
How Do They Work?
What Can We Expect?

Patricia Steinhilber

UMCP

Ag Nutrient Management Program

Department of Environmental Science and Technology

Today's Approach

- Kratochvil's webinar on enhanced efficiency fertilizers on March 9
  - www.anmp.umd.edu
    - workshop tools
      - top of list
- many misconceptions are afloat among our clients
  - "slow release N"

Why the Interest in N?
1) Ag Profitability

- nitrogen fertilizer prices have dramatically increased in recent years
  - cost of N fertilizer is closely linked to cost of natural gas
- increase in price is indicative of a long term trend
  - global increase in demand for energy & crop nutrients

Why the Increase in Price?

- N fertilizer production is an energy-intensive process
  - Haber-Bosch process
    - hydrogen (H_2) + nitrogen (N_2) = ammonia (NH_3)
    - hydrogen gas (H_2) from natural gas
    - nitrogen gas (N_2) from the atmosphere
  - natural gas is steam reformed to make hydrogen gas
  - nitrogen gas must be separated from air
  - nitrogen and hydrogen are combined at very high temperature (850 F) and pressure (250 atm)

Energy Inputs for Big 3

- N – 45 GJ/ton (5% of the global consumption of natural gas)
- P – 20 GJ/ton
- K – 8 GJ/ton

Why the Interest in N?
2) Reactive Nitrogen (N_r)

- vulnerable to loss
  - leaching
  - denitrification
  - volatilization
- biologically, radiatively and photo-chemically active N compounds
  - N_2O nitrous oxide (greenhouse gas and ozone destroyer)
- "cascades through the environment external to the agroecosystem" (Cassman)
- economic loss and environmental risk

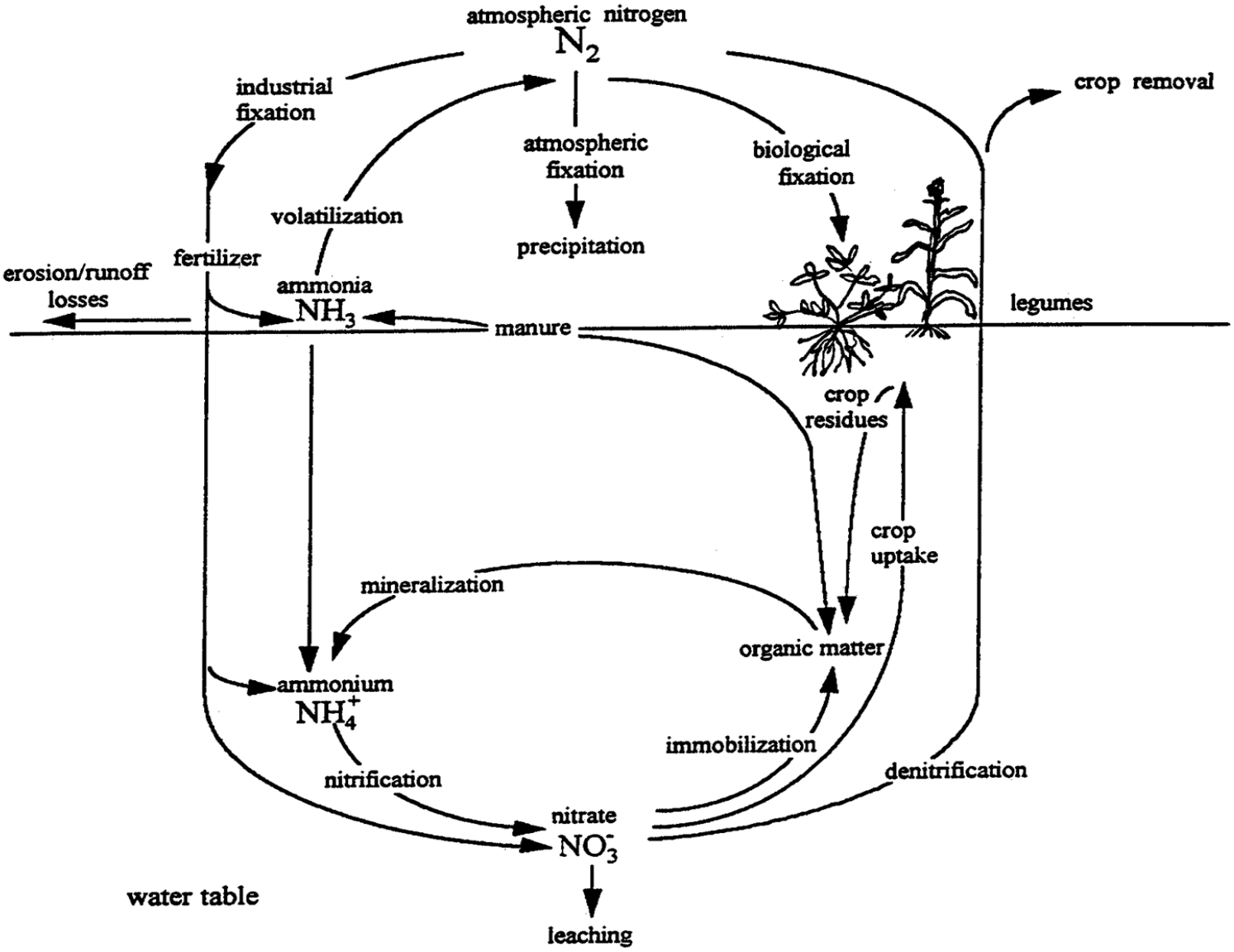


Figure 3-2. The Nitrogen Cycle.

Nitrogen Use Efficiency (NUE)

- Re_N - N fertilizer recovery efficiency
  - fertilizer-N recovered in the above-ground biomass during the growing season
  - 37% in corn (USA Corn Belt, Cassman)

- worldwide in cereals – 33% (Raun)
  - developed countries - 42%; developing countries - 29%

Keys to Improving NUE
"The 4 Rs"

- right rate
- right source
- right time
- right place

"Maximize utilization of nitrogen fertilizer you've applied."

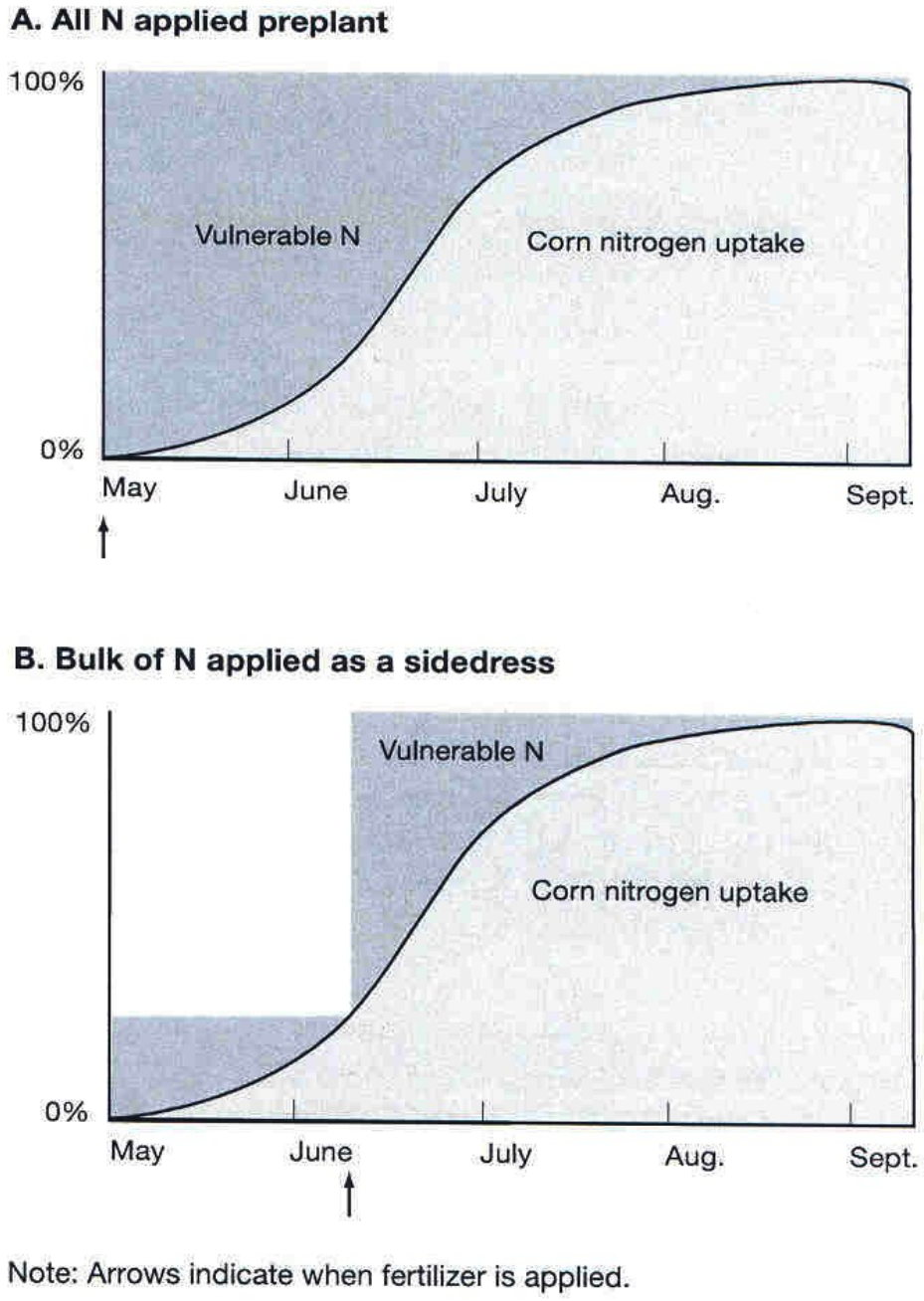
- reduce rate of nutrient release (N) to the soil solution

- reduce transformations to mobile forms
  - slow down nitrification (ammonium to nitrate)

- reduce the transformation to gaseous forms (N)
  - reduce denitrification (nitrate to nitrogen gas) **
  - reduce ammonium volatilization (ammonium to ammonia)

Enhancing Synchrony: Minimize Vulnerable Nitrogen

- if the N is not yet applied, it can not be lost
- solution? split application (Penn State Agronomy 12)

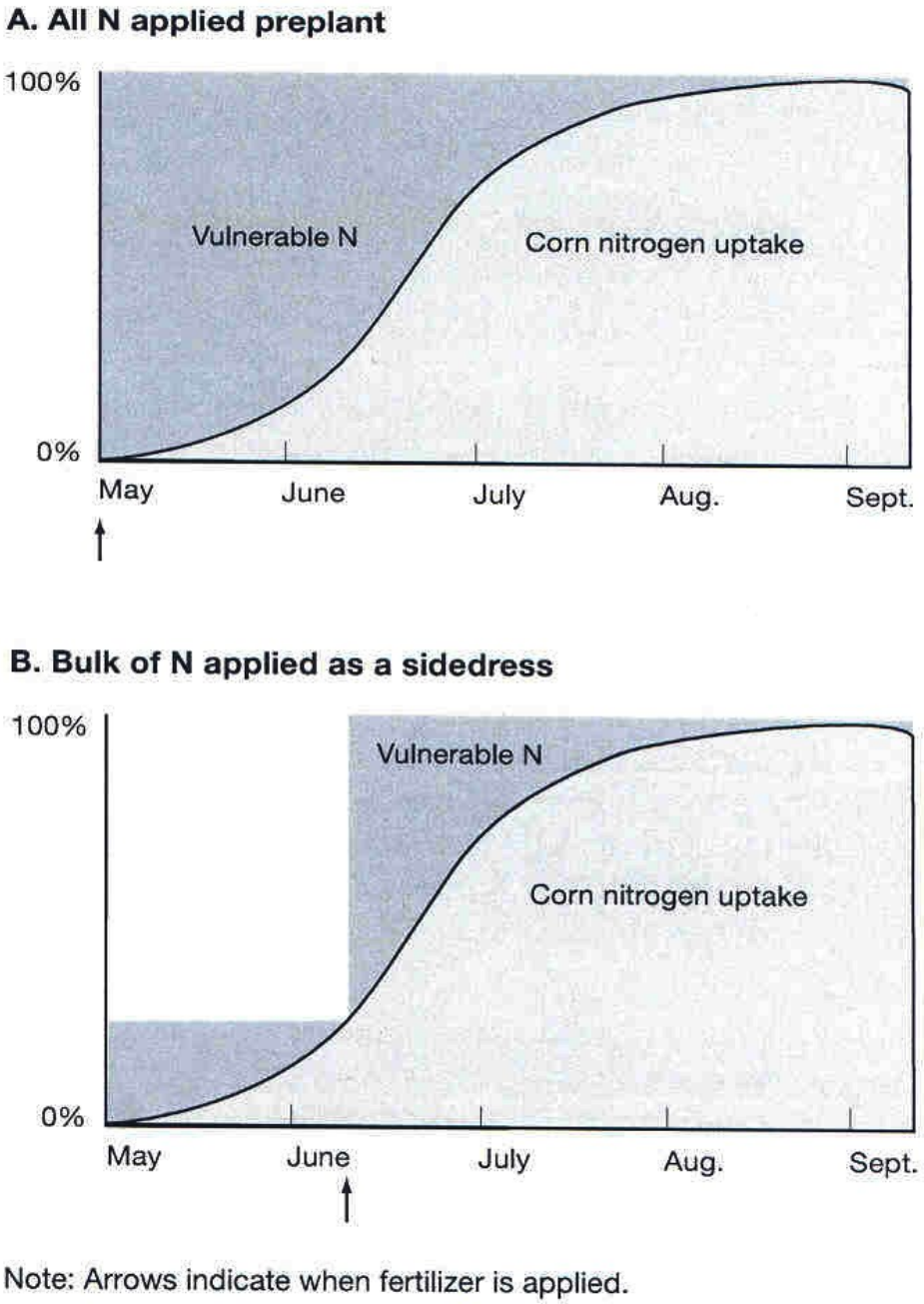


DE Yield Data on Split Application of N on Corn (bu/A)

	150 lbs/A pre-plant	40-110 lbs/A pre-plant sidedress
2003*, irrigated loamy sand soil	48a	102b
2003*, dryland, loamy sand soil	102c	126d
2005, irrigated, loamy sand	98e	158f

So, why isn't sidedressing a widespread nitrogen BMP?

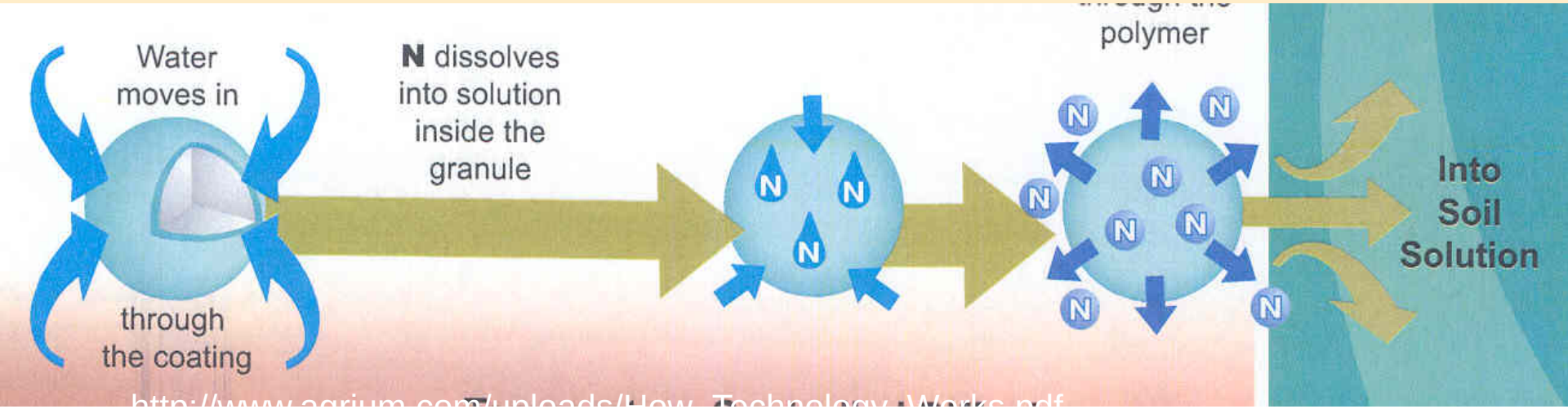
- Is there a product that can be applied pre-plant and not be vulnerable to loss?



Note: Arrows indicate when fertilizer is applied.

Controlled Release Nitrogen

- protect nutrients with a semi-permeable membrane
  - ESN®, Environmentally Smart Nitrogen
  - a polymer-coated urea
  - diffusion of urea is temperature controlled



ESN™

- a controlled release urea product
- relies upon diffusion
- diffusion is temperature-dependent
- ESN was designed for the Mid-West corn belt
- may not function optimally in other climatic zones

Corn Yield Data from DE (150 lbs/A N)

	all preplant UAN	all preplant ESN	40-110 preplant-sidedress UAN
2003 dryland, sil	102a	112a	126b
2003 irrigated, ls	48a	64b	102c
2005 irrigated, ls	98a	113b	158c

Fertilizer Additives

- **nitrification inhibitors**
  - **retard conversion of ammonium to nitrate**
  - **reduce conversion to a more mobile form**
- **urease inhibitors**
  - **ties up urease enzyme so to slow conversion of urea to ammonium**

Reduce Transformations to Mobile Forms

- nitrification inhibitors $NH_4^+ \not\rightarrow NO_2^-$
  - *N-Serve™* is a bactericide that kills targeted organisms, *Nitrosomonas,* works with anhydrous ammonia
  - *Instinct™* designed to work with surface-applied products
  - both are nitrapyrin
  - organic compound that itself is subject to microbial attack

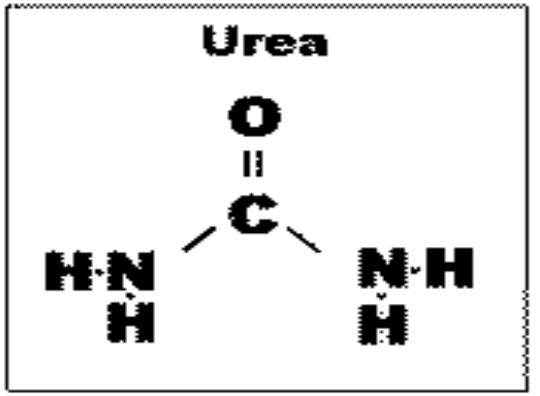
Reduce the Transformation to Gaseous Forms

- aka minimizing ammonia volatilization
- affects broadcast, surface-applied urea, UAN, ammonium nitrate and manure
- ammonium in the presence of hydroxyl (OH^-) can produce ammonia gas

$$NH_4^+ + OH^- \longrightarrow H_2O + NH_3\uparrow$$

So How Does Urea Relate to Ammonia Loss?

- urea is converted to ammonia by the enzyme, urease
- if urease activity is blocked, the rate of conversion is reduced
- urease is ubiquitous – in soil & on crop residue
  - 20 X more residue than soil
- enter ... urease inhibitors, like NBPT or Agrotain™



Urease Inhibitors

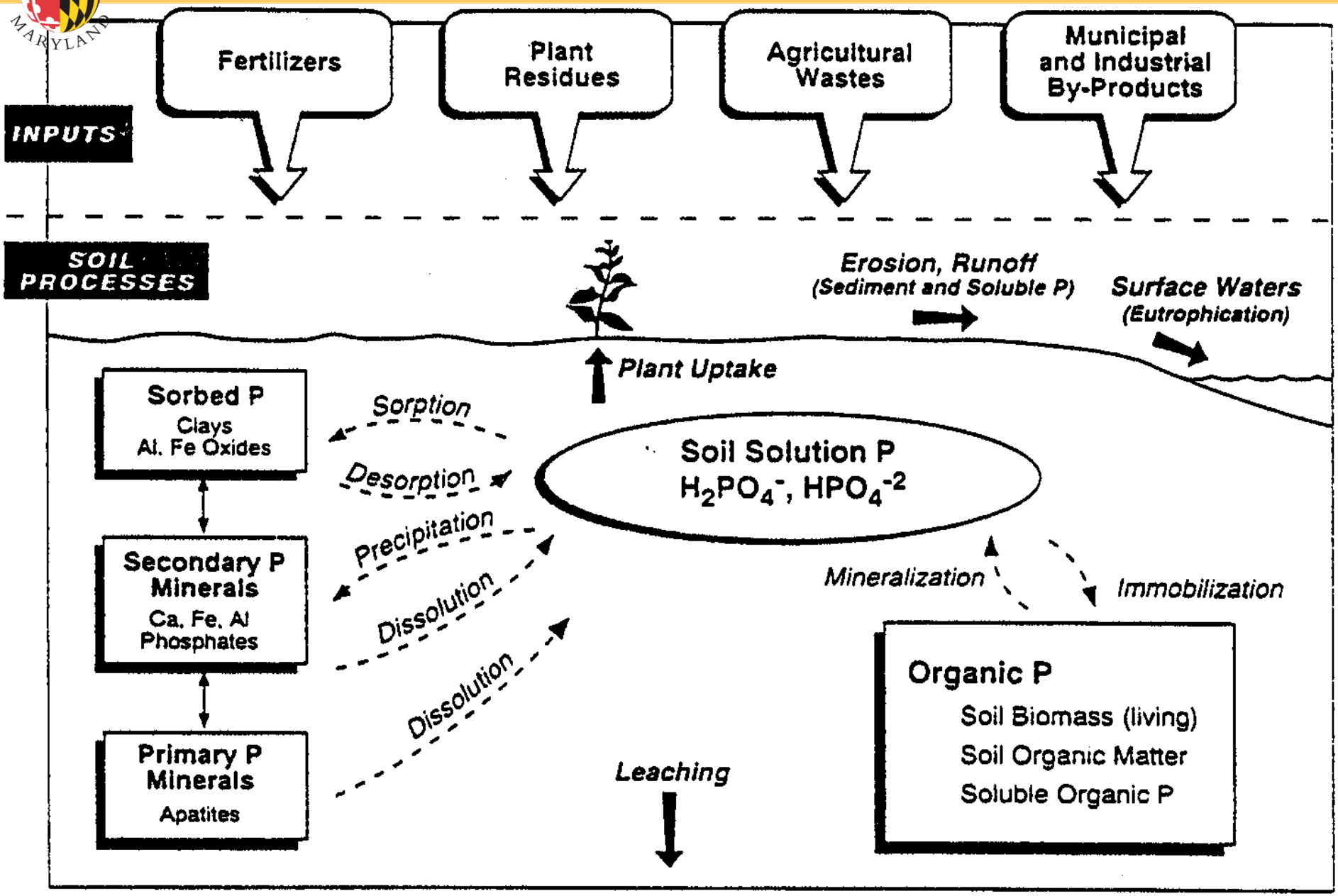
- urea $\xrightarrow{\text{urease}}$ $NH_3 + CO_2 + H_2O$
- $NH_3 \rightleftharpoons NH_4^+ + OH^-$
- urea is very soluble but hydrolysis of urea is rapid under warm temperatures
- urease inhibitors (UIs) temporarily block the action of urease
- UIs are organic compounds, subject to microbial attack

When Might It Be Effective?

- UIs may block urea conversion up to 2 weeks
- if rainfall occurs, urea will move into the soil
- effectiveness depends upon temperature and rainfall
- most effective in warm weather when broadcasting urea

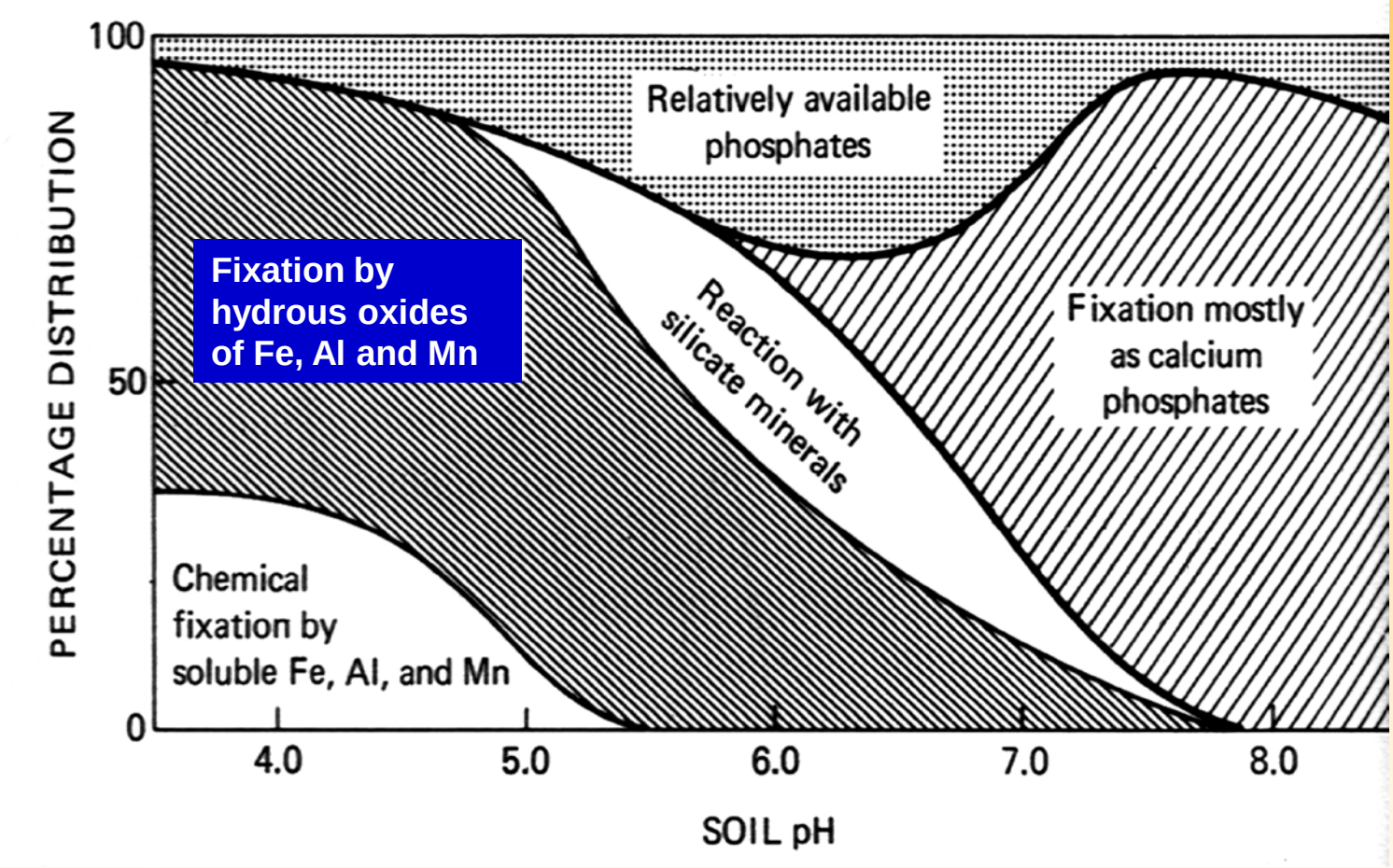
Long-term Phosphorus Issue

- "We're running out!"
- US has reserves for 25 year
- Morocco has 75% of the world's reserves
  - geographical imbalance could pose a geostrategic ticking time bomb
- US is importing P from Morocco
  - prolongs US reserves


Fertilizers
Plant Residues
Agricultural Wastes
Municipal and Industrial By-Products
INPUTS
SOIL PROCESSES
Erosion, Runoff
(Sediment and Soluble P)
Surface Waters
(Eutrophication)
Plant Uptake
Sorbed P
Clays
Al, Fe Oxides
Sorption
Desorption
Soil Solution P
$H_2PO_4^-$, HPO_4^{-2}
Precipitation
Secondary P Minerals
Ca, Fe, Al Phosphates
Dissolution
Mineralization
Immobilization
Organic P
Soil Biomass (living)
Soil Organic Matter
Soluble Organic P
Dissolution
Primary P Minerals
Apatites
Leaching

“Maximize utilization of phosphorus fertilizer you’ve applied.”

- reduce reactions of phosphorus with soil
  - phosphorus fixation
    - **adsorption** onto surfaces of iron and aluminum oxides
    - **precipitation** as secondary P compounds
      - in acid soils P combines with iron (Fe) and aluminum (Al) to form insoluble compound
      - in neutral and calcareous soils P combines with (Ca) to form insoluble compounds



N.C. Brady, 1974

Department of Environmental Science and Technology

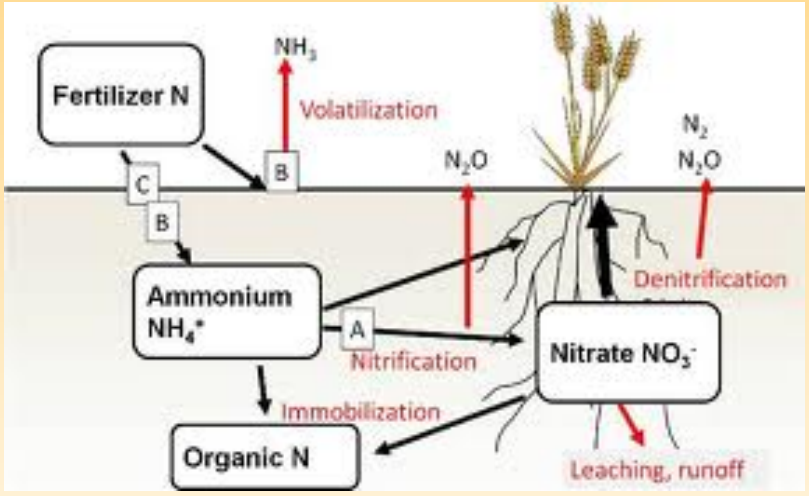
Reduce Reactions of Phosphorus with Soil

- protect phosphorus with a chemical shield
  - AVAIL® - “enhance P availability”
  - coated with a chemically-reactive material
  - protects P from reacting with Fe, Al or Ca in the soil solution
- Question?
  - Under what circumstances might it be useful?

EFFs

- **engineer controlled release products**
- **design additives that slow down natural processes that lead to loss**
- **develop “shields” to protect nutrients from the reacting with soil components**

Questions or Comments?



gov.mb.ca