

CCA Training :
Soil and Water Management

Dick Wolkowski

608-263-3913

rpwolkow@facstaff.wisc.edu

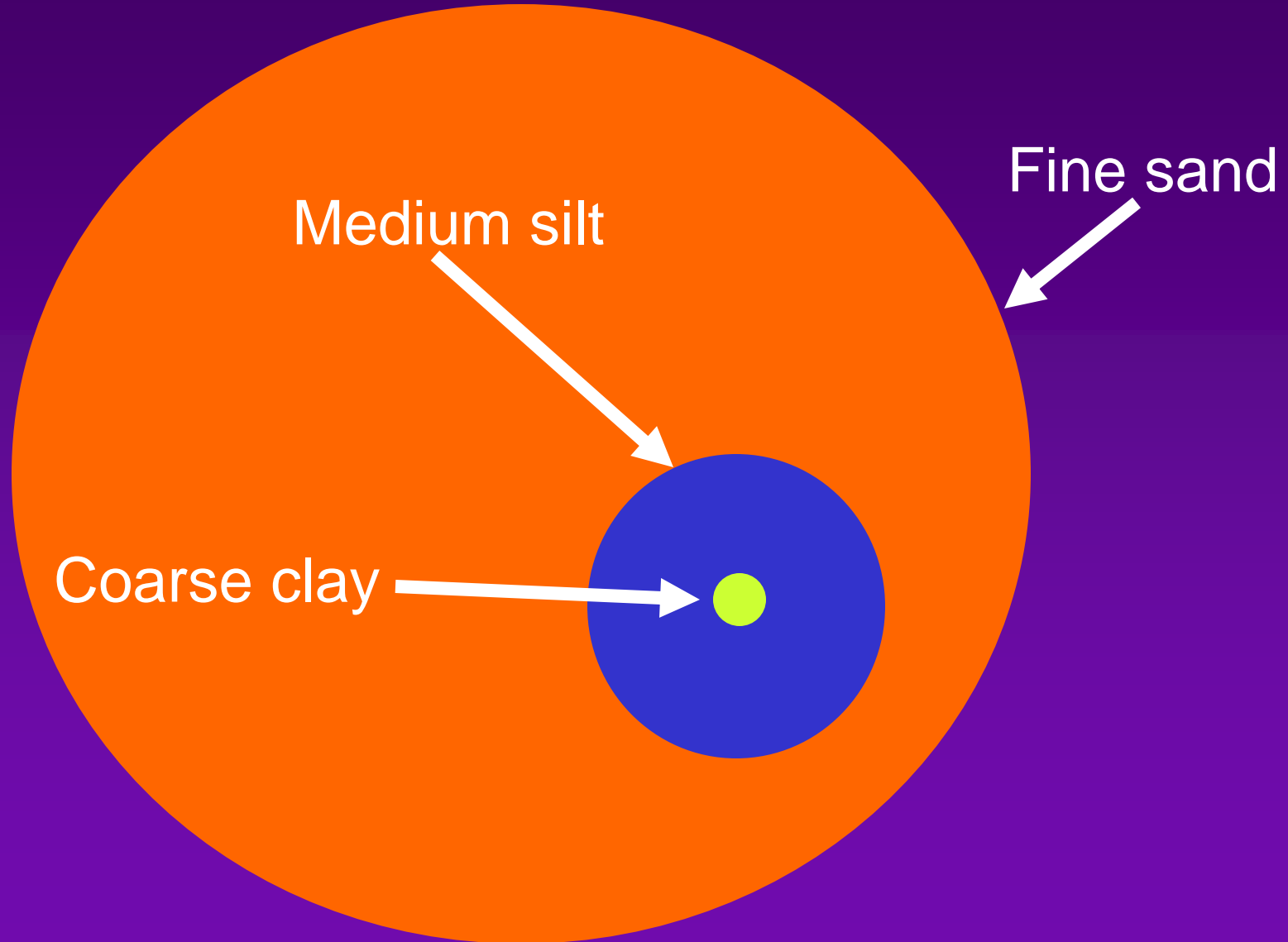
Soil and Water Performance Objectives

- Basic soil physical and biological properties
- Soil erosion
- Crop residue management
- Restrictive soil layers
- Site characterization
- Site-specific management
- Land application of waste
- Water management
- Irrigation and drainage
- Water quality

Soil Physical Properties: Texture

- **Relative proportion of sand, silt, and clay that lends a distinct feel to the soil**
 - Relative size difference
 - Clay particles have greatest effect on soil management
 - Heavy soil relates to power required for tillage
 - Hand texture

Relative size of fine sand, medium silt, and coarse clay particles enlarged 500 times. Coarse sand is about 1 mm in diameter

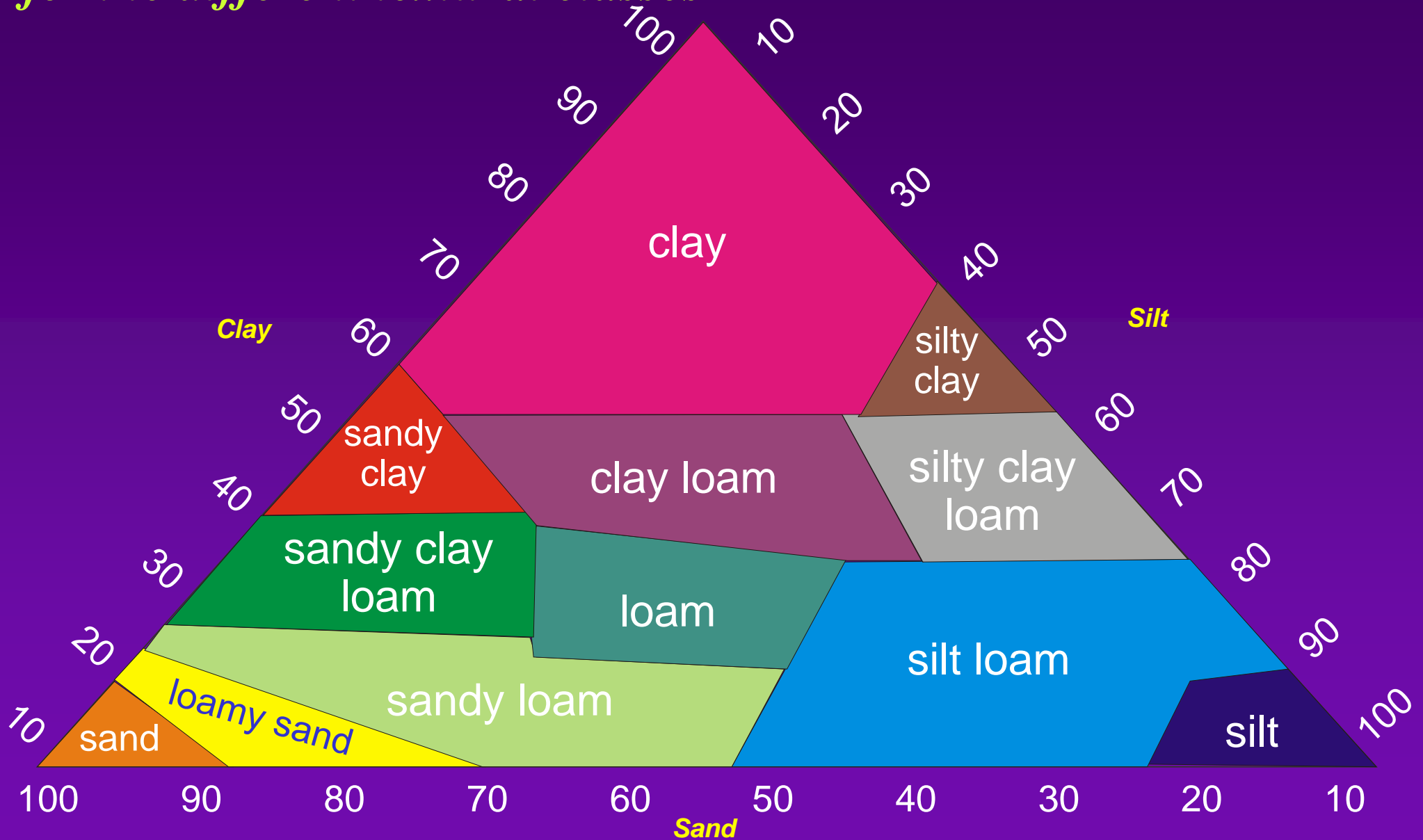


Properties of sand, silt, and clay-sized soil particles

Particle size	Physical properties	Surface area of soil particles in an acre plowed 7 in. deep
Coarse sand	Loose, non-sticky, gritty	500 acres
Fine & very fine sand	Loose, non-sticky	5,000 acres
Coarse, medium, fine silts	Smooth and floury, slightly sticky	50,000 acres
Coarse, medium, fine clay	Sticky and plastic when wet; hard and cohesive when dry	25,000,000 acres ^a

Includes both external surfaces and surfaces between crystal plates.

The soil textural triangle shows ranges in sand, silt, and clay for the different textural classes



Textural properties of mineral soils

Soil class	Properties of moist soil*
Sand	Squeezed in the hand it forms a cast or mold that crumbles when touched. Does not form a ribbon.
Sandy loam	Forms a cast requiring careful handling to keep it from breaking. Does not form a ribbon.
Loam	Cast can be handled quite freely without breaking. Very slight tendency to ribbon. Rubbed surface is rough.

*The properties described for the clayey soils refer to those found in the temperate regions.

Textural properties of mineral soils

Soil class Properties of moist soil*

Silt loam Cast can be freely handled without breaking. Slight tendency to ribbon with rubbed surface having a broken or rippled appearance.

Clay Casts can bear considerable handling without breaking. Forms a flexible ribbon and retains its plasticity when elongated. Rubbed very smooth, surface has a satin feeling. Sticky when wet and easily puddled.

Clay loam Cast can bear much handling without breaking. Pinched between thumb and finger, it forms a ribbon, the surface of which feels slightly gritty when dampened and rubbed. Soil is plastic, sticky, and puddles easily.

*The properties described for the clayey soils refer to those found in the temperate regions.

Soil Physical Properties: Bulk Density

- Mass of soil/volume of soil (g/cc)
- Water = 1 g/cc (62.4 lb/ft³)
- Affected by texture

Relationship between soil texture, bulk density, and pore space

Soil texture	Bulk density	Pore space
	-----g/cc-----	-----%-----
Sand	1.6	39
Loam	1.3	50
Silt loam	1.2	54
Clay	1.1	58
Muck	0.9-1.1	variable
Peat	0.7-1.0	variable

Soil Physical Properties: Aeration

- Provides O₂ to roots and soil microorganisms
- Important for nutrient uptake and nutrient transformations
- Associated with soil porosity

Soil Physical Properties: Structure

- **The arrangement of primary soil particle into aggregates of a definite shape and size**
 - Affects water movement, root growth, aeration
 - Destroyed by traffic abuse, raindrop impact, or high sodium
 - Not found in sand or loamy sand
 - Particles attached by a combination of clay surface effects, humus, bacterial secretions, iron, and aluminum oxides

Well aggregated soil: Note structural units or peds



Soil Physical Properties: Structure

- **Structure type = aggregation has different shape and varies with depth**
 - Granular = surface
 - Platey = between surface and subsoil
 - Blocky = upper subsoil
 - Prismatic or columnar = deep subsoil

Soil Physical Properties: Structure

- **Improving structure:**
 - Traffic management
 - Rotating to forage legumes/sod crops
 - Organic additions
 - Residue management
 - Natural effects

Earthworm activity builds soil structure



Soil Physical Properties: Soil Color

- Determined by organic matter and iron
- Not a good indicator of relative fertility
- Dark humus coats mineral particles
- Oxidation state of iron lends color
 - Red = highly oxidized
 - Yellow = hydrated
 - Grey = reduced (color of minerals)
- Mottling indicates seasonally high water

Arlington soil (Saybrook silt loam)

Organic enriched surface

Light brown subsoil

Earthworm and root traces

Mottling



Soil Physical Properties: Organic Matter Decomposition

- **Factors affecting:**
 - Aeration, temperature, soil pH, moisture, type of organic material
 - Organic matter accumulates in cold, wet situations
 - Cropping practice effect
- **Difficult to increase soil OM**
 - 90% converted to CO₂, salts, and water
 - 4% OM soil has 80,000 lb/a OM
 - 6,000 lb/a stover adds 600 lb/a OM

Decrease in soil organic matter in a Wooster silt loam after 30 years under several cropping systems

Time	Organic Carbon	Organic matter	Decrease in organic matter
	-----%-----		
Initial	2.04	3.52	-----
Continuous corn	0.74	1.28	64
Continuous oats or wheat	1.28	2.22	37
Corn-wheat-clover	1.16	2.00	43
Corn-oats-wheat-clover-timothy	1.55	2.67	24

Source: Salter and Greene, 1933. J. Amer. Soc. Agron., 25:622-23.

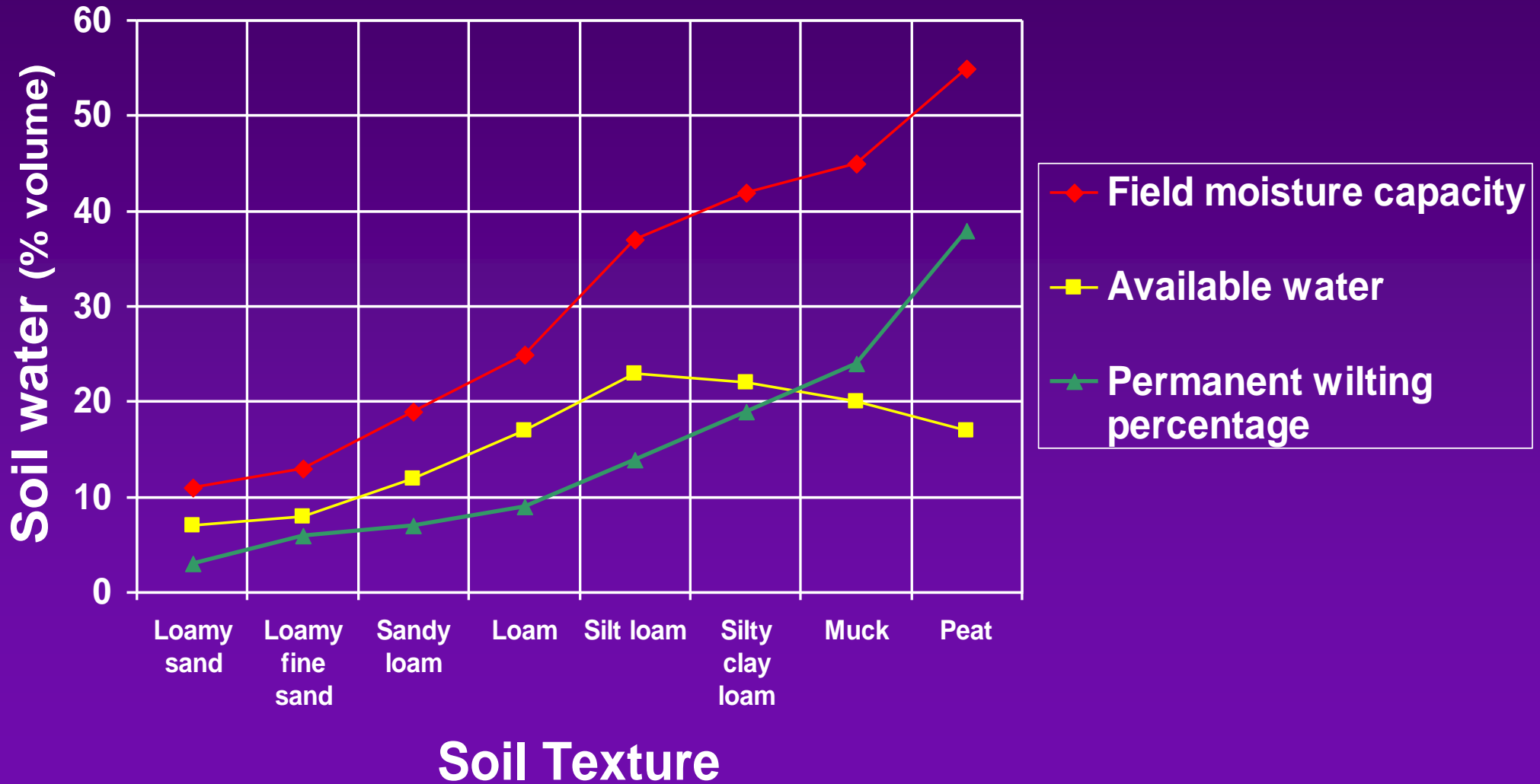
Soil Physical Properties: Soil Water

- **Soil water retention (sponge model)**
 - Polar water molecules stick together (cohesion)
 - Water molecules are attracted to soil surfaces (adhesion)
 - Water held in pores by these forces
 - As pore size increases, gravity drains pores
 - Water content

Soil Physical Properties: Soil Water

- **Water movement in soils**
 - Under saturated conditions, water moves in response to gravity. Most moves downward through large pores.
 - Under unsaturated conditions, water moves in any direction in response to a moisture tension gradient (wet to dry).
 - Textural layers impede movement.

Water availability relative to soil texture



Soil and Water Management: Soil Water

- **Agricultural water budget**
 - Wisconsin receives about 31” precip./year
 - 21” lost through evapotranspiration
 - 6” percolates through the soil
 - 4” lost in runoff (1” during growing season)
 - Soil texture effects
 - Little runoff from sands
 - Little leaching in MTS during growing season

Soil and Water Management: Soil Water

- **Moisture effects on nutrient availability**
 - Deficiency
 - Reduced microbial activity
 - Reduced mass flow delivery of nutrients
 - Reduced plant metabolism
 - Excess
 - Denitrification of nitrate
 - Reduced aeration lowers K uptake

Poor drainage affects nutrient availability

*Early June, 1993
following heavy rain
Arlington, Wis.*



Poor drainage affects nutrient availability

August, 1993
Denitrified area following
heavy June rain
Arlington, Wis.



Soil and Water Management: Controlling Excess Water

- **Surface water**

- Structures to safely remove water (e.g. diversions, waterways)
- Surface inlets to drain tile (e.g. risers, curtain drains)
- Land forming on soils with poor internal drainage

- **Soil water**

- Drain tile: Soil must be saturated for water to enter tile
- Requires an outlet or ditch to connect to surface water channel

Diversion and surface inlet

*Fond du Lac, Co.
(Note cover crop)*



Soil and Water Management: Erosion Control and Residue Management

- **Effects on air and water quality and productivity**
 - Effects on productivity
 - Loss of OM, clay, and nutrients reduces productivity
 - Formation of rills and gullies affects management
 - Sedimentation in waterways, diversions, terraces
 - Wind erosion damage to plants

Clean tillage = Higher erosion potential



Soil and Water Management: Erosion Control and Residue Management

- **Effects on air and water quality and productivity**
 - Environmental concerns
 - Wind erosion: highway visibility, dust, allergies
 - Water erosion: sedimentation in streams and lakes, fertilization of aquatic plants
 - Every hour the Mississippi River carries the equivalent of 1 acre of topsoil

Wind erosion a problem in central sands

Plainfield, Wis.



Wind erosion can be significant

Near Mitchell, SD



Soil and Water Management: Erosion

- Process (Water erosion)
 - Detachment: Mainly caused by raindrop impact
 - Transportation: Water volume, slope length and pitch, surface roughness
 - Deposition: Occurs when water slows down or volume decreases

Soil and Water Management: Erosion

- Factors affecting erosion
 - Intensity and duration of rainfall
 - Erodibility of the soil
 - Steepness and length of slope
 - Soil cover

Soil and Water Management: Erosion

- **Universal soil loss equation**

$$\underline{\text{soil loss (t/a)} = R \times K \times LS \times C \times P}$$

- R = erosivity of rainfall
 - K = slope erodibility
 - L = slope length
 - S = slope pitch
 - C = conservation practice
 - P = crop management
- Now revised as RUSLE II
 - Modify factors to calculate allowable soil loss

Soil and Water Management: Erosion

- **Erosion control practices**
 - structures: diversions, terraces, waterways
 - Reduce slope length
 - Divert excess water safely
 - Avoid runoff over barnyard, feedlots, etc.
 - Crop rotation
 - Less erosion from established sod

Soil and Water Management: Erosion

- **Erosion control practices**
 - Crop residue management: 30% reduces erosion 50-60%
 - Cover crops protect surface and store nutrients
 - Contour tillage
 - Slope < 8% and 300' long
 - Contour strip cropping
 - Alternating sod strip for steep land

Erosion control practices

Contour strips
Crawford Co.



Erosion control practices

Contour buffer strips
Chippewa Co.



Erosion control practices

Terraces
Grant Co.



Soil and Water Management: Tillage

- Primary tillage controls the amount of residue at the surface (e.g. chisel, moldboard)
- Secondary tillage prepares the seedbed and usually buries residue (disking, field cultivators, soil finisher)
- Tillage when the soil is wet, can damage the soil structure and reduce porosity, which decreases productivity
- Tillage directly affects surface crop residue level

Soil and Water Management: Tillage

- **Factors affecting tillage selection**
 - Regulations
 - Conservation plan requirements
 - Manure management
 - Soil properties
 - Fall tillage on heavy soils
 - No-till not favored on heavy soils

Soil and Water Management: Tillage

- **Factors affecting tillage selection**
 - Residue management
 - Too much (spring temp., soil moisture, planting speed)
 - Too little (erosion potential)
 - Rainfall distribution
 - High residue preserves moisture on droughty soils

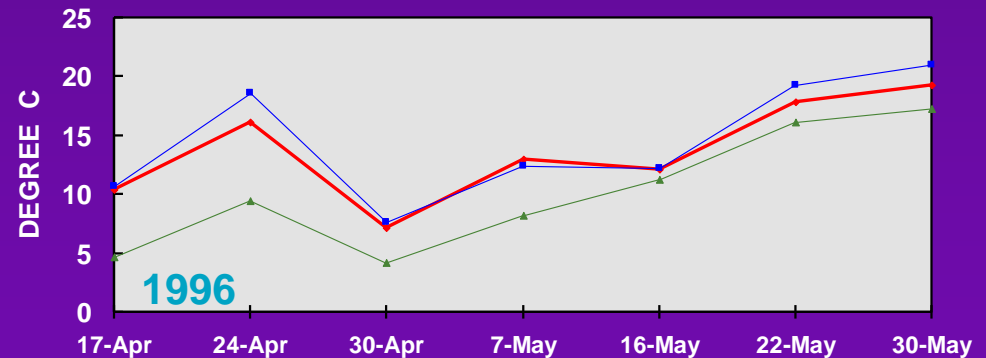
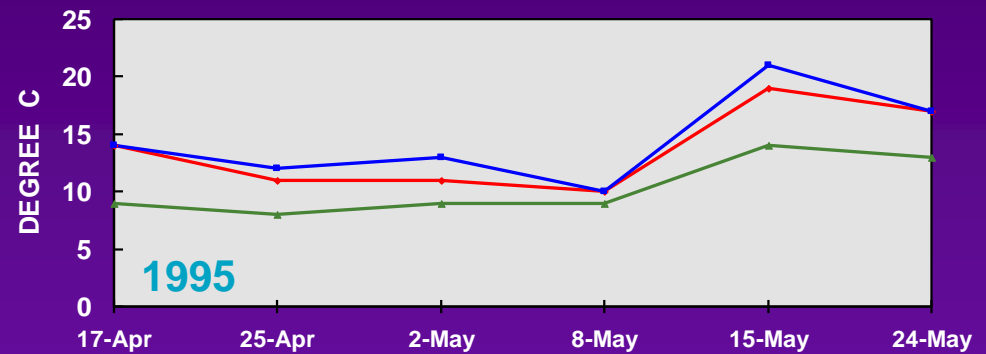
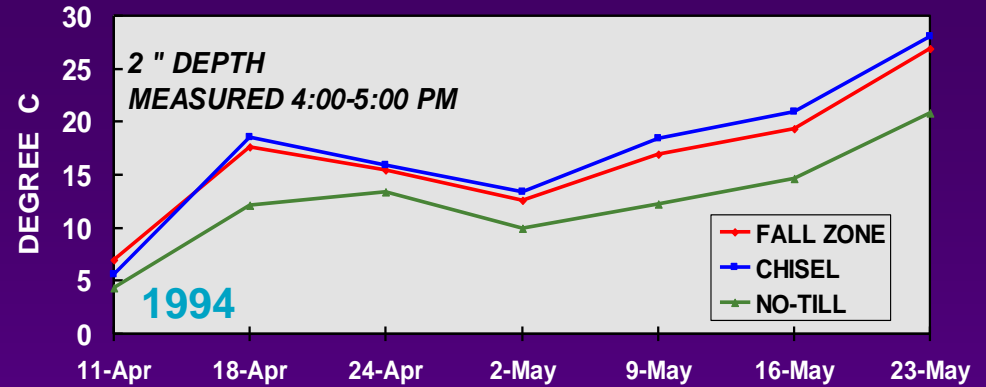
Soil and Water Management: Tillage

- residue remaining
- lime and fertilizer incorporation
 - nutrient stratification (no effects yet)
 - best to incorporate before switching to conservation tillage
 - some smoothing of rough tilled ground needed before spraying herbicides
- soil disturbance
 - increases erosion potential
 - variation between tools and manufacturers

Strip tillage offers compromise between full width tillage and no-till



EFFECT OF TILLAGE AND TIME ON SOIL TEMPERATURE AT ARLINGTON, WIS., 1994-1996



Corn residue cover following various tillage methods on farms in southern Wisconsin

Tillage implements	Average cover	Expected range
	%	%
No-till	70	65-80
Chisel plow	37	30-70
Chisel plow and field cultivator	34	30-65
Chisel plow and soil furnisher	31	25-50
Chisel plow and tandem disk	27	20-40
Chisel plow and field cultivator (two passes)	30	25-50
Chisel plow and tandem disk (two passes)	23	15-35
Chisel plow, tandem disk, and field cultivator	32	25-50

Comparison of chisel points

Twisted shovel



Comparison of chisel points

Sweep



Effect of type of chisel plow point on surface crop residue following fall chisel plowing (one pass)

Tool	Residue cover (%)
3" Concave twisted shovel	53
2' chisel point	60
16' medium crown sweep	66

Soil and Water Management: Measuring Surface Crop Residue

- **Estimate residue cover with line transect method**
 - % residue = number of 'hits'/100 ft. of line
 - must be viewed straight down
 - larger than BB shot
 - manure counts, stones don't

Line transect method of measuring residue

Stretch tape diagonally



Count "hit" per tape length



Soil and Water Management: Compaction

- **Physical destruction of the soil structure**
 - Caused by force (usually wheel traffic)
 - Crushes and rearranges aggregates
 - Reduces porosity
 - Increases root penetration resistance and can affect nutrient uptake
 - Symptoms include irregular or stunted growth, nutrient deficiency, poor internal drainage

Why is compaction increasing

Larger equipment



Uncontrolled traffic



Operations on wet soils



Soil and Water Management: Compaction

- **Signs and symptoms**
 - Soil
 - Penetration resistance
 - Standing water
 - Poor structure
 - Plant
 - Stunted growth
 - Nutrient deficiencies
 - Malformed roots
 - Reduced yield

Diagnosing compaction

Plant roots affected



Soil structure destroyed



Soil and Water Management: Site-Specific Management

- **Two step process**
 - Assess variability
 - Grid sampling, yield mapping, electrical conductivity, etc.
 - Variability must be non-random
 - Variability must be sufficiently large and in responsive range
 - Manage variability
 - Variable-rate vs. uniform rate treatment
 - Delineate management zones
 - Precision application

Grid sampling identifies soil variability

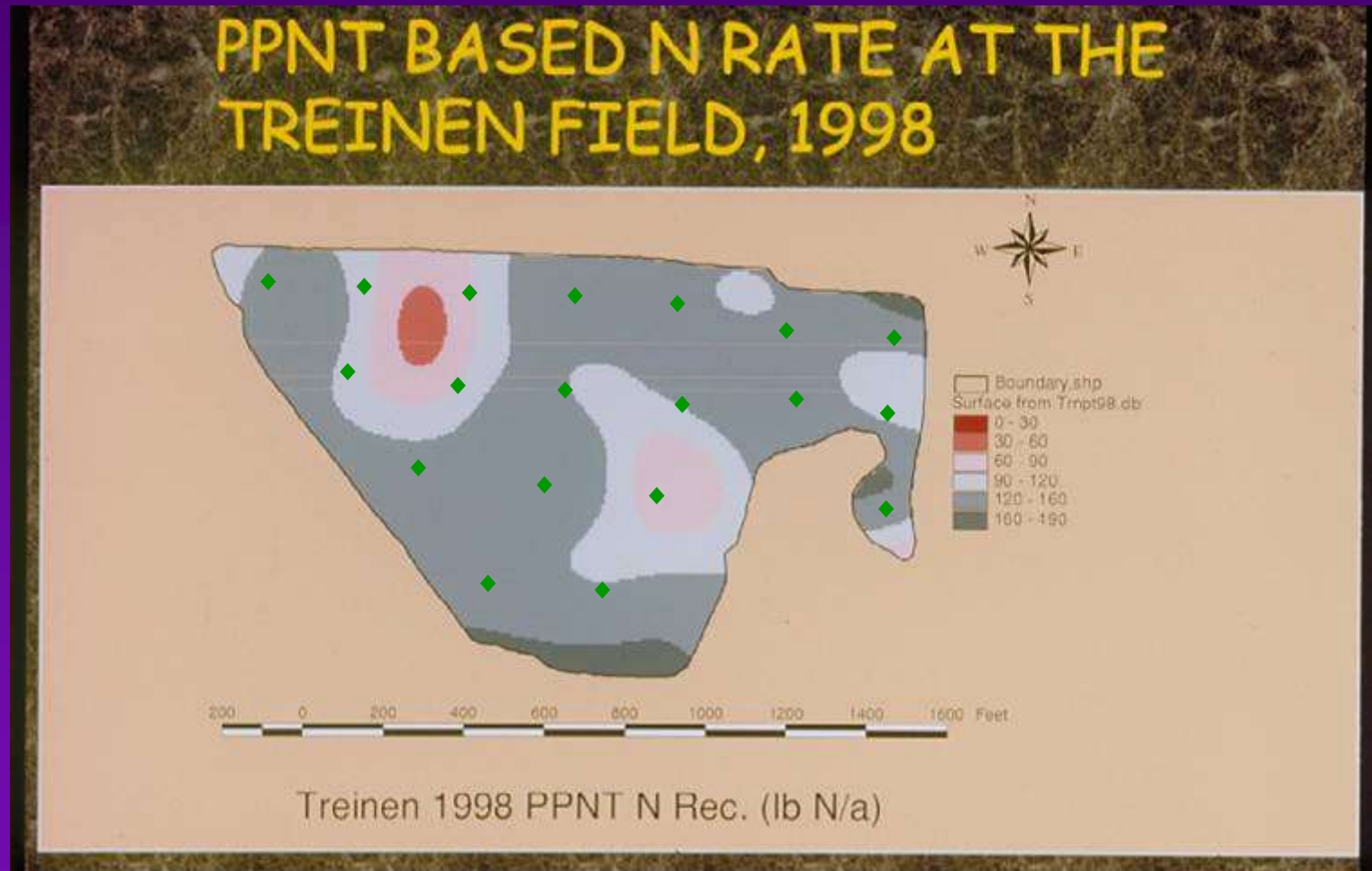
*First grid sampling in
Wisconsin, 1994*

*Samples are collected
around a point
Identified by GPS*



Grid sampling identifies soil variability

**Grid sample based
N recommendation**



Soil and Water Management: Site-Specific Management

- **Benefits and concerns**

- **Benefits**

- Information
- Develop GIS for various factors
- Base decisions on economics
- Management doesn't have to be high tech

- **Concerns**

- Data collection logistics
- Cost to consultant and grower
- Philosophy

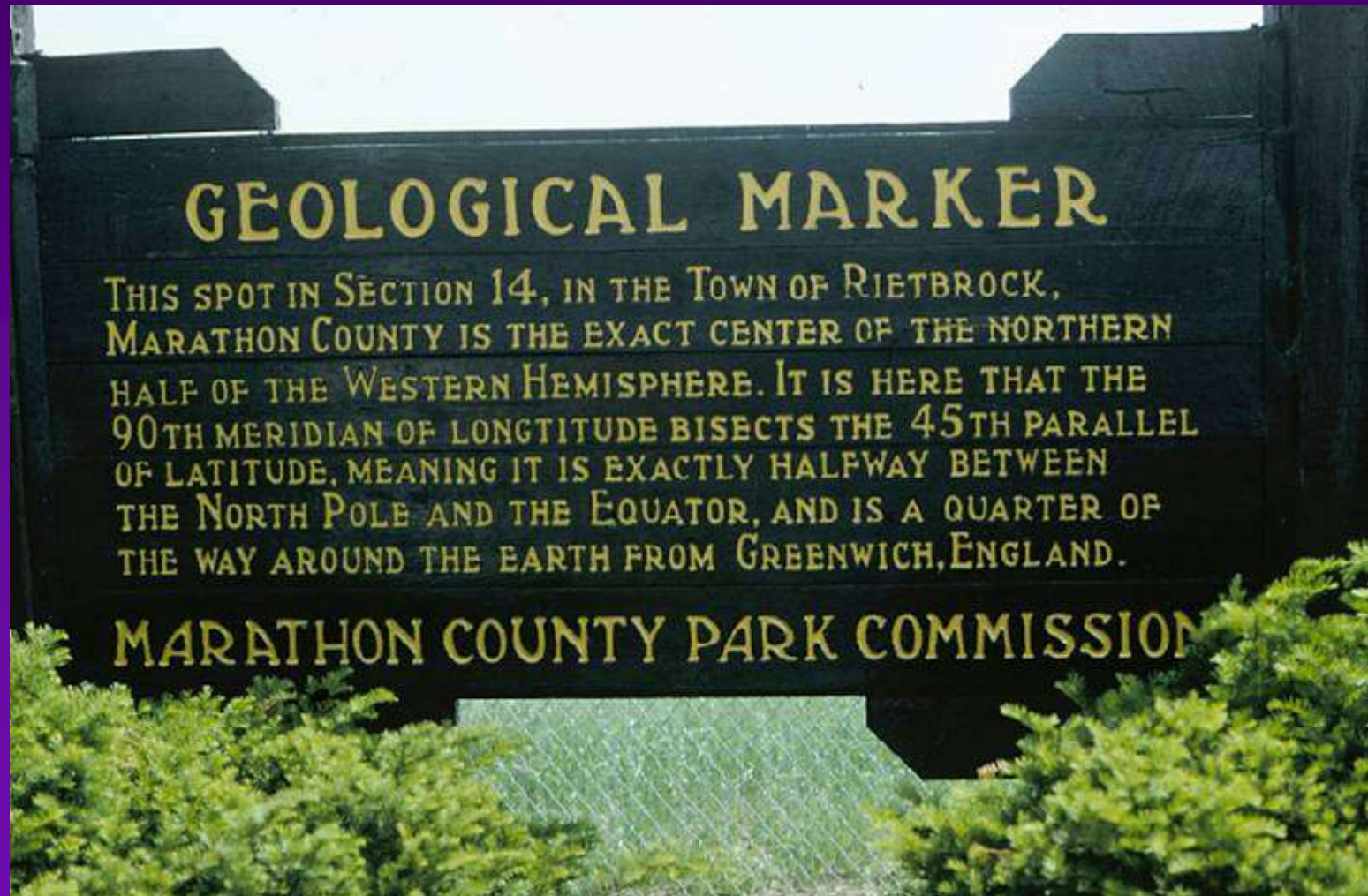
Soil and Water Management: Site-Specific Management

- **GPS has facilitated the practice**
 - System of satellites controlled by DOD
 - Fast, accurate, on-the-go positioning
 - Reliable and consistent
 - State plane vs. Lat/Lon coordinates

What so special about Poniatowski ?

Latitude: 45 00.00 N
Longitude: 90 00.00 W

**Hint: Sign can be
found on Meridian Rd.**



Soil and Water Management: Land Application of Municipal and Industrial Wastes

- **Considerations**

- What is it

- Material source and processing
- Previous experience

- What is in it

- Analysis (nutrients, metals, toxics)
- C:N
- Inert materials

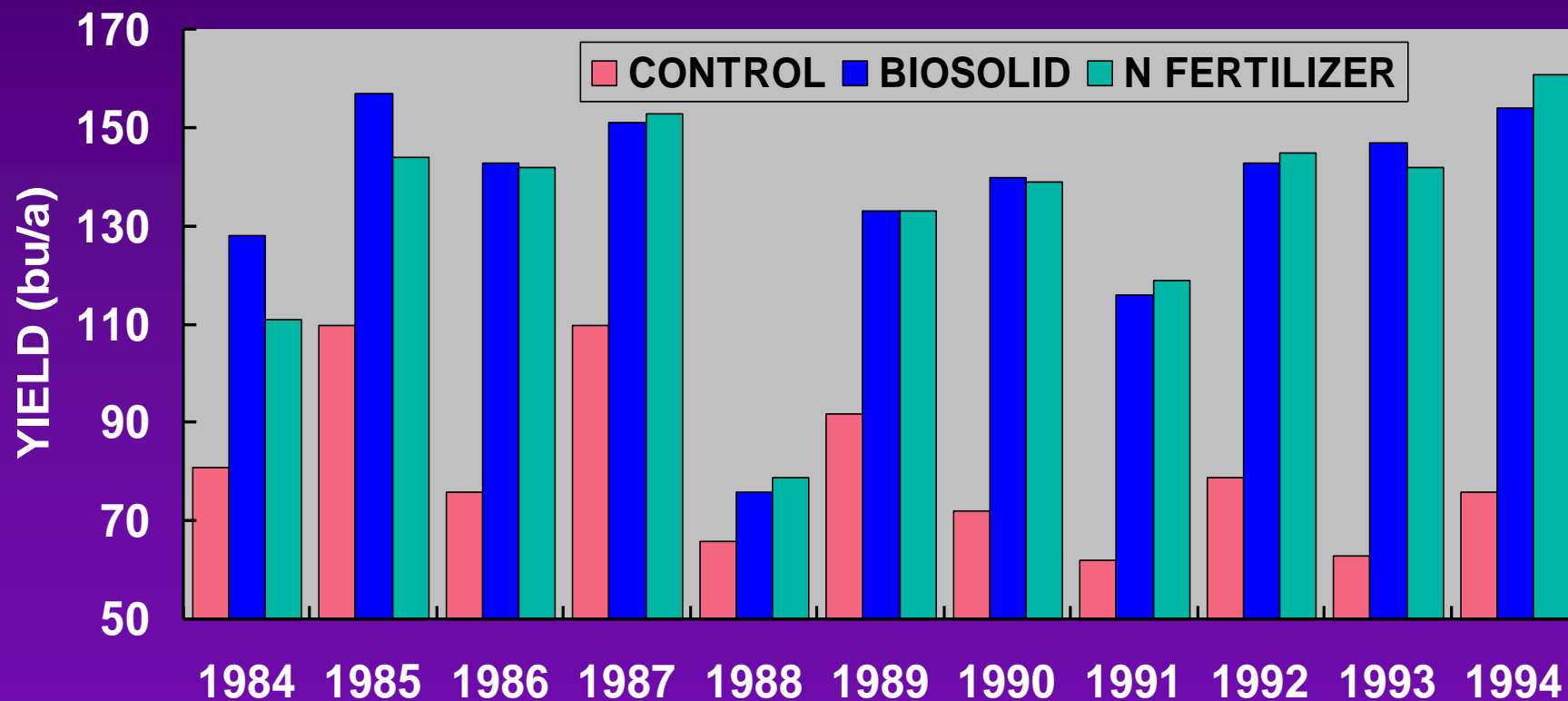
- Application considerations

- Nutrient availability
- Rate, method, timing
- Regulations

Soil and Water Management: Land Application of Wastes

- **Common waste materials in Wisconsin**
 - Municipal biosolids (sewage sludge)
 - NR 204
 - Land application is favored
 - Various forms depending on treatment process
 - Applied to meet crop N need
 - Heavy metals, pathogens, vector attraction
 - Class A vs. Class B affects setbacks
 - No winter spreading

LONG-TERM EFFECT OF BIOSOLID APPLICATION ON CORN YIELD, ELKHORN, WIS. 1984-1994.



HEAVY METAL CONTENT OF THREE BIOSOLIDS

<u>ELEMENT</u>	<u>APPLETON</u>	<u>WAUPACA</u>	<u>WEYAUWEGA</u>	<u>LIMIT</u>
	----- ppm -----			
As	3.8	7.3	2.0	75
Cd	2.0	8.1	<0.5	85
Cu	403	700	68	4300
Pb	74	41	6.8	840
Hg	1.2	1.1	0.4	57
Mo	23	nd	6.8	75
Ni	24	16	8.0	420
Se	1.4	2.7	1.1	100
Zn	709	820	123	7500

Soil and Water Management: Land Application of Wastes

- **Common waste materials in Wisconsin**
 - Solid waste materials (Composts, papermill sludge, by product lime, whey, construction debris)
 - NR 518
 - Papermill fiber sludge is the largest solid waste in state
 - Many have high C:N
 - Apply to meet crop N need
 - May not add hazardous substances or cause a detrimental effect on water quality
 - Site approvals needed
 - Contact local DNR

Soil and Water Management: Irrigation and Drainage

- **Irrigation scheduling (WISP program)**
 - Important on sandy soils (ET ~ 0.15"/day)
 - Crops begin to wilt when 45% AW used
 - Stomata close to reduce ET, this stops CO₂ use
 - Excess water leaches nitrate and pesticides
 - Example: Sandy loam soil has 10% AW
 - $0.10 \times 24" = 2.4" \text{ AW in top } 2'$
 - $0.45 \times 2.4" = 1.08" \text{ used between irrigations}$
 - $@ 0.15"/\text{day}: 1.08/0.15 = 7 \text{ day interval}$

Soil and Water Management: Water Quality

- **Recognize contaminants related to agriculture**
 - Nitrogen
 - Groundwater
 - Hypoxia
 - Phosphorus
 - Pesticides
 - Sediment
 - Pathogens

Agriculture often blamed for water quality problems

***Cryptosporidium outbreak,
Milwaukee, April, 1993***



Avoid direct access to groundwater

*Old well in cornfield,
Calumet Co.*



Soil and Water Management: Water Quality

- **Suggest practices to protect water quality**
 - Nutrients
 - Rate, Timing, Source, Placement
 - Manure incorporation?
 - Crop residue management
 - Conservation practices
 - Pesticide prohibitions

Suggested Review: Study “Management of Wisconsin Soils”

- Basic properties
- Soil erosion
- Crop residue management
- Restrictive soil layers
- Site characterization
- Site-specific management
- Land application of waste
- Water management
- Irrigation and drainage
- Water quality