# Nitrogen & Phosphorus


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# Questions

- Yield expectations and therefore nutrient requirements are not the same for all fields – why?
- Nutrient management harder on a dairy farm than a cash grain farm using only inorganic fertilizer - why?
- In VA, large dairy, poultry, swine farms under nutrient management regulations but grain farms not - why?
- Predict plant available P and K by soil testing, but not reliably N – why?
- If we know 55ppm P in soil is adequate for crop growth, why do some soils test >500ppm?

# Typical Crop Nutrient Removal

| | Lbs per unit of yield | | |
|---|---|---|---|
| Crop (unit yield) | N | $P_2O_5$ | $K_2O$ |
| Corn grain (bu) | 1.1 | 0.38 | 0.27 |
| Corn silage (ton) | 7.65 | 4.2 | 8.3 |
| Wheat (bu) | 1.25 | 0.51 | 0.61 |
| Soybean (bu) | 3.75 | 0.89 | 1.42 |
| Tall grass hay (ton) | 53.3 | 16 | 52 |
| Alfalfa (ton) | 45 | 14.5 | 45 |

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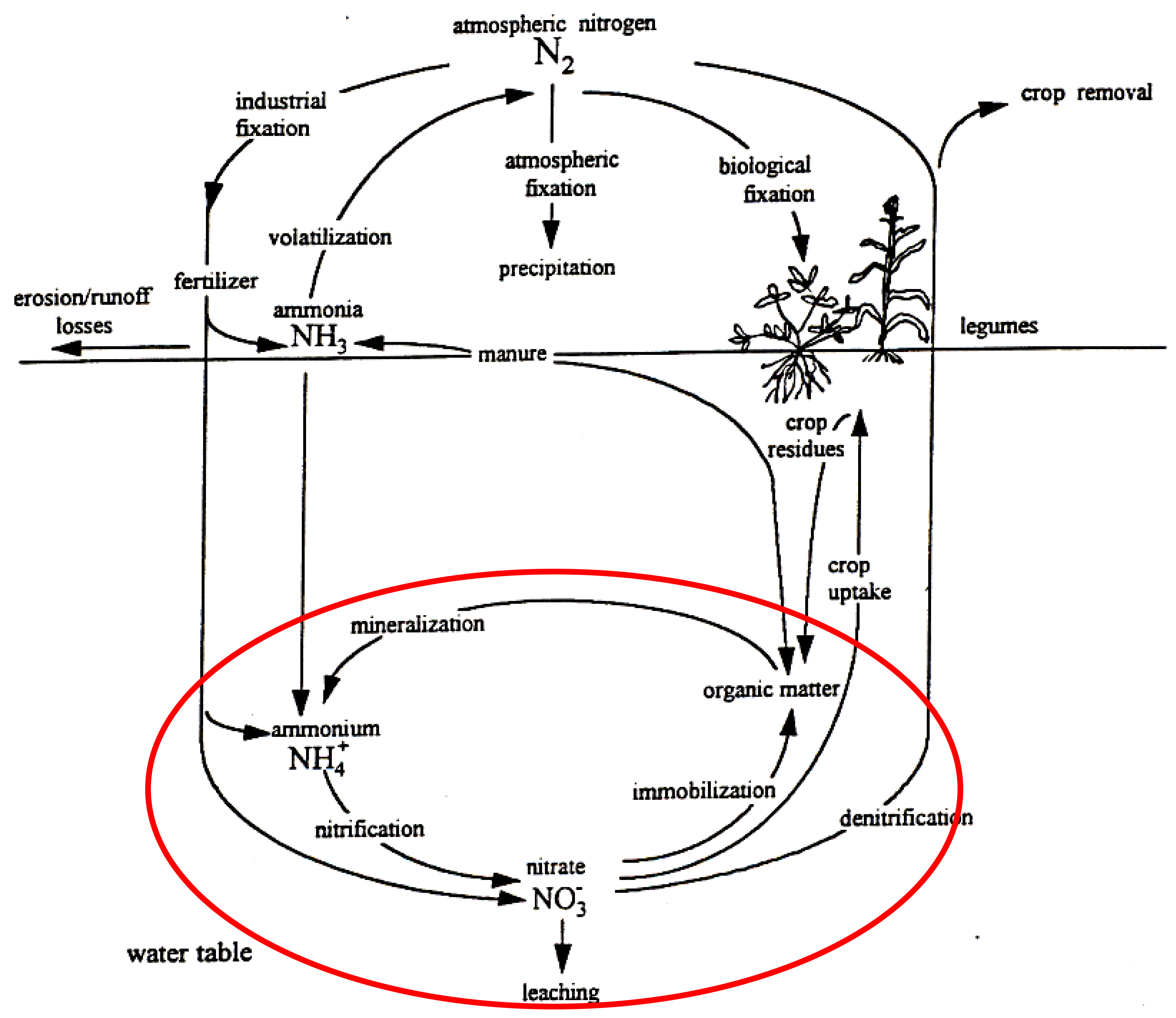
# N & P Environmental Effects

- **Both N and P can contribute to water quality problems**
  - **Groundwater (10 ppm $NO_3$-N limit)**
  - **Surface water: eutrophication**
    - **N – Primary concern in estuaries (Chesapeake Bay)**
    - **P - Primary concern in fresh water**

# Nitrogen Forms

- **Inorganic:**
  - $NH_4^+$, $NO_3^-$
  - $NO_2^-$, $N_2$, $NH_3$, $N_2O$
- **Organic Sources:**
  - Amino acids and sugars, proteins, and other complex compounds
  - Decomposition can produce plant available N



atmospheric nitrogen
$N_2$
industrial fixation
atmospheric fixation
biological fixation
crop removal
volatilization
precipitation
fertilizer
erosion/runoff losses
ammonia
$NH_3$
manure
legumes
crop residues
crop uptake
mineralization
organic matter
ammonium
$NH_4^+$
immobilization
nitrification
denitrification
nitrate
$NO_3^-$
water table
leaching


ch

# Nitrogen Transformations

- **Mineralization:** Conversion of organic-N (R-$NH_2$) to inorganic-N

$$R\text{-}NH_2 \xrightarrow{\text{Ammonification}} NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$

Depends on carbon: nitrogen ratio (C:N) of amendment (Mineralization when C:N < 20:1).

[Soil Organic Matter: 97 to 99% of total soil N]

# Nitrogen Transformations

- **Nitrification:** Conversion of ammonium ($NH_4^+$) to nitrite ($NO_2^-$) and to nitrate ($NO_3^-$) by soil bacteria

$$2NH_4^+ + 3O_2 \xrightarrow{\textit{Nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+$$

$$2NO_2^- + O_2 \xrightarrow{\textit{Nitrobacter}} 2NO_3^-$$

- **Nitrate:** plant uptake, denitrification, leaching, or erosion/runoff

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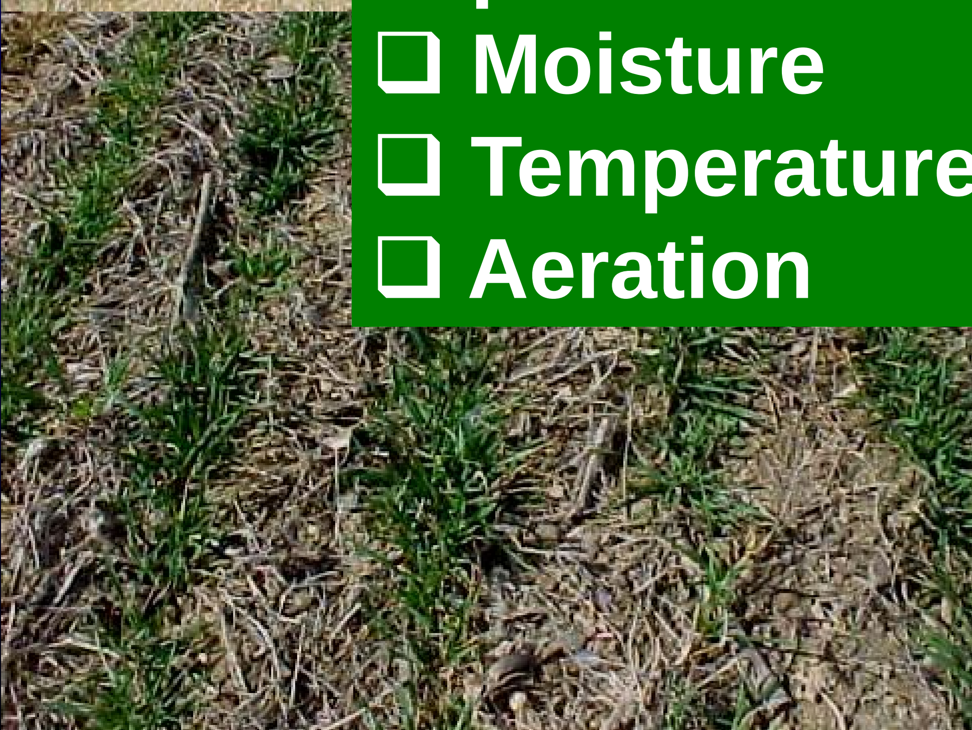
## Soil Factors Affecting Mineralization & Nitrification:

- pH
- Moisture
- Temperature
- Aeration




# Soil Acidification via Nitrification:

- Nitrification of $NH_4^+$ generates $H^+$ cations, which reduce soil pH.
- Use of ammonium-based fertilizers will decrease soil pH (nitrification).
- Significant cause of  liming needs.

# Nitrogen Transformations

- **Immobilization:**

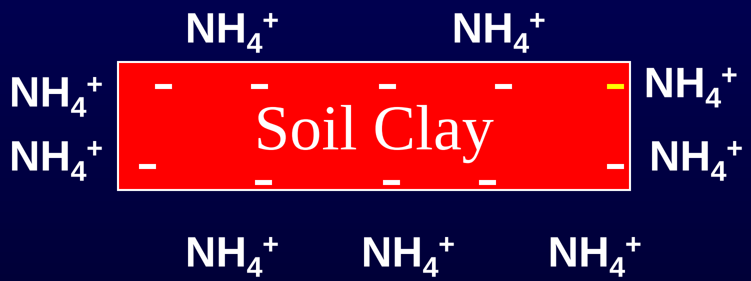
  **Conversion of inorganic-N to organic-N**

  $$NH_4^+ \text{ or } NO_3^- \longrightarrow \text{organic N compounds}$$

- **Depends on the C:N ratio of the soil amendment (**Immobilization when C:N > 30:1)

# Nitrogen Transformations

- **Ammonium Adsorption:** Retention of positively charged ammonium ions on the surface of soil colloids (clay)




- **Fixation:**

  Entrapment of ammonium Ions between the platelets of certain clay minerals

# Losses of Nitrogen

- **Volatilization: Gaseous loss**
- **Leaching: Downward soil transport**
- **Runoff: Transport across landscape**
- **Crop removal: Plant uptake**

# Nitrogen Transformations

- **Ammonia Volatilization:**

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

- $NH_3$ = Ammonia Gas
- Ammonia losses: High pH & surface application of manure or ammoniacal (urea) fertilizer
- Urea Hydrolysis:

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

$$NH_4^+ \longrightarrow NH_3 + H^+$$

# Nitrogen Transformations

- **Denitrification:**

  Reduction of nitrate ($NO_3^-$) to gaseous forms of N by soil bacteria

| $NO_3^-$ | $\longrightarrow$ | $NO_2^-$ | $\longrightarrow$ | $NO$ | $\longrightarrow$ | $N_2O$ | $\longrightarrow$ | $N_2$ |
|---|---|---|---|---|---|---|---|---|
| Nitrate | | Nitrite | | Nitric Oxide | | Nitrous Oxide | | dinitrogen gas |

- Occurs under anaerobic conditions - bacteria use nitrate as electron acceptor
- High/alkaline soil pH favors

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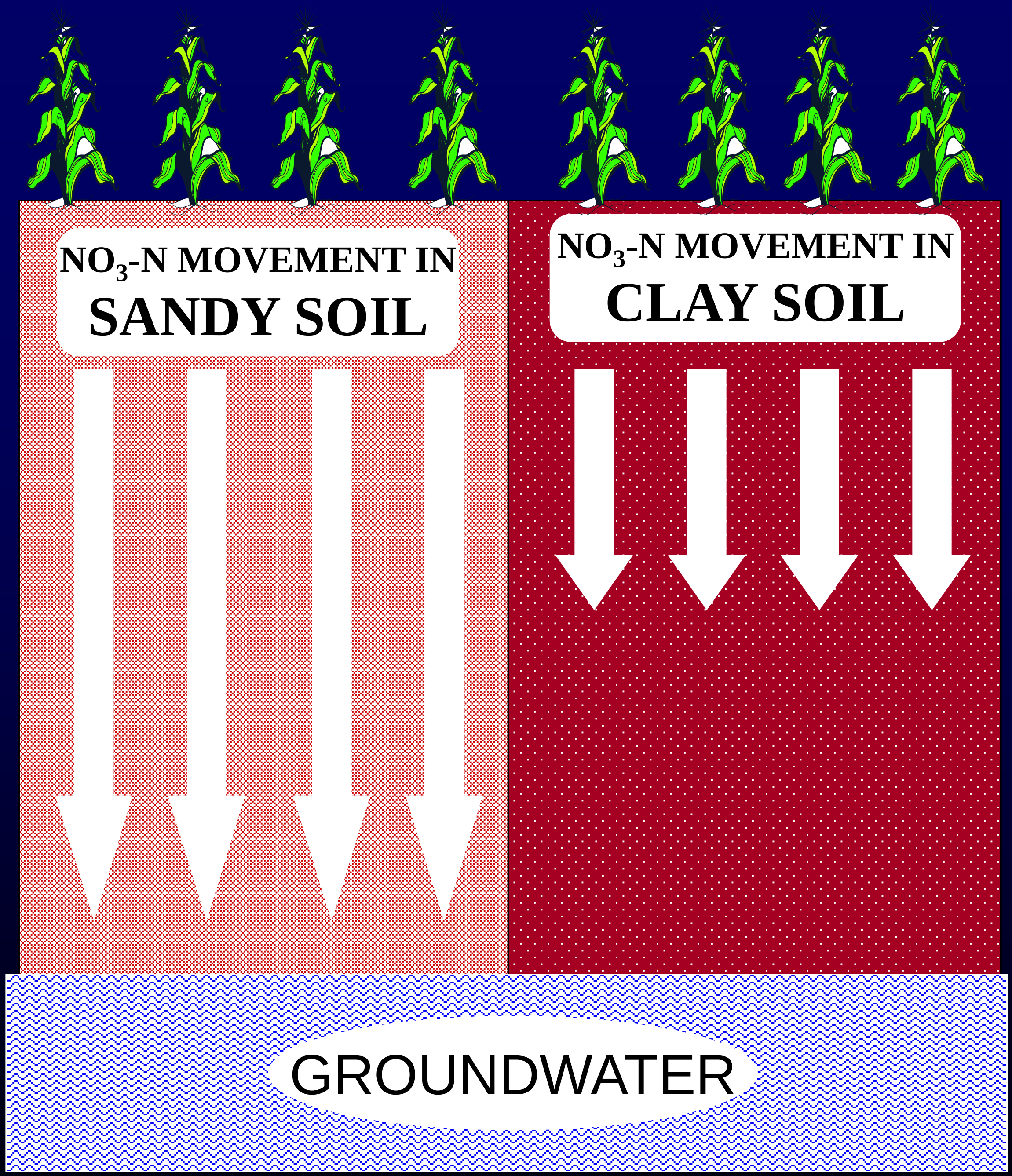


# <u>Leaching</u> Losses of Nitrate-N

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# Factors affecting leaching of N

- Heavy fertilizer N applications on sandy soils
- Overapplication of manure/biosolids
- Improper timing of application
- Poorly designed or non-existent soil conservation measures
- Periods of exceptionally heavy rain

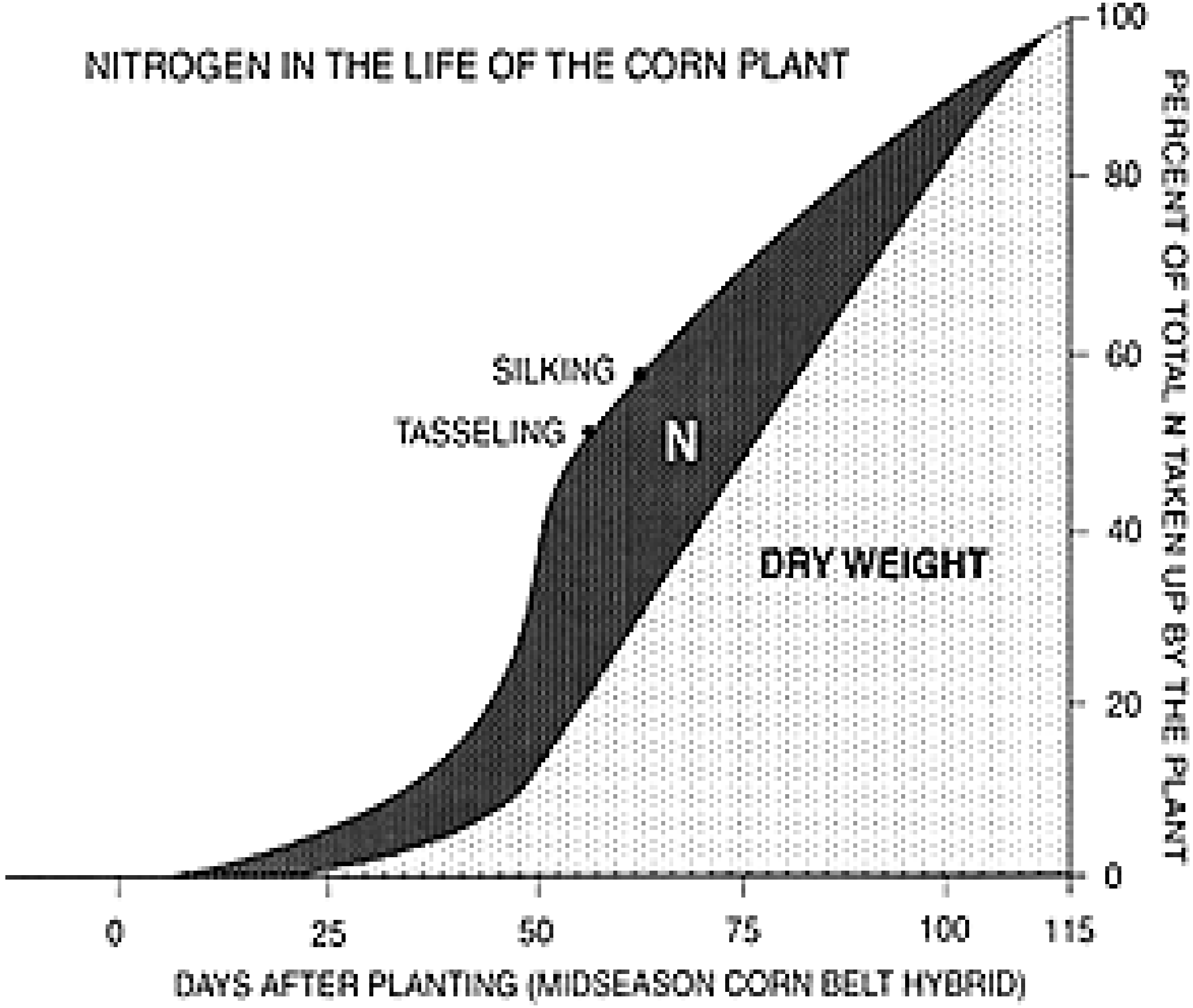



Fig. 1. Dry weight and N uptake by corn (Hanway, 1963).

# Nitrogen Transformations

- **Biological Nitrogen Fixation:**
  Conversion of atmospheric N ($N_2$) to an organic form of N.
- Symbiotic (legumes) and free living organisms

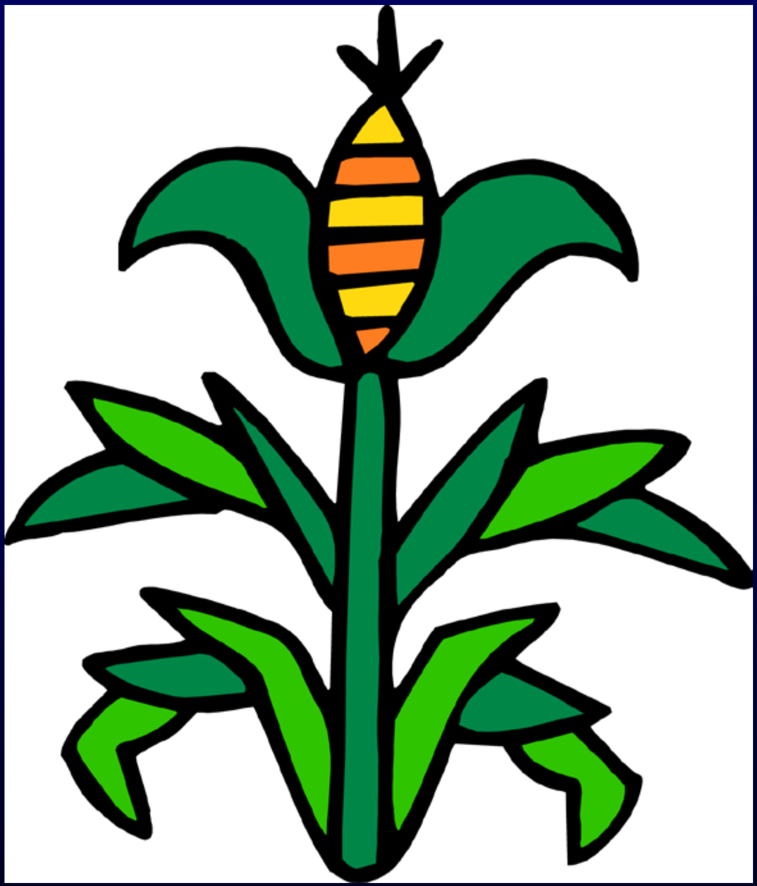
$$N_2 + 8H^+ + 6e^- \longrightarrow 2NH_3 + H_2$$

# Residual N credits from legumes

| Crop | % Stand | Description | Residual N |
|---|---|---|---|
| | | | Lbs/A |
| Alfalfa | 50-75 | Good (>4 t/A) | 90 |
| | 25-49 | Fair (3-4 t/A) | 70 |
| | <25 | Poor (<3 t/A) | 50 |
| Red Clover | >50 | Good (> 3t/A) | 80 |
| | 25-49 | Fair (2-3 t/A) | 60 |
| | <25 | Poor (<2 t/A) | 40 |
| Hairy Vetch | 80-100 | Good | 100 |
| | 50-79 | Fair | 75 |
| | <50 | Poor | 50 |
| Peanuts | | | 45 |
| Soybeans | ½ lb N/bushel of yield, or 20 lbs | | |

**DCR, Standards & Criteria, page 108**

# Phosphorus



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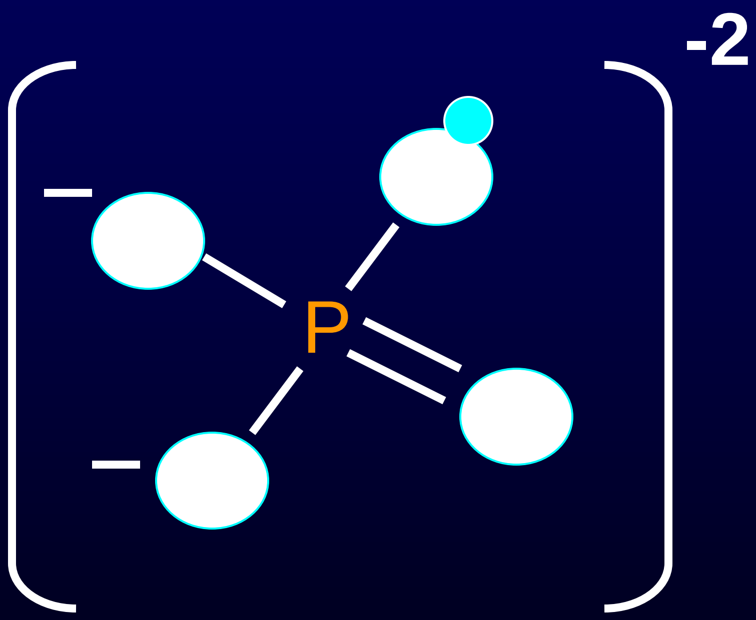
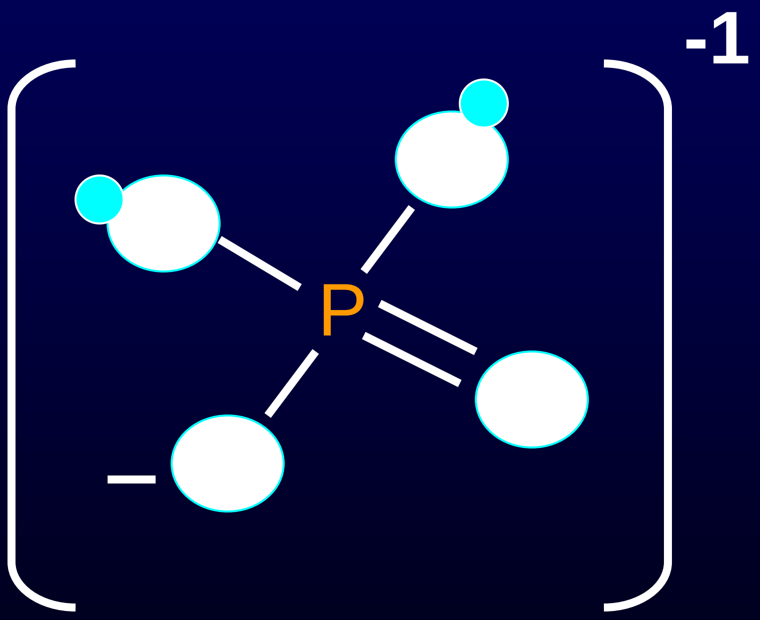
# Forms of Soil P

Orthophosphate




$HPO_4^{-2}$ $H_2PO_4^{-}$

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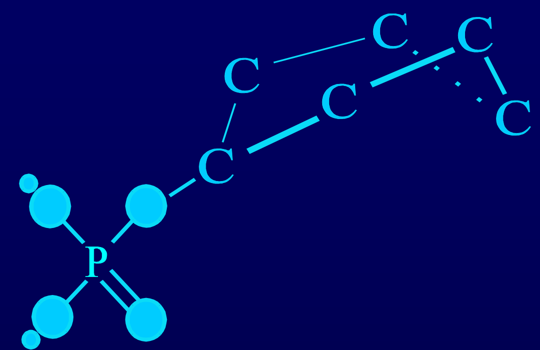
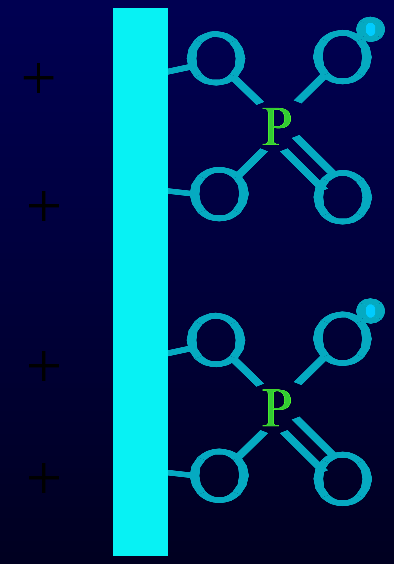
# Phosphorus Transformations

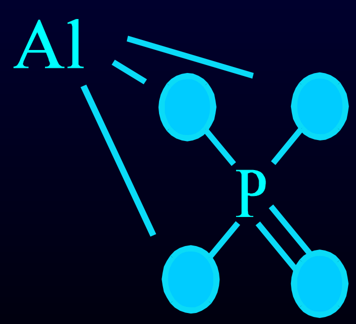
- **Organic P (30-50%)**



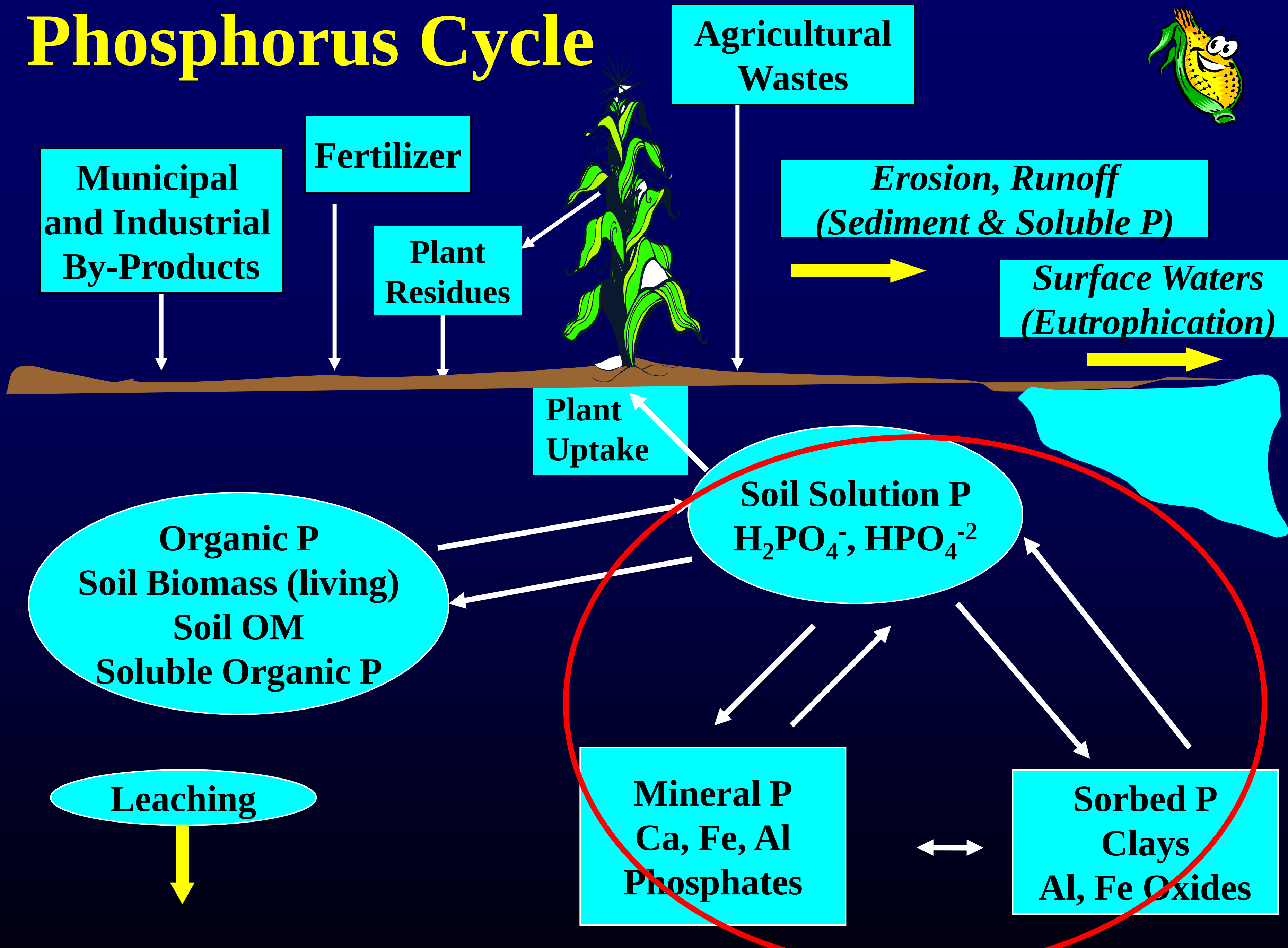

- **Inorganic P fairly insoluble**
- **Adsorbed Inorganic**




- **Precipitates**



# Phosphorus Cycle

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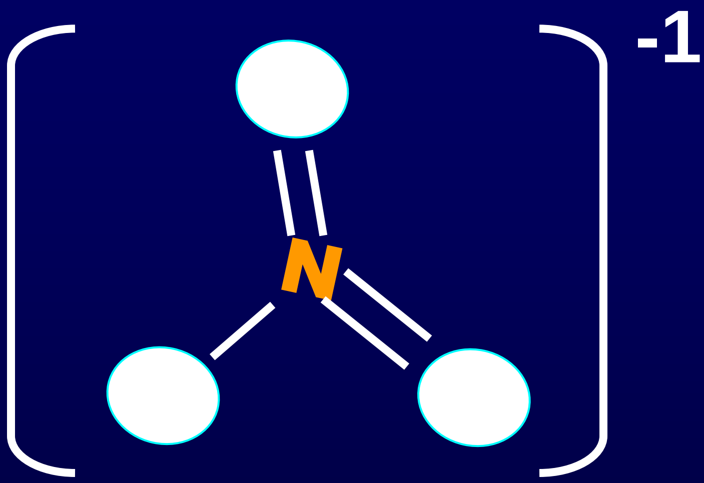
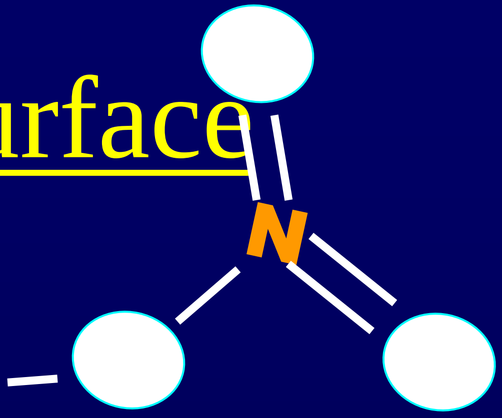
# Soil Phosphorus

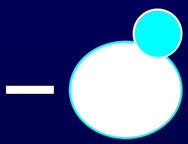
- Total soil P: 800-1600 lb/acre

  50 to 70% in inorganic forms
- Low solubility: Mostly unavailable for plants
- Roots absorb P from the soil solution: <0.01 to 1 ppm (0.2 ppm adequate for plants)
- Soil solution must be replaced continuously

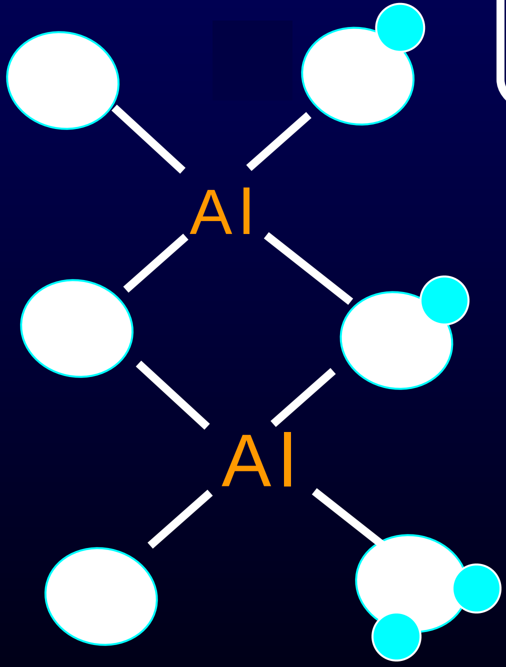
# P Adsorption:  Oxide Surface



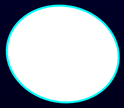



Hydroxyl:  $OH^-$




Aluminum Oxide

Al = Aluminum



= oxygen

= hydrogen

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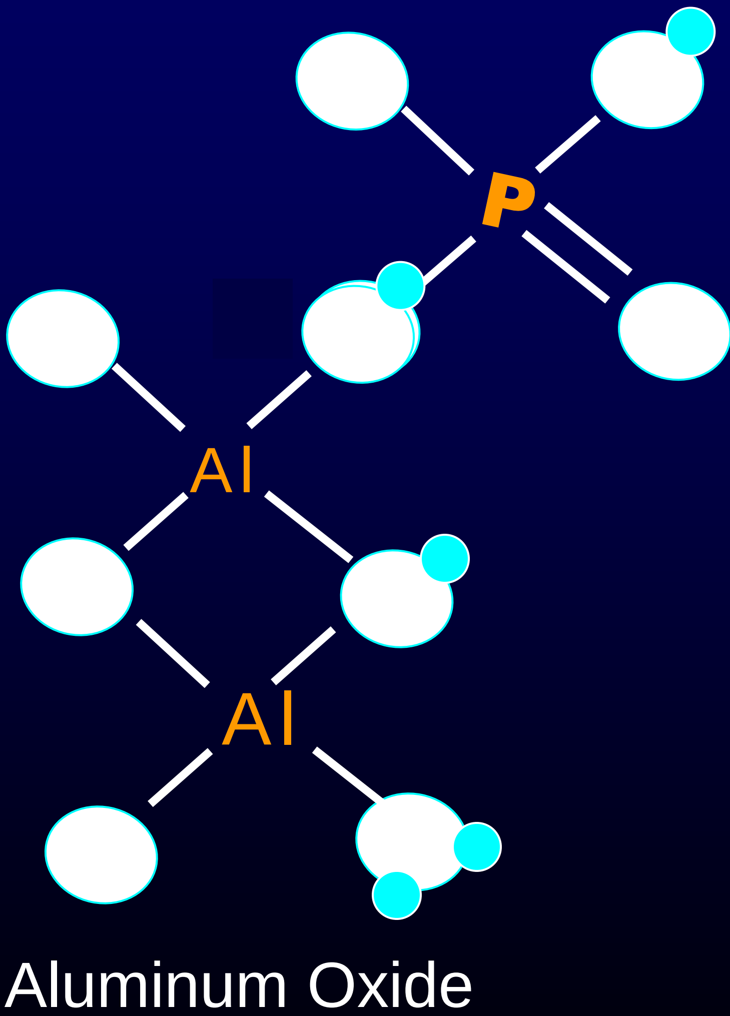
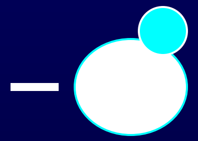
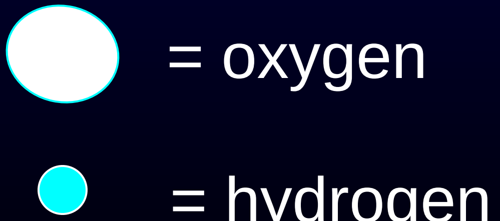
# P Adsorption: Oxide Surface

*Labile* Soil P




Al = Aluminum

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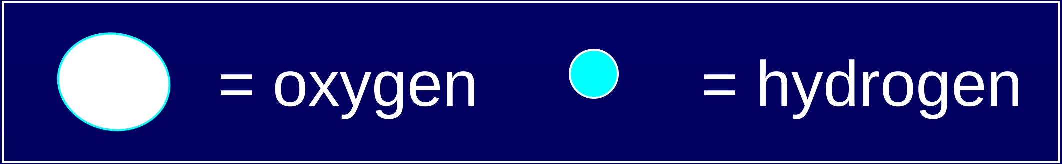
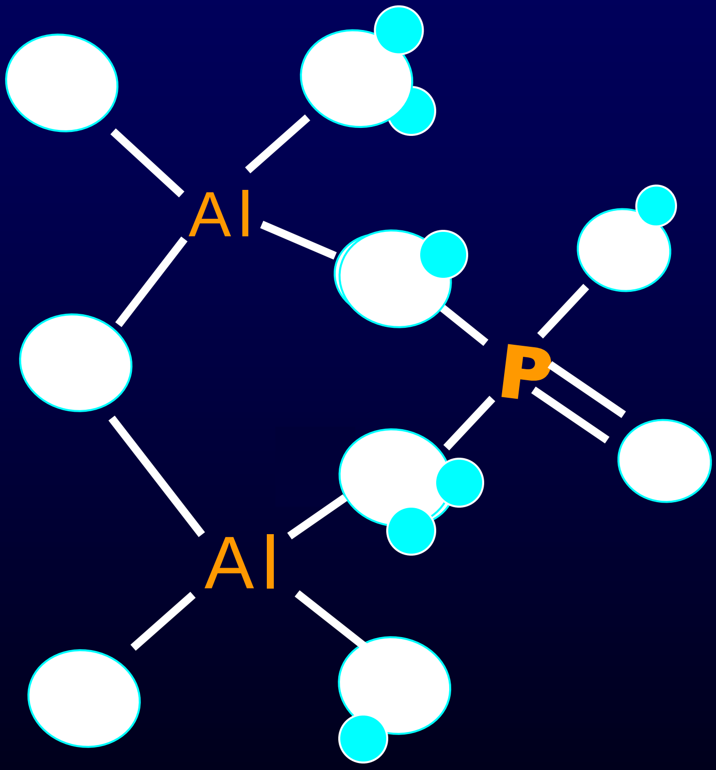
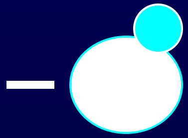
# P Adsorption:  Oxide Surface



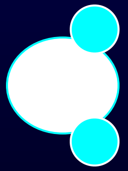

Phosphorus *fixation*




Aluminum Oxide



Hydroxyl: $OH^-$



Water

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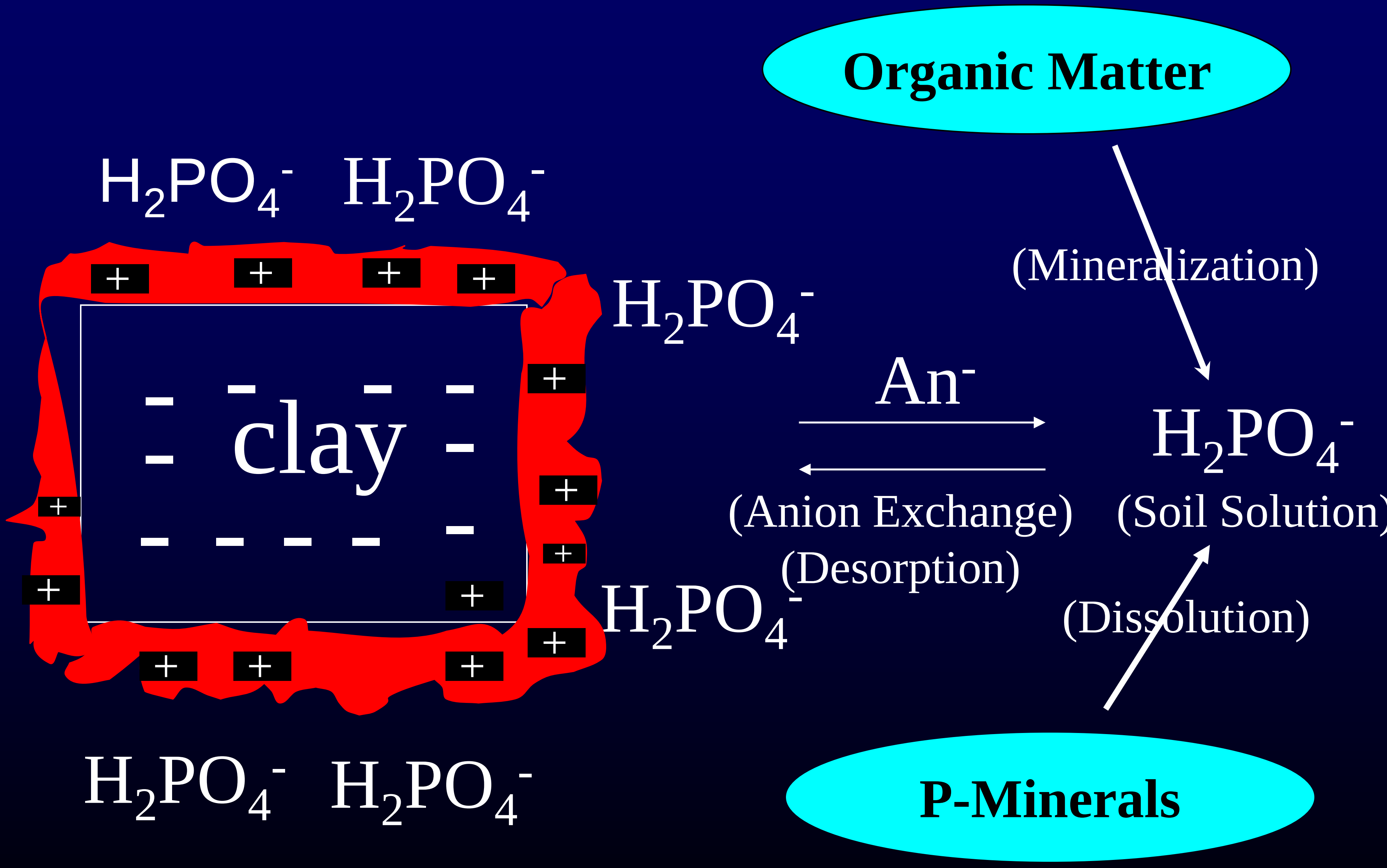
# Available Soil Phosphorus

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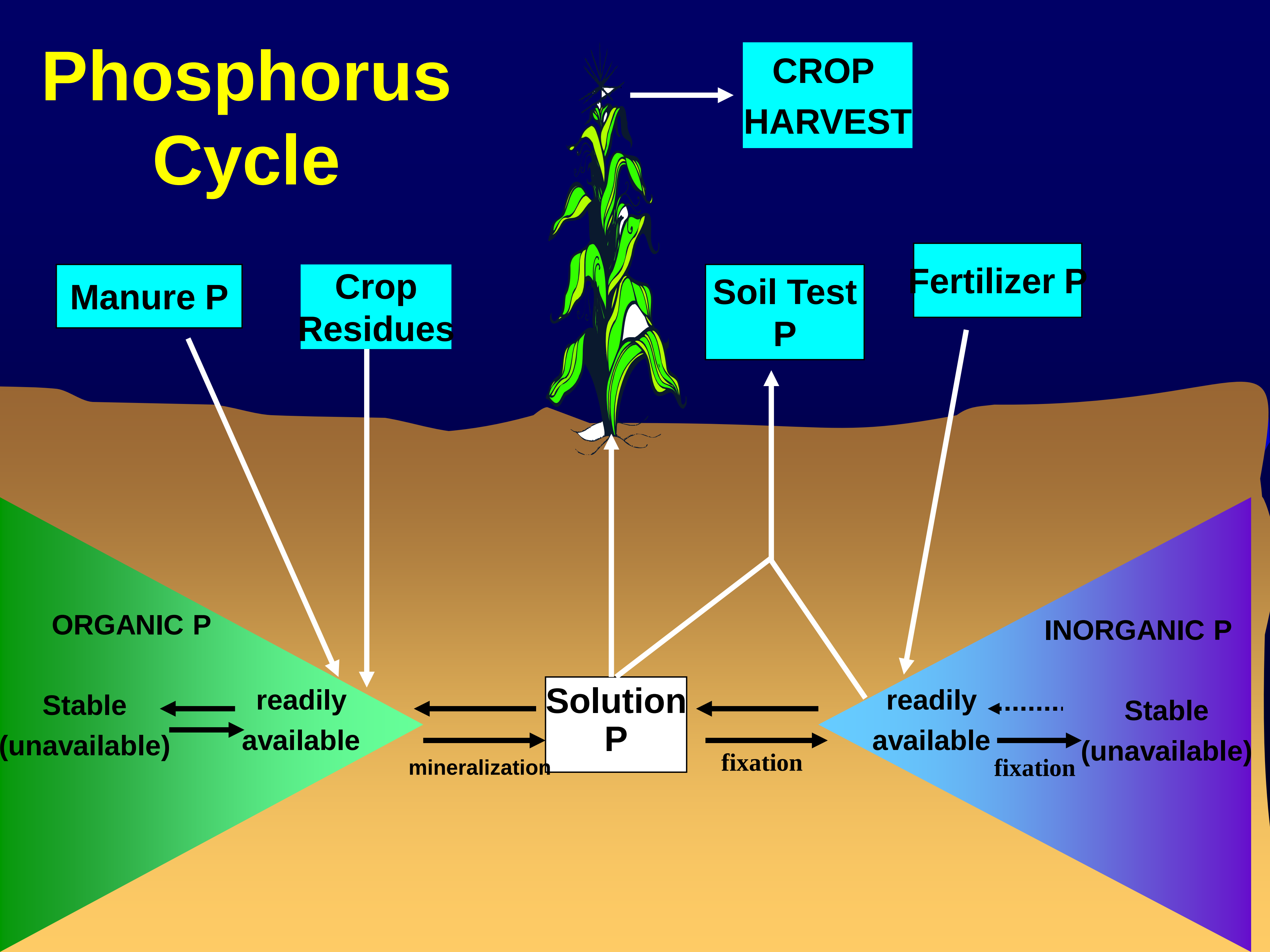
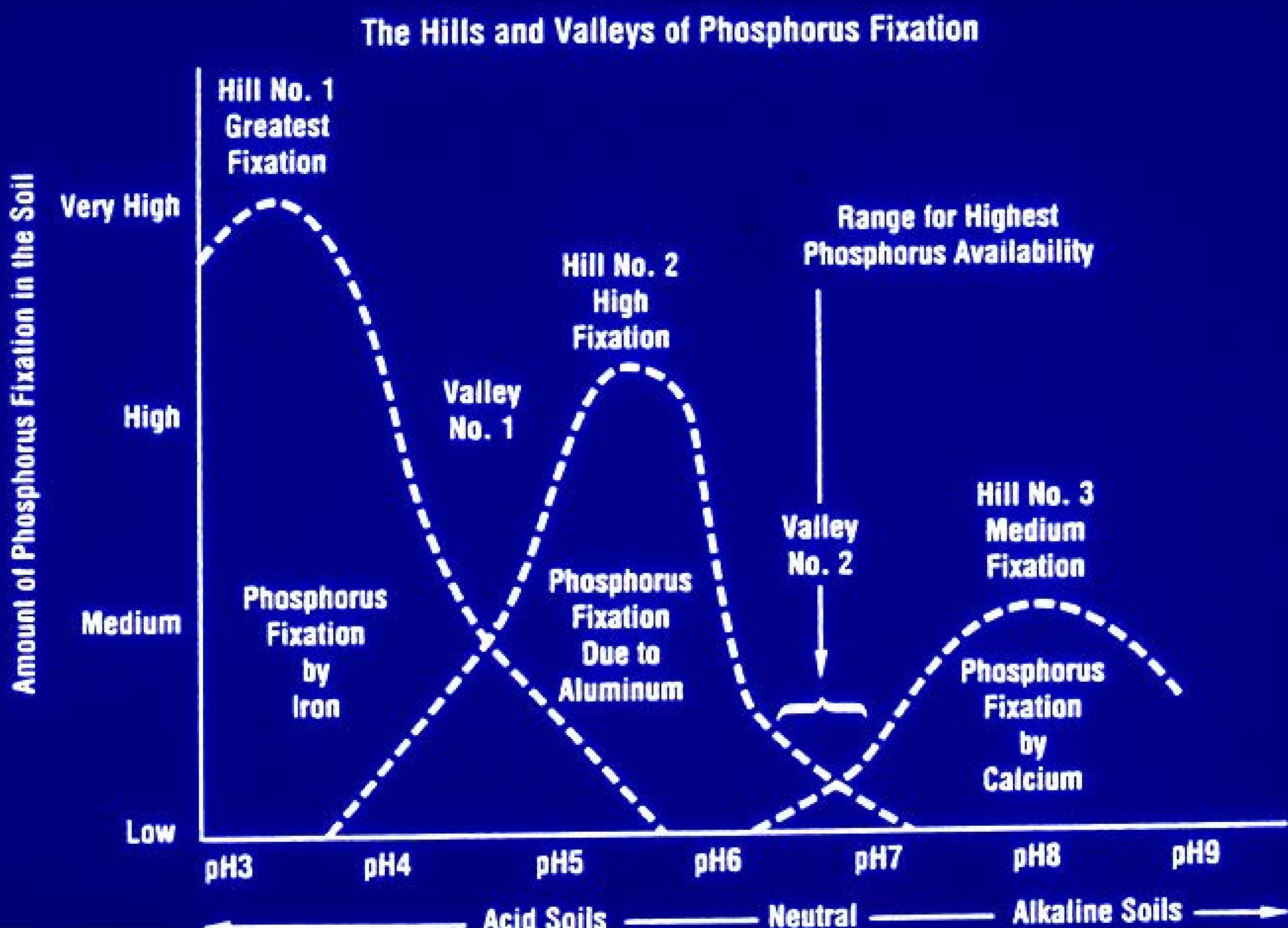

Phosphorus Cycle
CROP HARVEST
Manure P
Crop Residues
Soil Test P
Fertilizer P
ORGANIC P
Stable (unavailable)
readily available
mineralization
Solution P
fixation
INORGANIC P
readily available
Stable (unavailable)
fixation

# Factors Affecting P Availability

- **Amount and type of clay:**
  **High clay soils retain more P**
  **Kaolinitic & oxide clays retain more P**
- **Time of application:**
  **Longer time of contact increases the chances of fixation**
- **Phosphate status of soil:**
  **More soil P ---> more available**

# Factors Affecting P Availability

- Acid soils (low pH): Availability is low because P is “tied up” as iron and aluminum phosphates
- Alkaline or basic soils (high pH): Availability is low because P is “tied up” as calcium phosphates
- Minimum P fixation: Minimum P fixation occurs between pH 5.5 to 6.5

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# Phosphorus & Water Quality

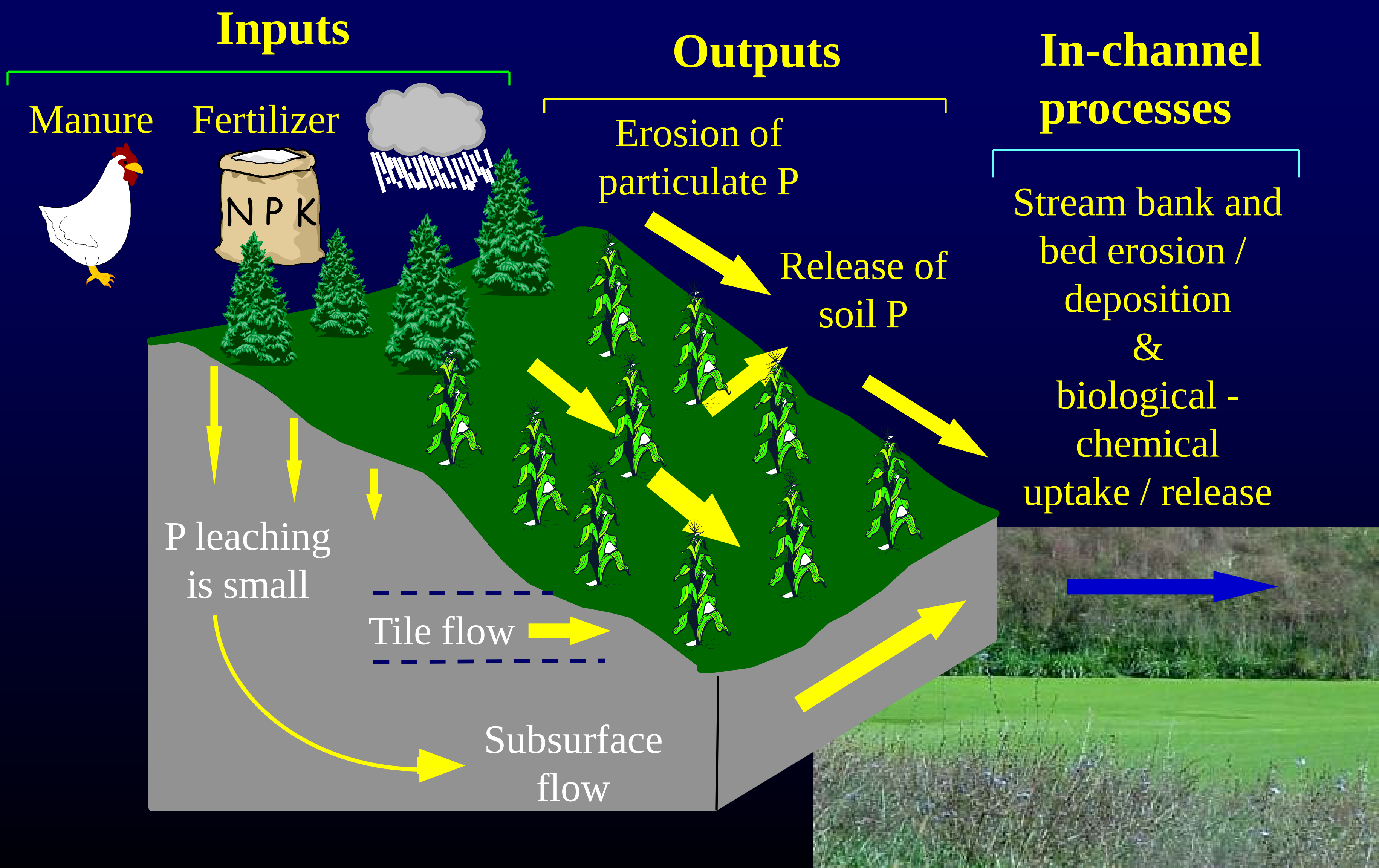
N Movement

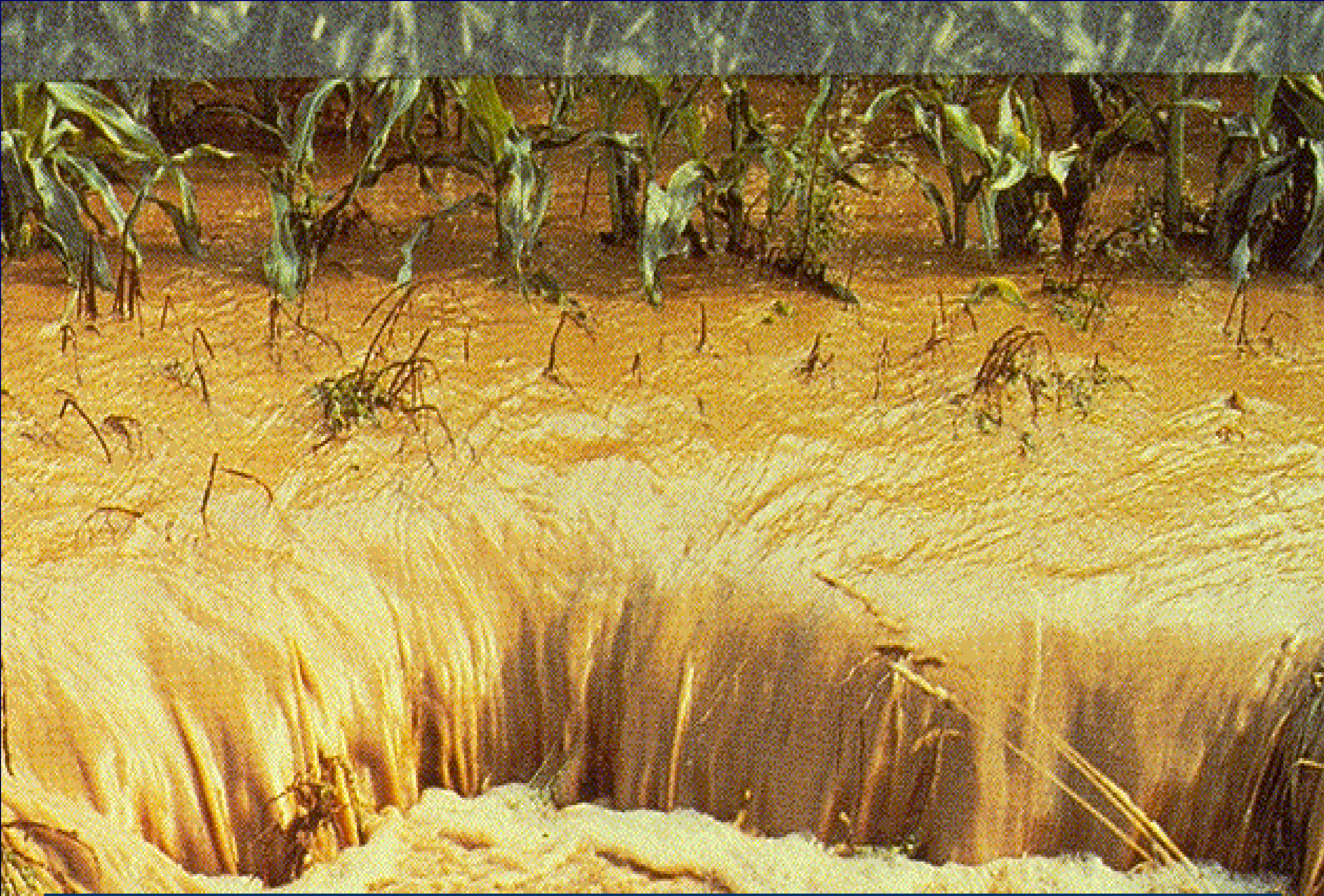
**Nitrate Leaches!!**

P Movement

**P Leaches Slowly**

# Pathways of Transport



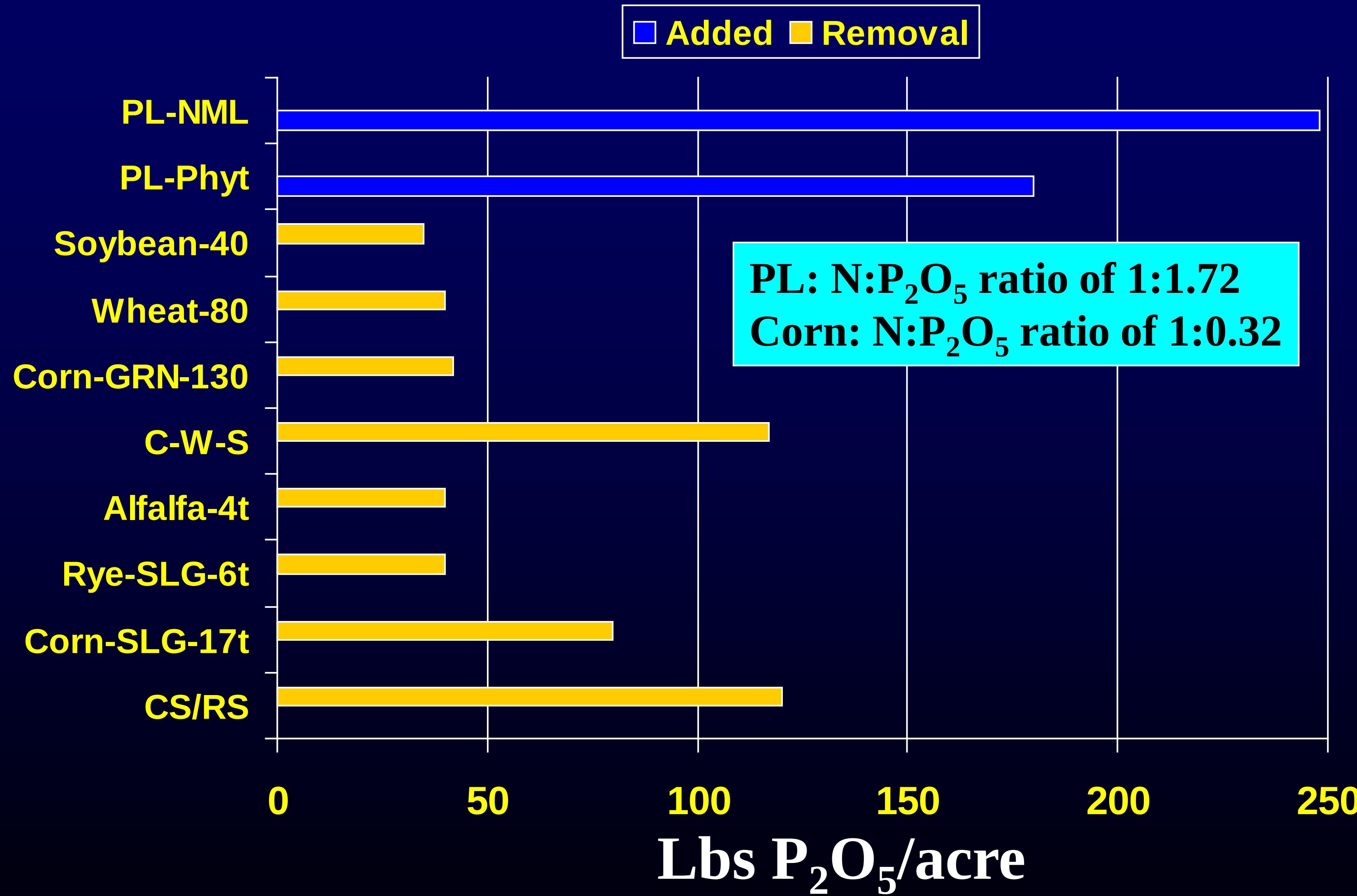


# How Important is Soil Erosion?

# How Important is Soil Erosion?

How important is soil erosion?
How important is soil test P?

# Phosphorus applied as poultry litter (4t/acre) versus crop removal

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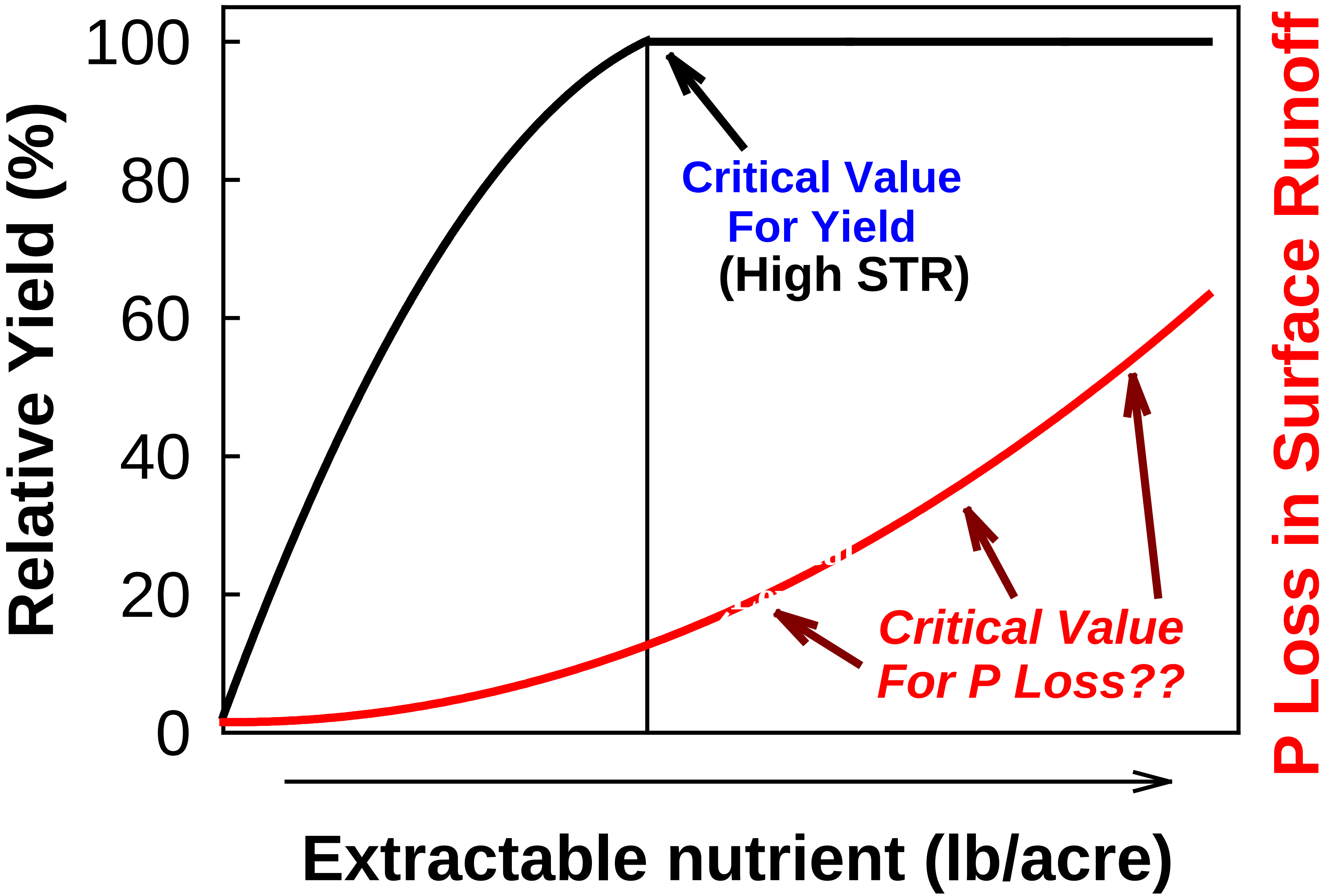
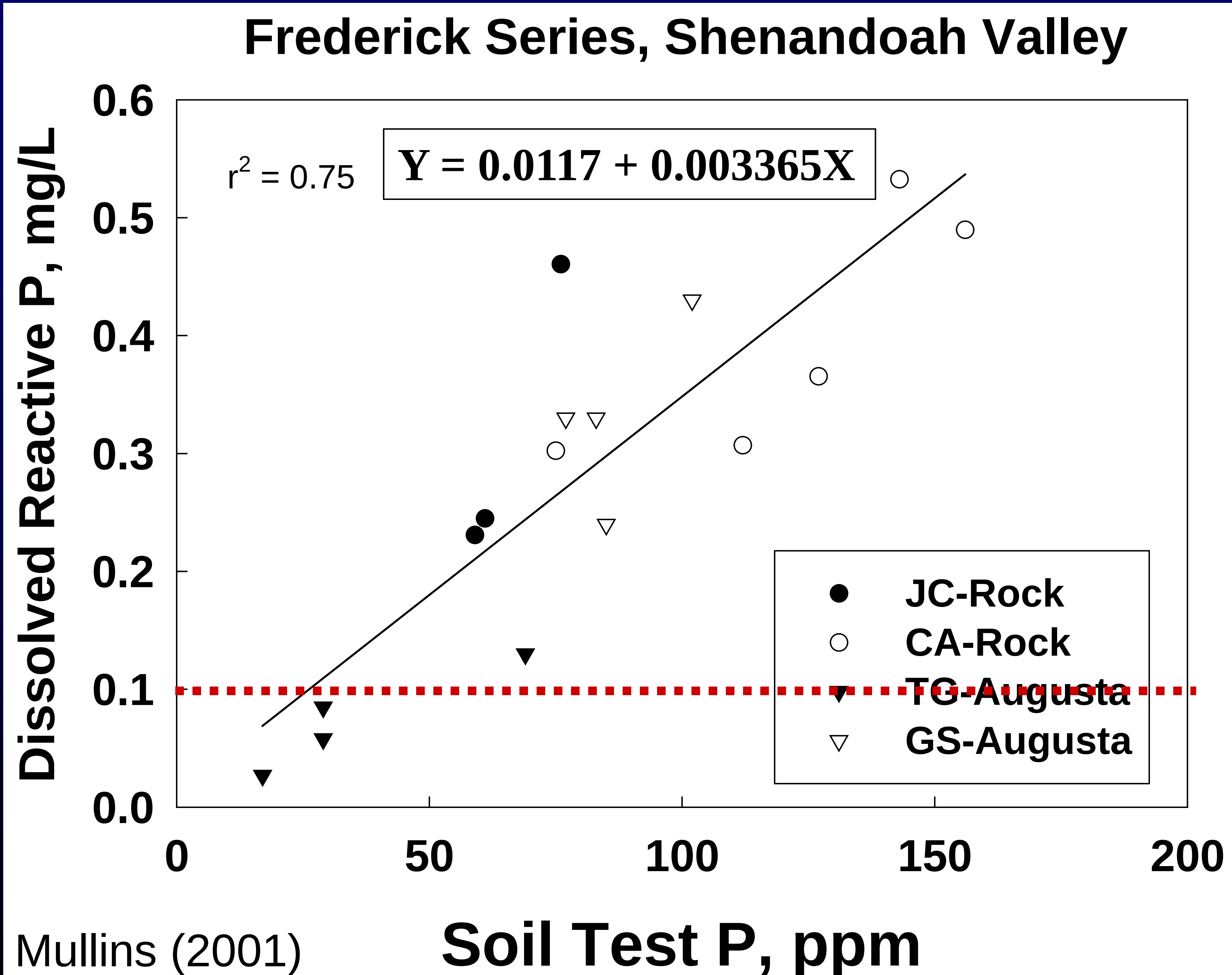


Relative Yield (%)
100
80
60
40
20
0
Critical Value
For Yield
(High STR)
Critical Value
For P Loss??
P Loss in Surface Runoff
Extractable nutrient (lb/acre)

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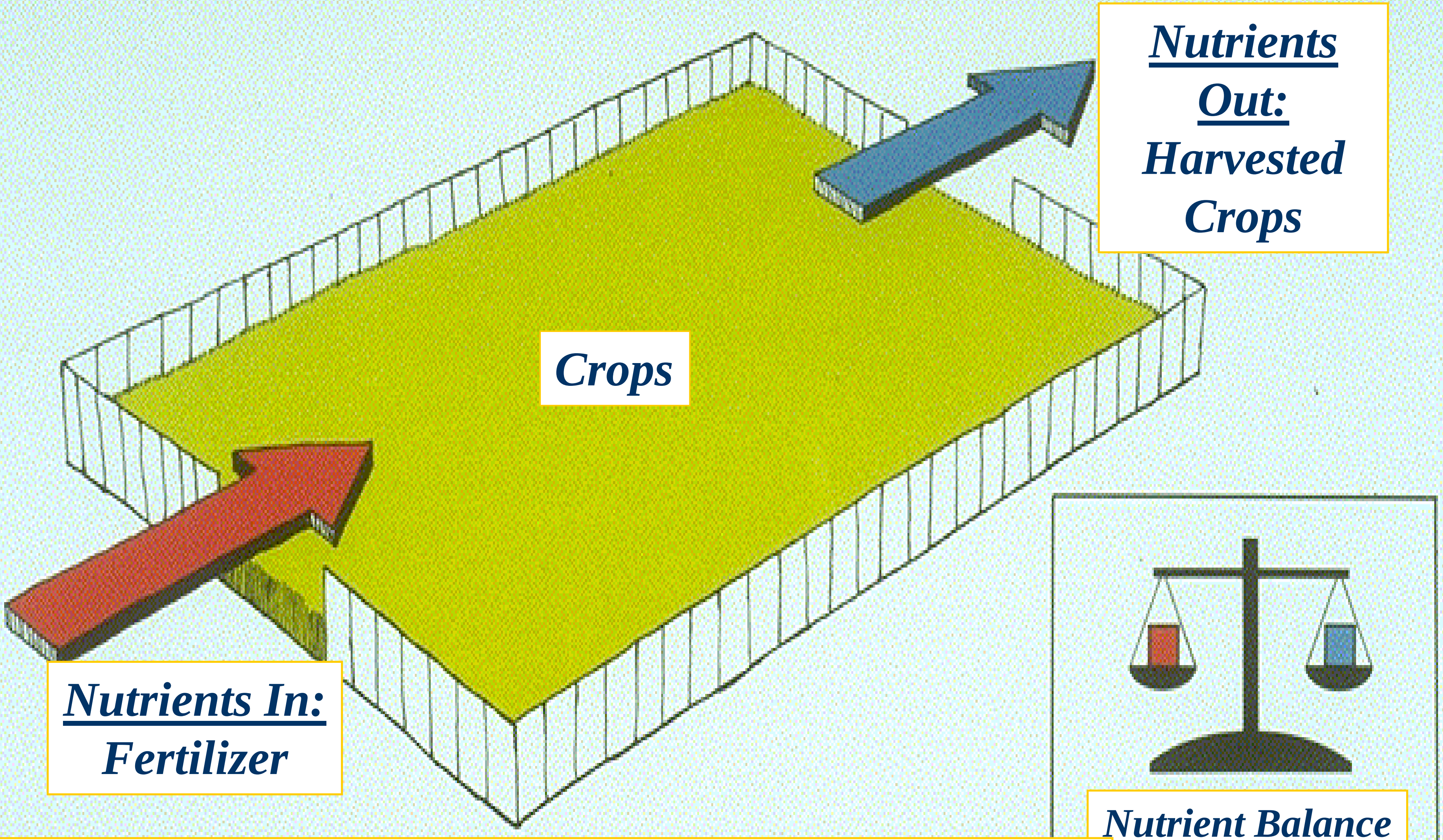
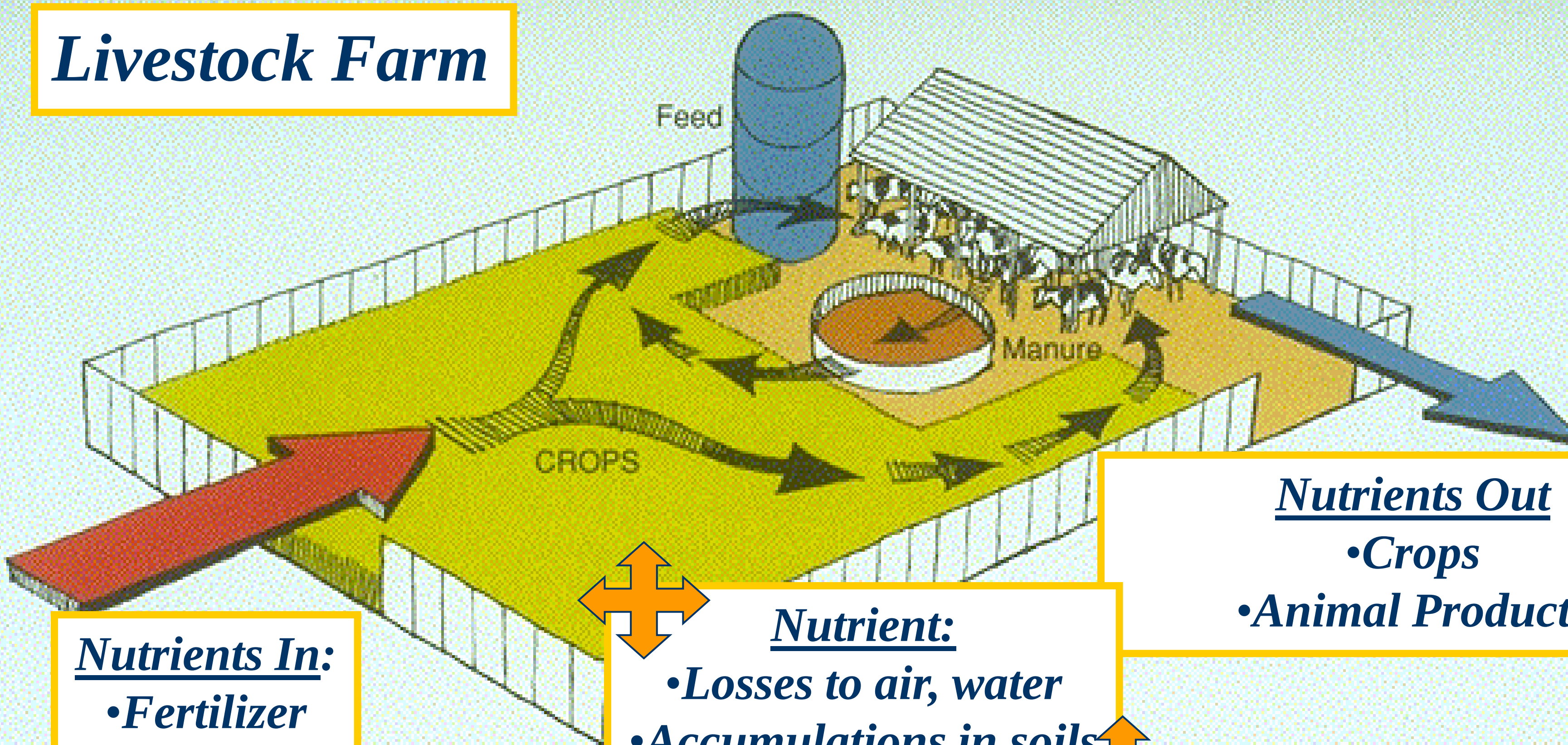
# *Cash Grain Farm*




**"Nutrient balance on a cash grain farm is simple"**

# *Livestock Farm*

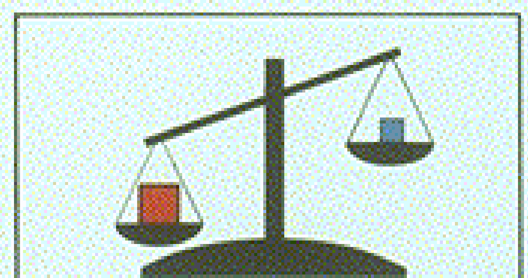



***Nutrients In*:**
***•Fertilizer***
***•Feed***

***Nutrient:***
***•Losses to air, water***
***•Accumulations in soils***

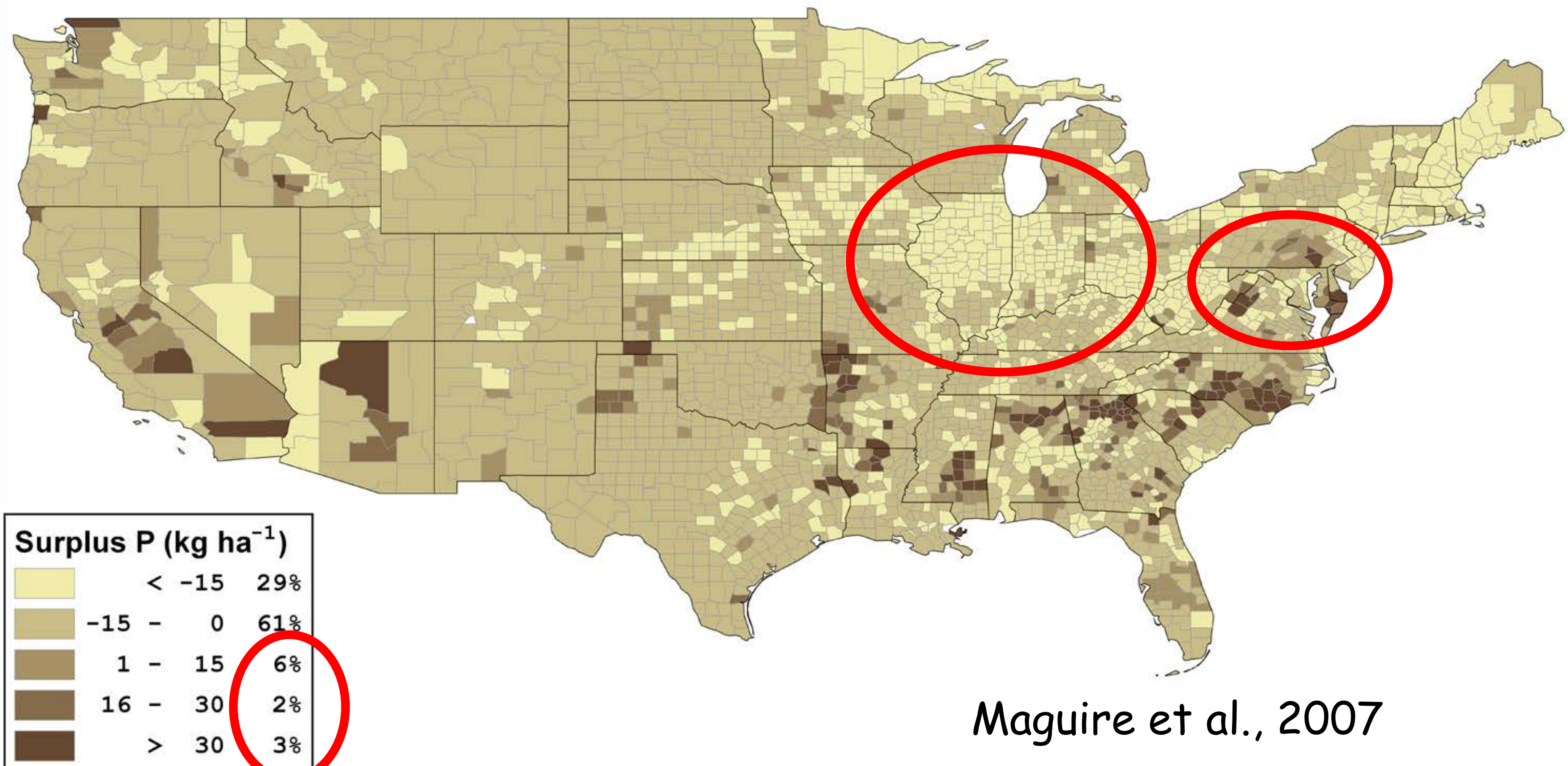
***Nutrients Out***
***•Crops***
***•Animal Products***

***" A livestock farm is much more complex. We often cannot balance inputs of feed and fertilizers with outputs. This results in excess nutrients that can be lost to air or water or build up in soils.***



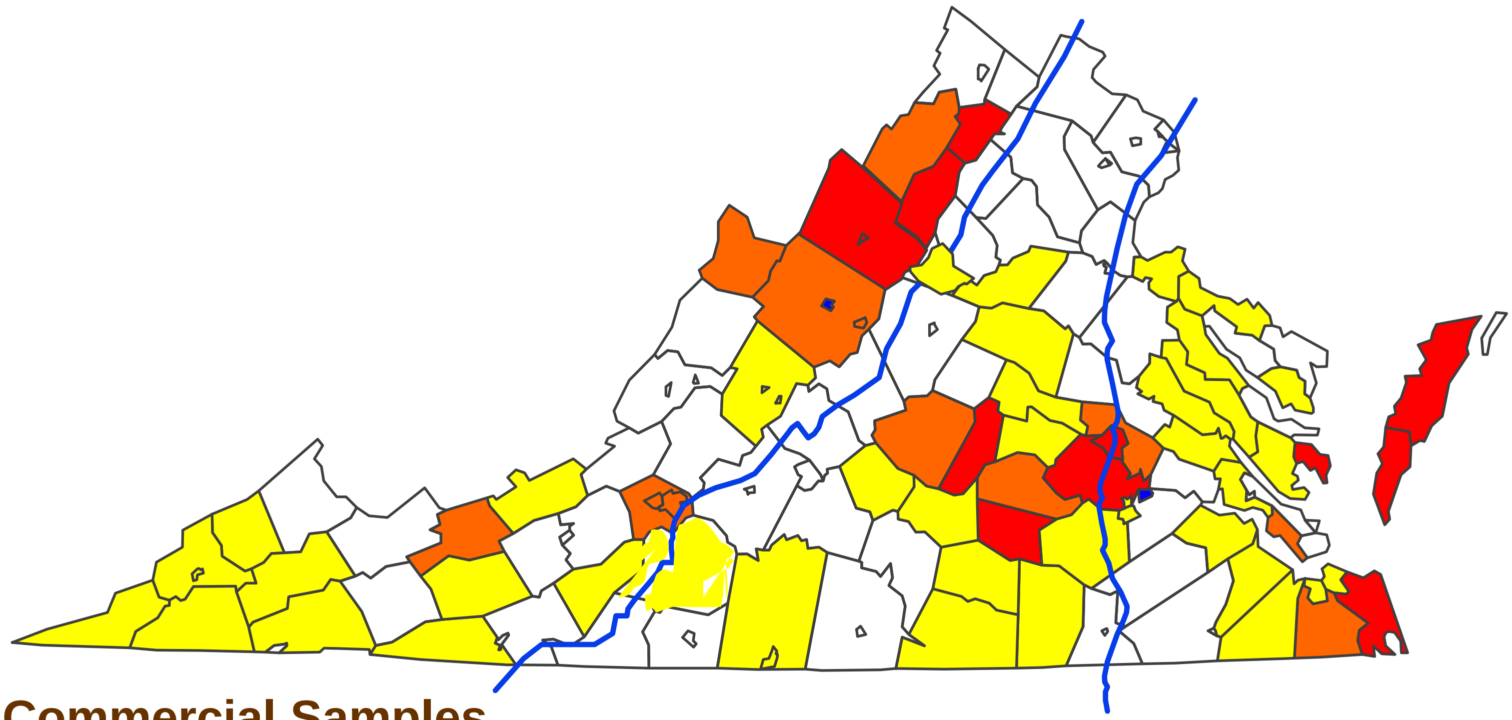
***Nutrient Balance***

# Manure P Surplus:
# (Manure P – Crop Removal)




Maguire et al., 2007

# Agronomic Soil Test P in Virginia for years 2004-2006. (% soils rated "Very High")



**92,303 Commercial Samples**

≥10%-Yellow

≥20%-Orange

≥33%-Red

Heckendorn and Maguire, 2007

# Poultry litter from 20000 broilers applied to 150 bu/acre corn crop

**Nitrogen**

**Rate = 4.2 t/A**

**150 lb PAN/A**

**218 lb $P_2O_5$/A (57 lb [Table 4-7 p55 S&C])**

**122 lb $K_2O$/A (40)**

**N needs met**

**161 lb $P_2O_5$/A Surplus**

**Land required = 36 A**

**82 lb $K_2O$/A Surplus**

**Soil Test: P & K = H+**

**Phosphorus**

**Rate = 1.1 t/A**

**35 lb PAN/A**

**57 lb $P_2O_5$/A**

**28 lb $K_2O$/A**

**115 lb N deficit/A**

**$P_2O_5$ needs met**

**Land required = 137 A**

**12 lb $K_2O$ Deficit/A**

**Total Manure = 20000 birds * 6 cycles * 1.25 tons/1000birds = 150 tons**

**Manure = 36 lbs PAN/t; 52 lbs $P_2O_5$/t; 29 lbs $K_2O$/t**

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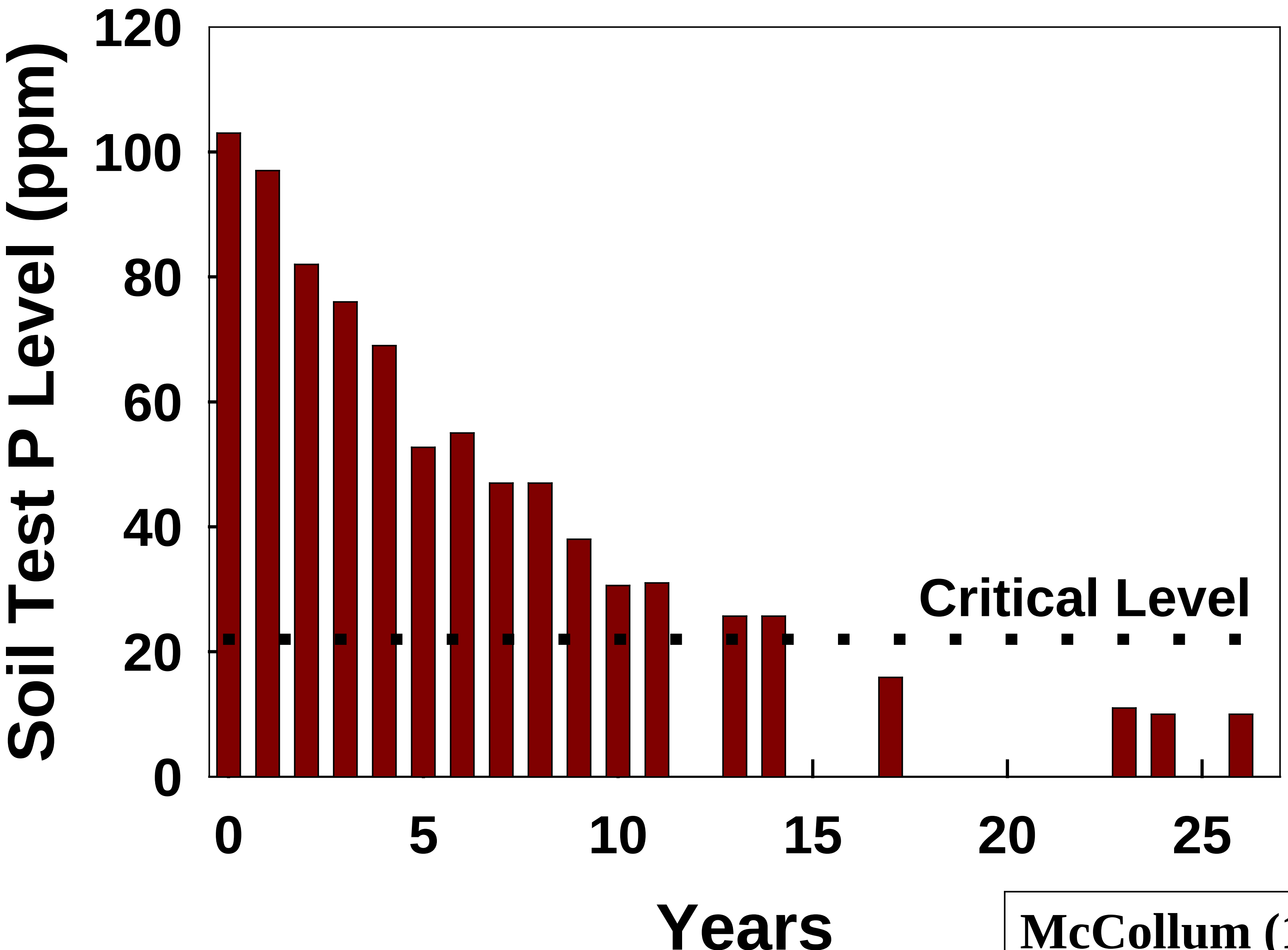


McCollum (1991)

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