SOIL HEALTH and DROUGHT

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National Sustainable Agriculture Information Service

Soil Health: Nature and Management

• Nature and soil characteristics
  – Local geology and climate determines soil type
  – Soil type determines natural water- and nutrient-holding capabilities

• Land management practices
  – Can decrease or enhance soil nutrient- and water-holding capabilities
  – These management changes may not be apparent for several years
Natural Soil Characteristics

- **Soil texture**
  - Soil mineralogy: sand, loam, clay, muck
  - Particle size
- **Soil profile**
  - Soil depth
  - Subsoil characteristics
- **Soil slope**
Soil Texture and Water

<table>
<thead>
<tr>
<th>Soil</th>
<th>Water</th>
<th>Absorbs water</th>
<th>Holds water</th>
<th>Drains water</th>
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</thead>
<tbody>
<tr>
<td>Sandy soil</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
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<tr>
<td>Clay soil</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
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<tr>
<td>Loam soil</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
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<tr>
<td>Muck soil</td>
<td>Excessive</td>
<td>Excessive</td>
<td>Poor</td>
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</table>
Soil Profile and Water

- Characteristics of deep topsoils
  - Absorb and hold water and nutrients
  - Promote thick root growth able to reach water

- Subsoil characteristics
  - Clay, hard rock, or compacted subsoils restrict water entry and movement \(\rightarrow\) low water absorption
  - Gravelly or cracked rock subsoils allow excessive water to flow through the soil profile \(\rightarrow\) low water holding
Soil Slope and Water

- **Water absorption**
  - Limited by water flow on steep slopes
  - Limited by thin topsoils on steep slopes

- **Water retention**
  - Conservation practices slow water flow downslope
  - Conservation practices protect topsoil, enhancing soil’s water-holding capacity
Soil Water Conservation

- **Cropping practices**
  - Rotations with perennial grasses
  - Adds organic matter to soil
  - Minimum tillage
  - Cover cropping

- **Grazing practices**
  - Managed rotational grazing
  - Riparian area protection
Cropping Practices for Healthy Soils

• Add manure and crop residues to soil
  - Promotes growth of soil organisms
  - Builds soil organic matter
  - Enhances soil aggregation and tilth

• Use cover crops, minimum tillage, and mulches
  - Protects against erosion and runoff
  - Minimizes water loss through evaporation
Soil Organic Matter and Soil Organisms

- Soil organisms decompose organic matter and build soil humus
  - Increase nutrient availability
  - Increase water-holding capacity
- Soil organisms build soil tilth
  - Insect and earthworm burrows make soil porous
  - Fungi and bacteria build soil aggregates
  - Mycorrhizae enhance plant uptake of water and nutrients and create soil aggregates
Aggregated Soils

- **Enhance water availability**
  - Decreased soil crust formation, resulting in better water absorption
  - Increased water storage throughout the soil profile
  - Decreased leaching and evaporation

- **Enhance plant water uptake**
  - Facilitates soil water and nutrient movement
  - Facilitate root growth through soil profile
Practices to Protect Soil Life

- Use minimum tillage
  - Soil cover moderates temperature and protects against water loss by evaporation
  - Does not disrupt the habitat of soil organisms
- Add manure and crop residues to land to provide soil organisms with food and favorable growing conditions
- Minimize or eliminate use of synthetic chemicals to protect soil biological health
Soil Health Indicators

- Moderate to high organic matter
- Even distribution of nutrients
- Good water infiltration
- Minimal soil erosion
- Deep crop root growth
- Active populations of soil insects, earthworms, and microbes
Residues for Water Conservation

- Surface residues conserve soil organic matter
  - Feed soil organisms that build aggregates
  - Cool soil and slow organic matter decomposition

- Soil cover facilitates water infiltration
  - Cushions against raindrop impact and crust formation
  - Protects soil against runoff and erosion

- Soil cover decreases water evaporation
Windbreaks to Reduce Evaporation

- Hot winds blowing across soils and plants increases evapo-transpiration
- Tree shelter belts reduce winds and evaporation potential
- Choose windbreak trees that
  - Use water efficiently
  - Create minimum shade
  - Provide habitat for beneficial organisms
Stubble to Increase Snow Infiltration

- Effective in arid areas with winter snows
- To capture snowfall, cut stubble at alternating heights, perpendicular to the wind
  - Acts as windbreak to collect snow within fields
  - Residue cover facilitates infiltration of snowmelt
  - Increases the amount of moisture available to soils in the field
Plant According to Water Needs

• Plants have critical periods of water need
  - Leafy vegetables need water throughout the growing period
  - Root, tuber, and bulb crops need water when roots are enlarging
  - Fruit and seed crops need water at flowering and at fruit or seed set

• When possible, plant crops so their critical periods of water need coincide with times of normally wet weather
Plant to Enhance Water Availability

• **Time planting to avoid known dry periods**
  - Use fall-seeded crops that overwinter and take advantage of spring moisture
  - Time planting to harvest before dry periods
  - Plant short-season crops that produce yields before onset of dry periods

• **Time planting to correspond with know wet periods, such as spring or mid-summer rains**
Conserve Moisture During Planting

- To conserve moisture during planting
  - Till shallowly to minimize moisture loss
  - Plant seeds deeper, where soil is moist
  - Pack seed following drilling to close soil
Use Drought Resistant Crops

- Early-maturing, low water-use crops
  - Barley
  - Peas
  - Oats
  - Lentils

- When moisture is favorable, harvest crops for sale

- If drought reduces crop yields or quality, graze these crops to recover some of their value
Rotate to Build Soil Quality

• Rotate between annual and perennial crops
  - Deep rooted perennials can get water and nutrients that have moved out reach of annual plant roots
  - Fine roots of perennial grasses build soil aggregation and tilth

• Rotate cropping and grazing land
  - Aids soil recovery from compaction
  - May decrease weed competition
Avoid Water Competition Between Rotated Crops

- Choose appropriate cover crops and crop rotations
  - Know each crop’s water needs
  - Match with soil moisture availability

- Determine best time to cut or kill cover crops
  - Limiting cover crop growth reduces water depletion
  - Extending cover crop growth produces more residues while decreasing the potential for soil erosion and water loss through evaporation
Control Weeds to Conserve Moisture Availability

- Weeds compete with crops for soil moisture
- Wide spacing between plants provides roots with more area to obtain moisture from soil, but wide spacing
  - Reduces moisture-conserving canopy
  - Can increase weed competition
Weed Control Practices

- **Organic weed control**
  - Crop rotations and cover crops decrease weed pressure over time
  - Flaming, acetic acid, corn gluten meal

- **Herbicides for weed control**
  - Often used in minimum tillage - “chem till”
  - Preplant herbicides dry out soil
  - Soil-applied herbicides need moist soil to be effective

- **Harm to soil organisms and soil tilth** is usually **less** from herbicides than from tillage
Tillage and Compaction

- Tillage and heavy equipment use compacts soils
  - Tilling or driving equipment on wet soils compresses them and forms clods
  - Repeated plowing at the same depth forms plow pans

- Tillage degrades soil aggregates
  - Disrupts soil organisms that form aggregates
  - Allows heat to breaks down organic gels and glues
Tillage and Moisture Loss

• Tillage increases moisture loss by evaporation
  - Exposes moist soil to drying forces of sun and wind
  - Reduces residues that protect against evaporation

• Soil moisture loss increases with tillage passes and tillage depth
  - Most moisture is lost on the first pass, with approximately \( \frac{1}{3} \) to \( \frac{1}{2} \) inch additional loss with each tillage pass
  - Deeper tillage increases moisture loss
Tillage Equipment and Evaporation

As tillage decreases residue cover, it increases water evaporation from soil.

Minimum till
- Undercutter (v-blade)
- Rodweeder
- Chisel with sweeps
- Cultivator with harrow
- Disc
- Moldboard

Most residue cover/least evaporation

Least residue cover/most evaporation
Minimum Till Practices

• Killed mulch
  - Used with cover crops
  - Crop planted or transplanted into killed cover crop

• Chem till
  - Uses herbicides to kill weeds
  - Often involves use of GMO crops
Minimum Till Trade-Offs

- **Killed mulch**
  - Cover crop needs sufficient moisture and time for growth
  - Suitable for organic production

- **Chem-till**
  - Soil applied herbicides are less effective when soil is dry
  - Not suitable for organic production

- All minimum tillage practices retain moisture, slowing soil warm-up in spring
Killed-Mulch Tillage Tools

- Stalk pullers pull stalks, leaves residues
- Uprooter-shredder-mulchers uproot and shred stalks, then inject them into the soil
- Undercutters sever plants below crown, then flatten residues
- Roll-choppers flatten plants and cut stems perpendicularly
- Flail choppers shred stalks behind picker
Minimum Tillage Alternatives

- Minimum till practices are not suitable for areas with cold and wet winters
  - Surface mulches prevent wet soil from drying and warming in spring
  - Cool, wet soils cause seed rot and poor root growth

Zone or ridge tillage

- Seeding zone tilled and raised
- Allows the seed zone to warm up and dry out
Frost Tillage

• Soil tilled in winter when frost is less than 4” deep (But these weather conditions may not occur every year.)

• Produces a rough soil surface
  - Encourages moisture infiltration
  - Reduces potential for soil compaction

• Early tillage allows for earlier spring planting
Rangeland Health Indicators

- Biological soil crusts
  - Composed of bacteria, algae, and fungi
  - Enhance water infiltration and water-holding capacity of soils

- Even distribution of vegetation, residues, and organic matter across the landscape

- Minimal soil surface loss or degradation
Grazing Practices for Healthy Soils

• Graze short-term on small paddocks
  – Forces even grazing across paddocks
  – Results in an even distribution of plant residues and manure
  – Reduces bare spots and compaction from lounging

• Rest paddocks between grazing periods
  – Permits forage regrowth and enhances forage diversity
  – Allows soils to recover from compaction
Rotating for Forage Persistence

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<th>Grazing</th>
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<th>Long term</th>
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<td>Rest</td>
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<tr>
<td>Short term</td>
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<td>Effective use of rapidly growing forages</td>
<td>Force use of unwanted forages</td>
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<td>forage, or wet soils</td>
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Riparian Protection

- Exclude or limit animal access
  - Designate water crossings
  - Provide alternative water systems
  - Place minerals, shade, and water away from streams

- Protect vegetation on riparian soils
  - Plant grass and trees
  - When upland vegetation is sparse, exclude animals from riparian areas to prevent overgrazing
Riparian Protection Benefits

- Enhances water recharge
- Reduces flooding by absorbing rainfall, then slowly releasing water into streams
- Protects water quality by limiting nutrient and pathogen movement into streams
- Protects plant and wildlife habitat
Summary

- Manage your soils to reduce impacts of drought
  - Return organic matter to the soil
  - Minimize soil compaction
  - Protect soil organisms
  - Protect against runoff and erosion

- Reduce water loss from evaporation, runoff, and weed growth
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