Soil Reaction

Soil Chemistry (Soil 503)

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SOIL REACTION

What is pH?

- pH can be viewed as an abbreviation for power of concentration of hydrogen ion in solution

- pH = - [log (H+)] in solution

- kw = pH + pOH
- kw = 14
- 14 = pH + pOH
- pH = 14 - pOH

Soil pH

- pH in solution
  - ACID if pH is < 7
  - BASIC if pH is > 7
  - Neutral if pH = 7

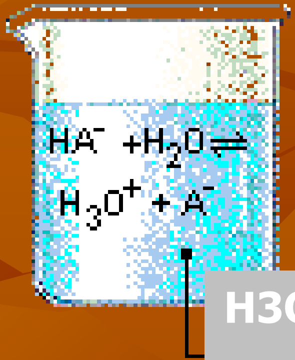
  - In soils the neutrality is not pH 7, the neutrality is a range between 6.5 and 7.2

- Soil pH is the single most important chemical property of the soil (like soil texture is to the physical properties)
- Knowing the pH of the soil will quickly allow you to determine if the soil is suitable for plant growth and what nutrients will be most limiting.

- Strictly speaking, hydrogen ions are protons and do not exist in the naked state in fluids; instead they react with water (H_2O) to form hydronium ions, such as H_3O^+
- For most purposes H+ can be used to represent these hydrated protons.

Acid Base Chemistry

- Acid-base chemistry is an important part of everyday life. The excess hydronium (H_3O^+) ions in acids give them interesting properties.
- Acids can react with metals and other materials. The strong acid HCl is produced in your stomach to help digest food. In dilute concentrations, acids are responsible for the sour taste of lemons, limes, vinegar and other substances.
- Bases are also very reactive. The strong base NaOH is used in many household cleaning agents such as oven cleaner and drain clog-remover.
- How do we measure the concentration of an acid or base?



H3O+ depends on the
Strength of acid and
Initial concentration
Of acid

Measuring Acidity

- The acidity (or basicity) of a solution is measured using the pH scale. (this scale is used because of the very small concentrations that are being measured)
- The pH scale corresponds to the concentration of hydronium ions in a solution.
- If you take the exponent of the H_3O^+ concentration and remove the negative sign, you have the pH of a solution.
- For example, in pure water the concentration of hydronium ions is 1×10^{-7} M.
- Thus, the pH of a solution of pure water is 7.
- The pH scale ranges from 0 to 14, where 7 is considered neutral ($[H_3O^+] = [OH^-]$),

Soil Acidity

- The absence of bases or excess of H+
- Importance:
  - Nutrient availability
  - Ion toxicity
  - Microbial activity
  - Influence on %BS
  - Influence on fertilizer efficiency
  - Influence on plant growth
  - Influence in the environment

Sources of acidity in soils

- Basic definitions
- Active acidity: Presence of H+ in soil solution
- Reserve acidity: Adsorbed H+ to colloid surfaces or other un-dissociated H+ sources, that will react with water to yield H+ (e.g. Al3+)
- Buffering capacity in soils
  - "Ability of a soil to resist a change in pH"
  - Direct correlated with CEC of a soil, a high CEC is associated with a large number of exchange sites
  - Example: High buffered soils are organic soils, and 2:1clay soils. Low buffered soils are low organic matter soils and 1:1 clay soils.

Sources of acidity in Soil

1. Nitrification: Ammonium to Nitrate (oxidation of NH_4^+)

$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$

2. O.M. decomposition

organic acids ionized :

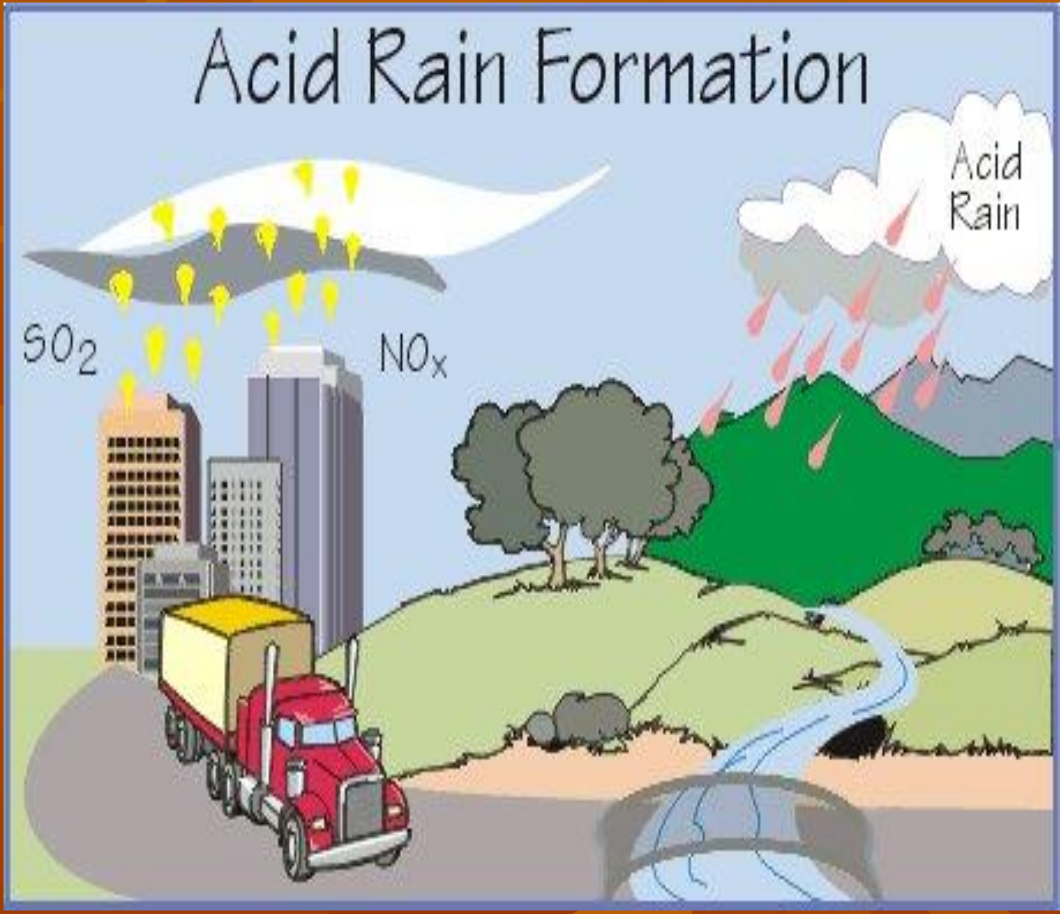
$R\text{-}COOH \longrightarrow R\text{-}COO^- + H^+$

respiration: $CO_2 + H_2O \longrightarrow$

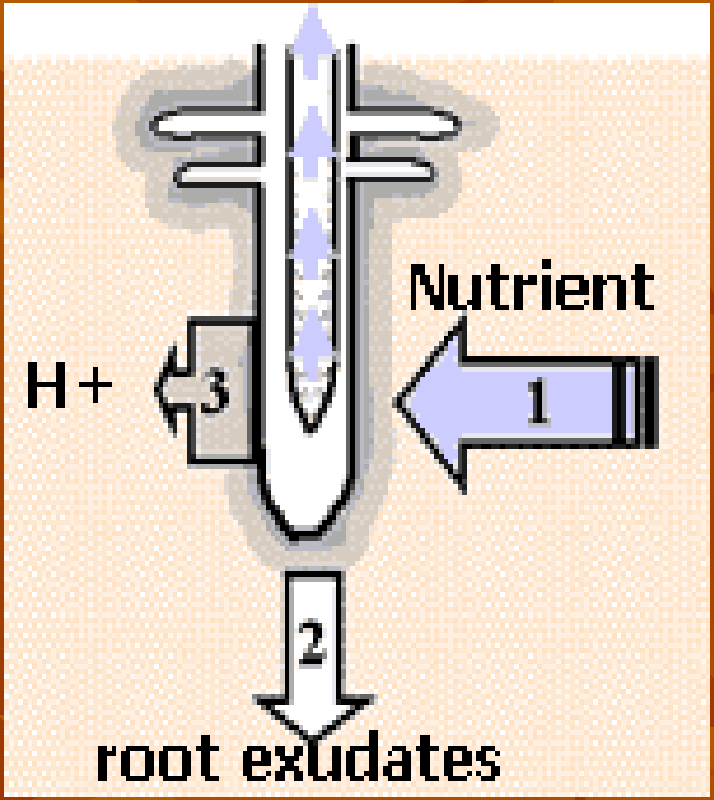
$H_2CO_3 = H^+ \; HCO_3^-$

3. Acid rain

- Acid rain is caused by the burning of fossil fuels.
- Burning oil, gas and coal in power stations releases Sulfuric Dioxide (SO2) into the atmosphere.
- Burning oil and gasoline in motor vehicles puts nitrogen oxides (NOX) into the atmosphere.
- These gases mix with water droplets in the atmosphere creating weak solutions of nitric and sulfuric acids.
- When precipitation occurs these solutions fall as acid rain.



- 4. Uptake of basic cations by plants. Basic cations are sources of OH- to the soil solution.
- **Ca^{++}, Mg^{++}, K^{+}**, =
- Basic cations that are taken up by plants no longer contribute OH- to the soil solution.
- H+ ions are released to the soil solution.

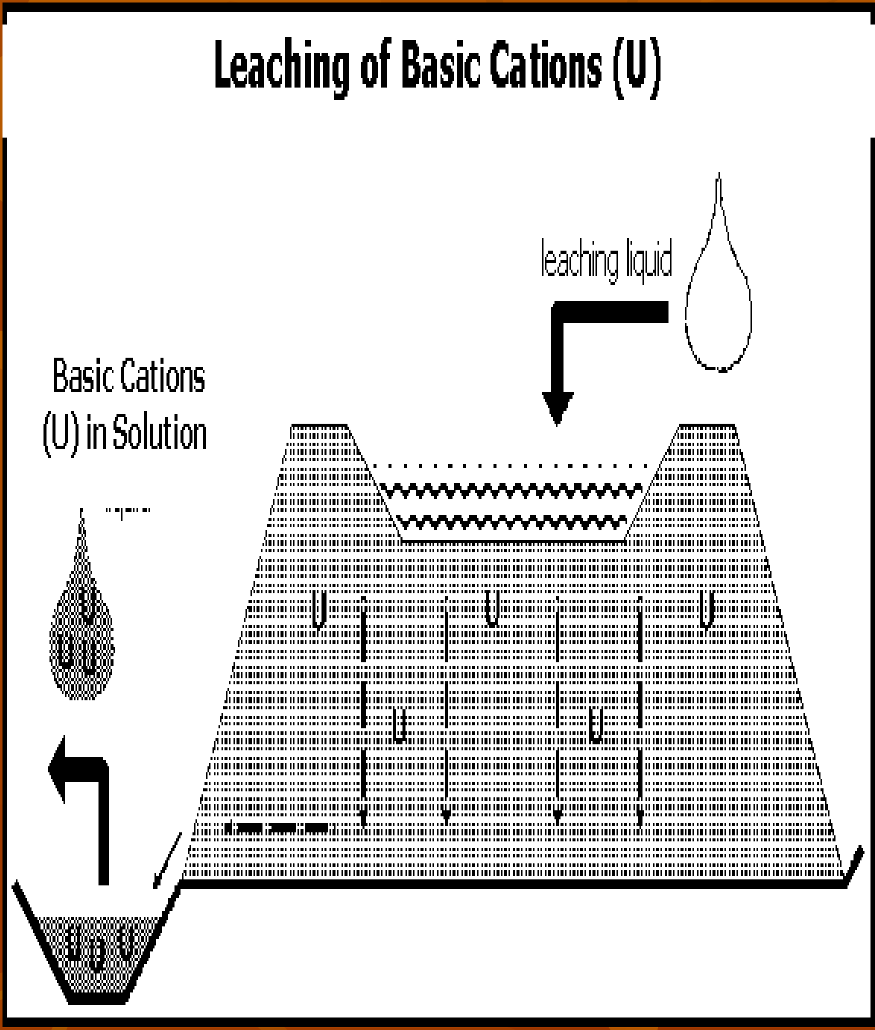


Leaching

5. Leaching of basic cations -
as basic cations are removed from the soil solution by leaching they no longer contribute the OH- ions to neutralize the ever increasing amounts of H+

$Ca^{++} + 2\ H_2O \rightarrow Ca(OH)_2 + 2H^+$

$\rightarrow Ca^{++} + 2OH^-$



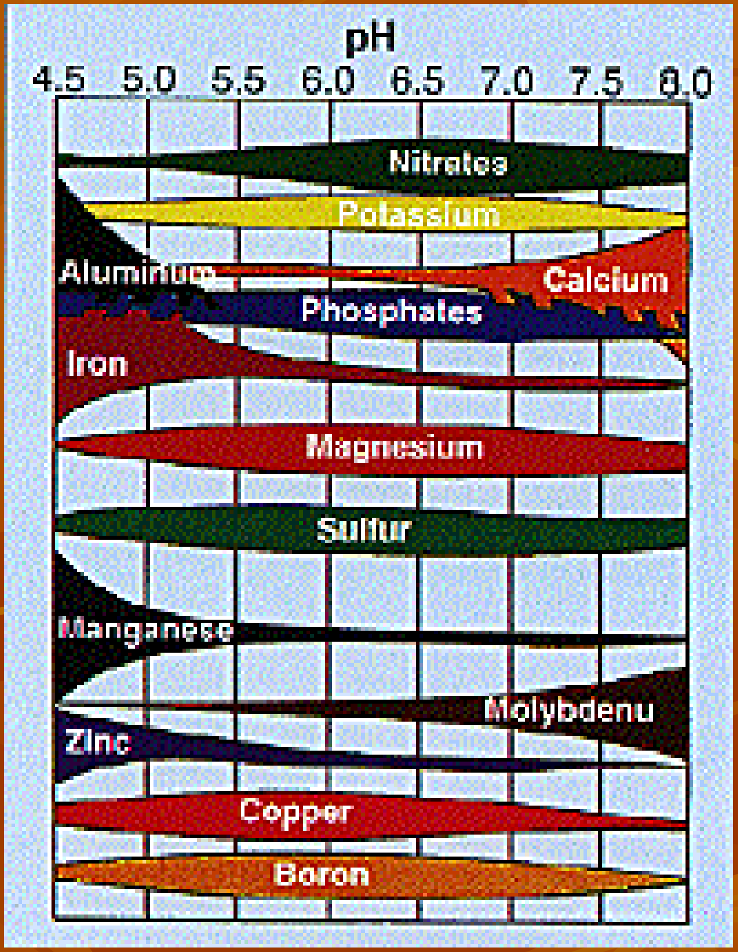
pH vs. CEC and %BS

- Increases in pH tends to increase CEC, however ***<u>only</u>*** in soils with pH dependant charges (Kaolinite, organic matter, Al/Fe oxides)
- The natural leaching process of nutrients and nutrient plant uptake will decrease pH, why?
  - When any base is either leached or taken up from the exchangeable sites, it must be replaced! If there is not more available bases, will be replaced by H+

Factors causing soils to become acidic

- Loss of exchangeable bases from the soil CEC
  - Leaching
  - Removal from plant uptake
- Production of organic acids from organic matter decay
- Use of fertilizers, particularly ammonium sources: (NH4)SO4, NH4NO3, Anhydrous ammonia, Urea
- Soil erosion: Loss of bases from surface runoff
- Parent material: Presence of acidic materials that weather giving rise to acid soils
- Weathering

pH vs. ion solubility



pH and nutrient availability summary

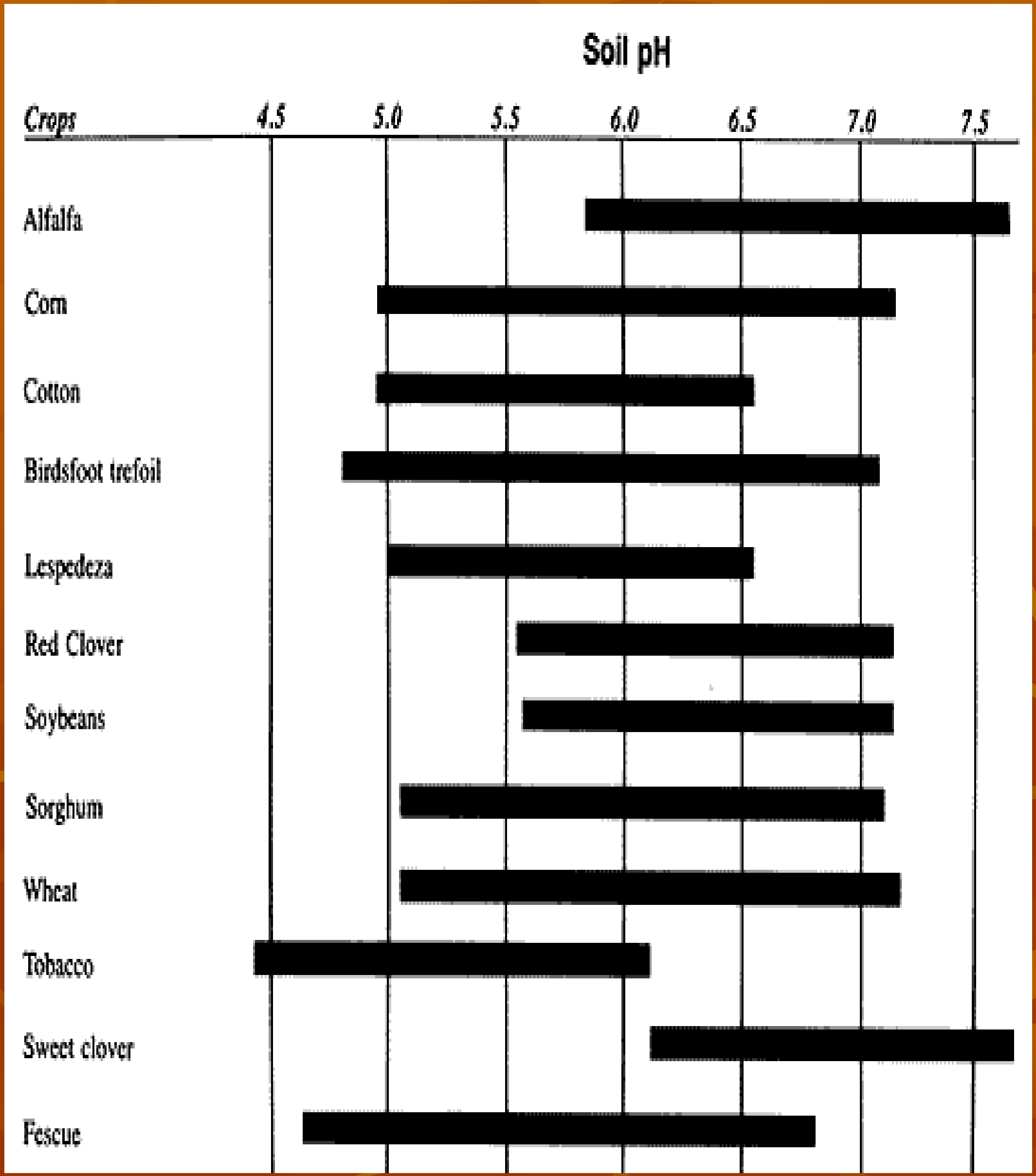
- As the soil pH increases from an acidic condition to pH 6.5
  - Macronutrients (N,P,K) increases in solubility
  - Secondary nutrients (Ca, Mg, S) increases in solubility
  - Micronutrients (except Molybdenum) decreases in solubility
  - Al decreases in availability (very important)

pH influence on microorganisms

- Bacteria and actinomicete are reduced at low pH
- Nitrification occurs at pH range 6.0 to 9.0, optimum pH 7
- Denitrification (biological loss of N) occurs at a minimum of pH 5.5, bellow this point chemical denitrification occurs
- Nitrogen fixation by Rhizobium (legume-bacteria symbiosis) optimum occurs between a pH of 6.0 to 6.5
- Organic matter decomposition: optimum pH 7.0

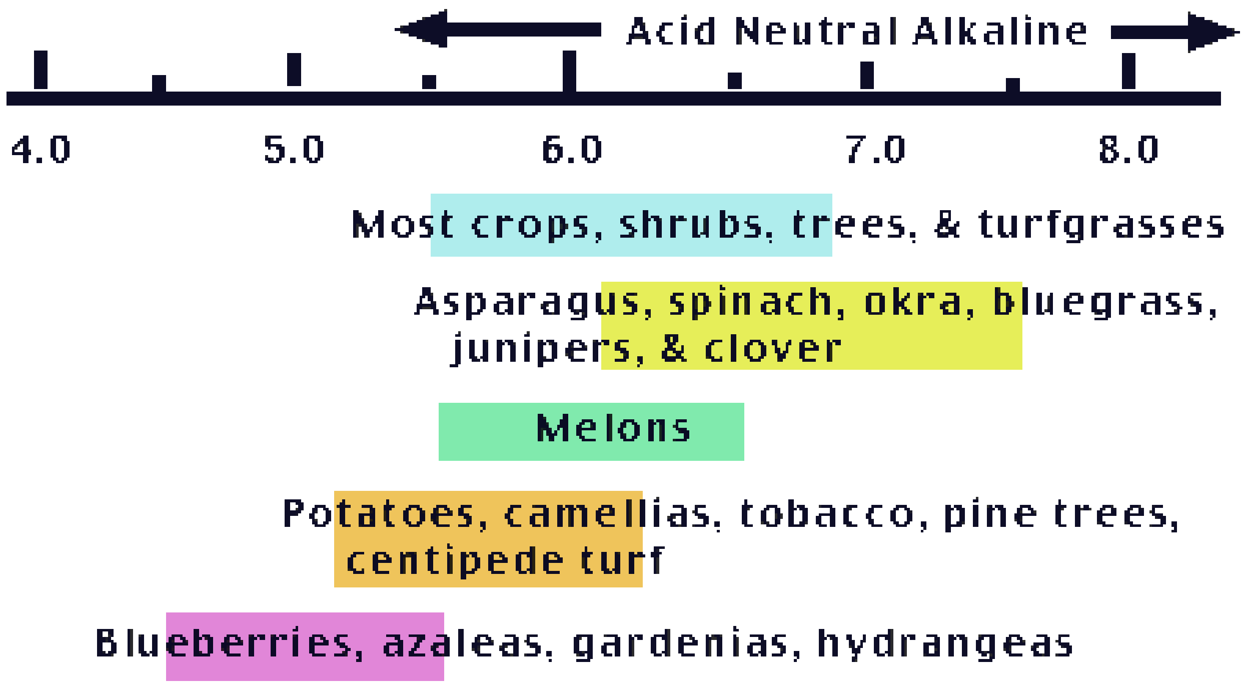
pH and fertilizer efficiency

- At low soil pH's: Al/Fe oxides reacts with phosphorus and molybdenum to form unavailable P and Mo forms
- At high soil pH's: Ca and Mg in excess tends to form unavailable form when react with phosphorus and most micronutrients
- If we are not at the optimum pH for plant nutrient availability, the addition of fertilizer could be a waste of energy and resources.
- Note: Every crop/plant/turf/tree has an unique optimum soil growth conditions



Soil pH
Crops
4.5
5.0
5.5
6.0
6.5
7.0
7.5
Alfalfa
Corn
Cotton
Birdsfoot trefoil
Lespedeza
Red Clover
Soybeans
Sorghum
Wheat
Tobacco
Sweet clover
Fescue

Soil Acidity and Desirable Ranges for Garden Crops, Ornamentals and Turfgrasses



Correcting soil acidity

- Liming the soil with LIMESTONE (CaCO3)

$CaCO_3 + H_2O + 2CO_2 \longleftrightarrow Ca + 2HCO_3$

$CLAY/HUMUS]\text{-}H^+ + 2HCO_3 \longleftrightarrow$

CLAY/HUMUS]-Ca + H2O + 2CO2 (gas)

$CLAY/HUMUS]\text{-}Al^{3+} + 2HCO_3 \longleftrightarrow$

CLAY/HUMUS]-Ca + Al(OH)3 solid + 2CO2 (gas)

- Products:
  - Neutralization of H and formation of H2O
  - Neutralization of Al and formation of Al(OH)3
  - Production of CO2 gas
  - Important note: WATER is required!

Type of lime material

- Limestone:
  - Calcite type (CaCO3)
  - Dolomite type (CaMgCO3)
  - Wood ashes (oxides of Ca, K and Mg)

The type of lime to use depend on availability, price, and type of soil. Dolomite type are preferred when Mg is also deficient.

The size of the limestone (coarse vs. fine) define the degree of reactivity. Fine limestone is MORE reactive than coarse limestone.

Considerations for correcting acidity

- Original soil pH
- Type of liming material and its fineness
- Availability of liming materials
- Type of soil (sandy, clayey, loamy, organic) and CEC
- Crop to be grown
- Depth of mixing in the soil
- Soil moisture

Acid Sulfate Soils

- Acid sulfate soils form when pyritic* (mineral of FeS_2) estuarine sediments in the subsoil are exposed to air, oxidizing to form sulfuric acid.
- A variety of soil minerals react with the acid and release free aluminum, toxic to crops and marine life.

The red color of the water is caused by oxidized iron

*Pyrite is the most common iron disulphide mineral in rock. It is found most often in metamorphic and sedimentary rocks where it occurs as either a primary mineral or a fine, widespread impregnation of subsequent origin. Pyrite is frequently found in association with coal and shale deposits.

- Acid sulfate soils are extremely acidic (at times less than 3.0) soil horizons resulting from the aeration of soil materials that are rich in iron sulfides, (FeS)

- Acid sulfate soils are unique in that the impacts can be so severe that they can affect engineering works, agricultural productivity, and water quality of estuarine systems

- Iron staining is often a good indicator of disturbed acid sulfate soils.
- When acid sulfate soils are disturbed and undergo oxidation, the sulfuric acid produced mobilizes iron, aluminum and heavy metals present in the soil.
- Toxic amounts of dissolved iron can then be washed into waterways.
- This iron can precipitate when in contact with less acid water, such as rainwater or seawater.
- This results in a rust-colored iron oxide scum or 'floc' which can smother vegetation and stain the soil.
- From: *'QASSIT, Qld Department of*

Green acid water leached from Acid Sulfate Soils pours into a river