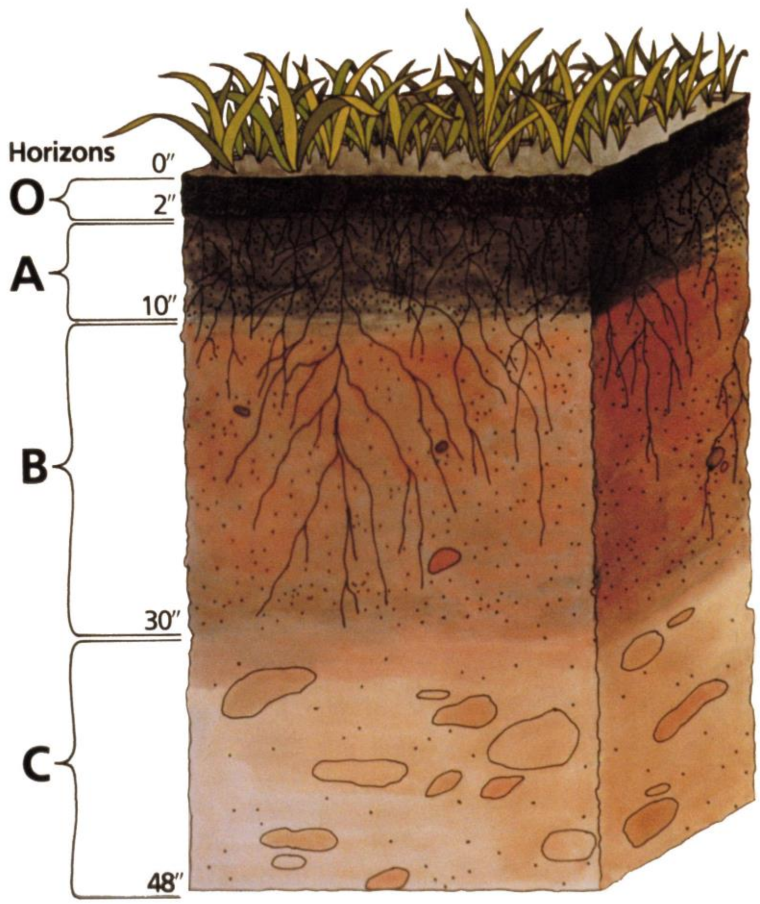
2021 NCF Envirothon Soil Test Study Guide

Lincoln, Nebraska



2021 NCF-Envirothon Nebraska
Soils and Land Use Study Resources

Key Topic #1: Physical Properties of Soil and Soil Formation

1. Describe the five soil forming factors, and how they influence soil properties.
2. Explain the defining characteristics of a soil describing how the basic soil forming processes influence affect these characteristics in different types of soil.
3. Identify different types of parent material, their origins, and how they impact the soil that develops from them.
4. Identify and describe soil characteristics (horizon, texture, structure, color).
5. Identify and understand physical features of soil profiles and be able to use this information interpret soil properties and limitations.

Study Resources

Sample Soil Description Scorecard – *University of Nebraska – Lincoln Land Judging Documents, edited by Judy Turk, 2021* (Pages 3-4)

Soil Description Field Manual Reference – *University of Nebraska – Lincoln Land Judging Documents, edited by Judy Turk, 2021* (Pages 5-17)

Correlation of Field Texturing Soils by Feel, Understanding Soil Laboratory Data, and Use of the Soil Textural Triangle – *Patrick Cowsert, 2021* (Pages 18-21)

Tips for Measuring Percent Slope on Contour Maps – *Excerpt from Forest Measurements by Joan DeYoung, 2018* (Pages 22-23)

Glossary – *Excerpts from Geomorphic Description System version 5.0, 2017, and Field Book for Describing Soils version 3.0, 2012* (Pages 24-27)

<u>Study Resources begin on the next page!</u> ➡

Sample Soil Description Card

Host: University of Nebraska – Lincoln

2021 –Scorecard

Contestant Number	
Site/Pit Number	
Number of Horizons	
Lower Profile Depth	
Nail Depth	

A. Soil Morphology

Part A Score __________

Horizons				**Boundary**		**Texture**			**Color**			**Redox.**		**Structure**		**Moist Cons.**	**Effer.**	**Total**
Prefix (2)	Master (4)	Suffix (2)	No. (2)	Lower Depth (2)	Dist. (2)	Rock Frag. (2)	Class (4)	Clay% (2)	Hue (2)	Value (2)	Chroma (2)	Conc. yes/no (2)	Depl. yes/no (2)	Grade (2)	Type (2)	(2)	yes/no (2)	Total (40)

B. Soil Hydrology and Profile Properties

Part B Score __________

Hydraulic Conductivity: Surface Layer (3-5-3)	**Hydraulic Conductivity: Limiting Layer (5)**	**Depth to Root Restricting Layer (5)**	**Water Retention Difference to 150 cm (5)**	**Soil Wetness Class (5)**	**Score Summary**
____ Very High	____ Very High	____ Very Deep (> 150 cm)	____ High (> 22.5 cm)	____ Class 1 (> 150 cm)	Part A ______
____ High	____ High	____ Deep (100-150 cm)	____ Medium (15-22.5 cm)	____ Class 2 (100-150 cm)	Part B ______
____ Moderately High	____ Moderately High	____ Mod. Deep (50-100 cm)	____ Low (7.5-15 cm)	____ Class 3 (50-100 cm)	Part C ______
____ Moderately Low	____ Moderately Low	____ Shallow (25-50 cm)	____ Very Low (< 7.5 cm)	____ Class 4 (25-50 cm)	Part D ______
____ Low	____ Low	____ Very Shallow (0-25 cm)		____ Class 5 (0-25 cm)	Part E ______
____ Very Low	____ Very Low				TOTAL _______

C. Site Characteristics

Part C Score __________

Landform (5)	Parent Material (5)*	Slope (5)	Hillslope Position (5)	Surface Runoff (5)
____ Floodplain	____ Alluvium	____ 0-2 %	____ Summit	____ Negligible (or Ponded)
____ Stream Terrace	____ Colluvium	____ 2-5 %	____ Shoulder	____ Very Low
____ Upland	____ Eolian Sand	____ 5-9 %	____ Backslope	____ Low
____ Upland Depression	____ Glacial Till	____ 9-14 %	____ Footslope	____ Medium
	____ Loess	____ 14-18 %	____ None	____ High
	____ Residuum	____ 18-25 %		____ Very High
		____ > 25 %		

D. Soil Classification

Part D Score __________

Epipedon (5)	Diagnostic Subsurface Horizons & Characteristics (5)*	Order (5)	Suborder (5)	Great Group (5)		Family Particle Size Class (5)
____ Mollic	____ Albic	____ Vertisol	____ Aquert	____ Endoaquert	____ Paleudalf	____ Sandy
____ Anthropic	____ Argillic	____ Mollisol	____ Udert	____ Hapludert	____ Hapludalf	____ Loamy
____ Ochric	____ Calcic	____ Alfisol	____ Alboll	____ Argialboll	____ Halaquept	____ Silty
	____ Cambic	____ Inceptisol	____ Aquoll	____ Argiaquoll	____ Epiaquept	____ Coarse Loamy
	____ Slickensides	____ Entisol	____ Udoll	____ Calciaquoll	____ Endoaquept	____ Fine Loamy
	____ Lithic Contact		____ Aqualf	____ Epiaquoll	____ Eutrudept	____ Coarse Silty
	____ Paralithic Contact		____ Udalf	____ Endoaquoll	____ Psammaquent	____ Fine Silty
	____ None		____ Aquept	____ Paleudoll	____ Fluvaquent	____ Fine
			____ Udept	____ Argiudoll	____ Endoaquent	____ Very Fine
			____ Aquent	____ Hapludoll	____ Udipsamment	____ Sandy Skeletal
			____ Psamment	____ Albaqualf	____ Udifluvent	____ Loamy Skeletal
			____ Fluvent	____ Epiaqualf	____ Udorthent	____ Silty Skeletal
			____ Orthent	____ Endoaqualf		____ Contrasting (any)

Particle Size Control Section		
	____ 0 cm to root limiting layer (limiting layer < 36 cm depth)	____ Upper 50 cm of argillic horizon
	____ 25-100 cm	____ Upper boundary of argillic to 100 cm (contrasting particle size class)
	____ 25 cm to root limiting layer (36-100 cm depth)	____ All of the argillic where it is < 50 cm thick

E. Site Interpretations

Part E Score __________

Septic Tank Absorption Field (5)	Dwellings without Basements (5)	Ecological Site Description (5)			
		____ Wet Subirrigated	____ Saline Lowland	____ Shallow Limy	____ Sandy
____ Slight	____ Slight	____ Saline Subirrigated	____ Sandy Lowland	____ Limy Upland	____ Loamy
____ Moderate	____ Moderate	____ Subirrigated	____ Loamy Lowland	____ Clayey Upland	
____ Severe	____ Severe	____ Loamy Overflow	____ Shallow Sandy	____ Dense Clay	

REFERENCE BOOKLET
Table of Contents (section reference)

A. Morphology **pages 2-6**

HORIZONATION				BOUNDARY		TEXTURE			COLOR			STRUCTURE		REDOX		MOIST CONSIST.	EFFERV
Prefix	Master	Sub.	No	Depth (cm)	Dist.	Rock Frag. Mod.	Class	Clay (%)	Hue	Value	Chroma	Grade	Type	Conc	Depl		
1a	1b	1c	1d	2a	2b	3	Yellow sheet		Yellow sheet			5a	5b	6	6	7	8

B. Soil Hydrology and Profile Characteristics **pages 6-7**

Hydraulic Conductivity	Effective Soil Depth (5)	Water Retention Diff. (5)	Soil Wetness Class (5)
Blue Sheet	10	11	12

C. Site Characteristics **pages 7-**

Landform (5)	Parent Material (5*)	Slope (5)	Hillslope Position (5)	Surface Runoff (5)
13 and Glossary	14 and Glossary	Yellow Sheet	16 and Glossary	Blue Sheet

D. Soil Classification **page 7-9**

Epipedon (5)	Diagnostic Subsurface Horizons & Features (5*)	Order (5)	Suborder (5)	Great Group (5)	Family Particle-Size Class (5)
18	19	20	Not used	No used in this contest	No used in this contest

Particle Size Control Section White Sheet

E. Site Interpretations **page 9**

Septic Tank Absorption Fields (5)	Local Roads and Streets (5)	Dwellings with Basements (5)
Blue Sheet		

Part A: Morphology

1. **Horizonation:** Complete this section after describing the rest of the morphology.
   a. **Prefix**:
      i. If there is only one parent material for the whole profile - Dash all boxes
      ii. If there is more than one parent material - Dash boxes for horizons formed in the upper parent material, enter "2" for horizons formed in the second parent material, 3 for the third, and so on.
   b. **Master**

      A- Mineral horizon that is dark in color due to accumulation of organic matter
      E- Light in color and low in clay due to leaching
      B- Subsoil horizon altered by pedogenic processes (always use subordinate distinction to specify type of alteration)
      C- Unaltered parent material that is soft enough to dig through
      R – Hard, unweathered bedrock (the rest of part A is not described)
      Transitional: Combine two of the letters above to indicate properties intermediate between two master horizons (**e.g., AB, BA, AE, EA, BC, CB**)

      Symbols sometimes used with Master horizons:
      Prime ('): Used following master horizon designation when two horizon with same designation (master and sub) are separate by another horizon (e.g., Ab-Cb-A'b)
      Slash (/): Used between two master horizon names when the horizon contains distinct zones with characteristics of each type of horizon (e.g., B/E).
      Ampersand (E&B or B&E): Used for lamellae (thin bands of clay in sand).

   c. **Subordinate distinctions (Sub.)** – more than one may be required (or may be dashed if none applies). Proper order for multiple subordinate distinctions: List r, t, and w first, g and b last, and others in between.

      b – "buried" - Indicates horizons from a soil previously exposed at the surface that has been buried by more recent sediment. Use with buried A and horizons below a buried A.
      g – "gley" – Indicates gray color resulting for reduction of iron oxide coatings on minerals. Use whenever matrix color has a value ≥4 and chroma ≤2 and redox concentrations are observed. If g is used also mark Y or depletions.
      k – "carbonates" – Indicates visible accumulation of secondary carbonates. These occur as bright white masses in the soil that effervesce with HCl.
      n - "sodium" – Indicates accumulation of exchangeable sodium. Almost always combined with t (illuvial clay accumulation). Use when SAR approaching 13 and there is evidence of illuvial clay accumulation.
      p – "plow" – Indicates tillage. Used with A horizons that have been mixed with a plow.
      r – "weathered bedrock" – Indicates rock that has been chemically weathered without physical or biological alteration. Looks like rock but is not strongly cemented. Used only with C. Most Cr horizon in contest are have visible pedogenic carbonates (Crk horizons)

ss – "slickensides" – Indicates polished/grooved surfaces produced when soil aggregates slide past one another due to shrinking and swelling of soil rich in smectite clays.
t – "illuvial clay" – Indicates accumulation of illuvial clays indicated by: (1) a higher clay content than horizon(s) above and (2) the presence of clay films.
w – "weak development" – Indicates development of structure or color without any specific illuvial accumulation. Used only with B horizons. Cannot be combined with other sub. distinctions (except b)
z – "soluble salts" – Indicates accumulation of soluble salts. Use when EC >4 dS/m.

d. **Number** (No.): When there are two or more horizon in a row with the same master and subordinate distinction, they are number starting from the top. Otherwise this is dashed.

2. Boundary:

a. Depth: Record depth of lower boundary at location of tape in the designated control section. "Nail depth" indicating lower boundary of the 3rd horizon will be given, as well as number of horizons, and profile depth.
A and E horizons must be at least 2.5 cm to be described. B, C, and transitional horizons must be at least 8 cm to be described.

b. **Distinctness**

Boundary	Abbreviation	Boundary Distinctness
Abrupt	**A**	< 2 cm
Clear	**C**	2.1 to 5 cm
Gradual	**G**	5.1 to 15 cm
Diffuse	**D**	> 15 cm

A dash should be place in the distinctness box for the lowest horizon unless there is a Cr or R horizon immediately beneath the depth described.

3. Rock fragment modifiers

Percent Rock by Volume	Rock Fragment Modifier
< 15%	No special term used with the soil texture class. Enter a dash or leave blank.
15 - 35%	Use "gravelly", "cobbly", "stony", "bouldery", "channery" or "flaggy" as a modifier of the texture term (e.g. gravelly loam or GR-L)
35 - 60%	Use "very (V) + size adjective" as a modifier of the texture term (e.g. very cobble fine sandy loam or CBV-FSL).
60 - 90%	Use "extremely (X) + size adjective" as a modifier of the texture term (e.g.. extremely stony clay loam or STX-CL)
> 90%	Use "coarse fragment noun" as the coarse fragment term (e.g. boulders or BD) and dash or leave blank the soil texture class and the % clay boxes.

Size (Diameter)	Adjective	Symbol
Rounded, Subrounded, Angular, Irregular		
0.2 cm - 7.5 cm **7.6 cm - 25.0 cm** **25.1 cm - 60.0 cm** **> 60.0 cm**	Gravel Cobbly Stony Bouldery	GR CB ST BD
Flat		
0.2 cm - 15 cm **15.1 cm - 38.0 cm** **38.0 cm - 60 cm** **> 60 cm**	Channery Flaggy Stony Bouldery	CH FL ST BD

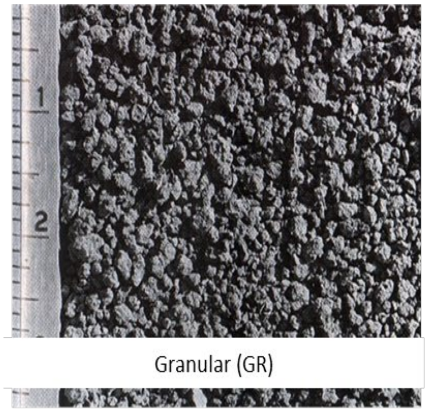
4. Texture: -- See YELLOW SHEET

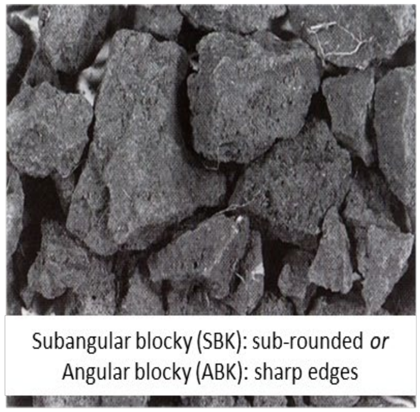
5. Structure

a. **Grade**

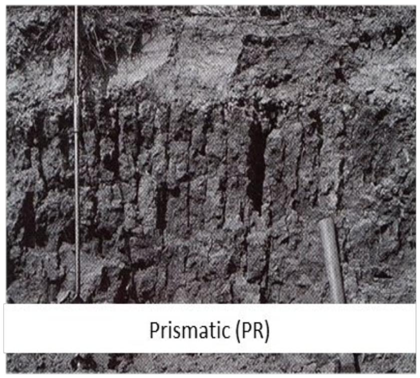
Grade Type	Code	Description
Structureless	0	• No observable aggregation (single grain) or • No orderly arrangement of natural lines of weakness (massive)
Weak	1	• Breaks into very few poorly formed, indistinct peds • Most peds destroyed in the process of removal • Shape of structure is barely observable in place
Moderate	2	• Well-formed, distinct peds when removed by hand • Moderately durable • Little unaggregated material • Shape of structure observed in the undisturbed pit face may be indistinct
Strong	3	• Durable peds • Very evident in undisturbed soil of the pit face • Very little or no unaggregated material when peds are removed

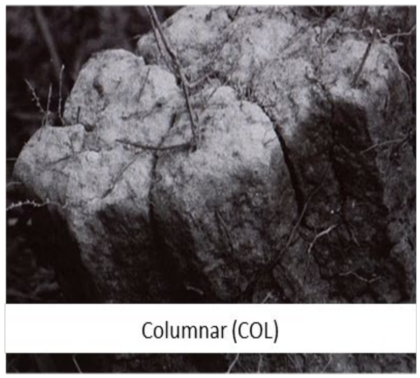
b. **Type or Shape (next page)**


Granular (GR)


Subangular blocky (SBK): sub-rounded *or*
Angular blocky (ABK): sharp edges


Platy (PL)


Prismatic (PR)

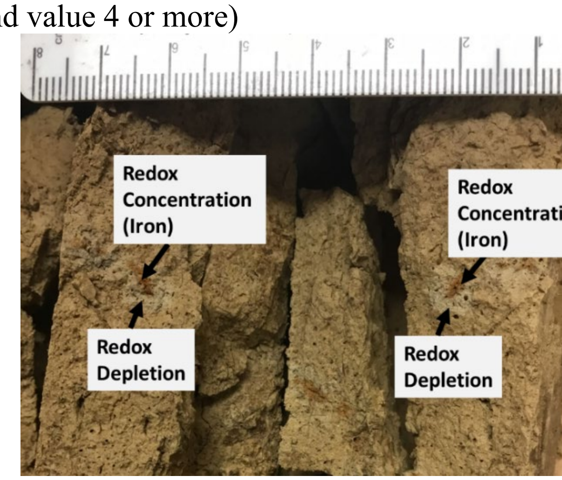

Columnar (COL)


Wedge (WEG)

Soils with no structure (not pictured)
Single grain (SGR): Loose grains *or*
Massive (MA): Coherent mass with no planes of weakness

6. **Redox**.

Conc: Enter "Y" if iron or manganese concentrations observed
Depl: Enter "Y" if redox depletions observed *or* if there is a reduced matrix (chroma 2 or less and value 4 or more)



7. **Moist consistence:** Evaluated in moist state. If soil is excessively wet, choose the next lower class. If the soil is dry, choose the next higher class

Type	Abbreviation	Description
Loose	LO	Soil is non-coherent (e.g. loose sand).
Very Friable	VFR	Soil crushes very easily under gentle pressure between thumb and finger
Friable	FR	Soil crushes easily under gentle to moderate pressure between thumb and forefinger
Firm	FI	Soil crushes under moderate pressure between thumb and forefinger, but resistance to crushing is distinctly noticeable.
Very Firm	VFI	Soil crushes or breaks only when strong force is applied between thumb and forefinger.
Extremely Firm	EFI	Soil cannot be crushed or broken between thumb and forefinger but can be by squeezing slowly between hands.
Slightly Rigid	SR	Soil cannot be crushed with hands, can be crushed under foot
Rigid	R	Soil does not crush under foot, can crush with moderate blow from hammer
Very Rigid	VR	Soil requires strong blow with hammer to crush

8. **Effervescence:** Enter "Y" if matrix bubbles when dilute HCl applied

Part B: Soil Hydrology and Profile Characteristics

9. **Hydraulic conductivity:** see BLUE SHEET

10. **Effective Soil Depth:** Determine the upper boundary of the Cr or R horizon and select the class corresponding to this depth. If there is no Cr or R horizon select "Very Deep".

11. **Water retention difference**
    a. Determine the factor for each horizon:
        COS, S, FS, VFS, LCOS……….0.05
        LS, LFS, LVFS, COSL……..…0.10
        SL, FSL, SCL, SC, SIC, C.…….0.15
        VFSL, L, SIL, SI, SICL, CL……0.20
    b. Make adjustments as needed:
        i. If there are significant rock fragments (RF) present, multiply the factor by (1-%RF/100)

ii. If the horizon is a natric or below a natric horizon, multiply the factor by 0.5

c. Multiply the adjusted factor times horizon thickness for all horizons above the root limiting layer (Cr or R horizon) or 150 cm is there is no root limiting layer (if the profile depth is <150cm and there is no root-limiting layer, extend the depth of the lowest horizon to 150 cm for the calculation).

12. **Soil Wetness Class:** Determine the upper boundary of the shallowest horizon with a “Y” for Redox Depl. Select the class corresponding to this depth. If there are no horizons with depletions or depleted matrix, select “Class 1”.

Part C: Site Characteristics

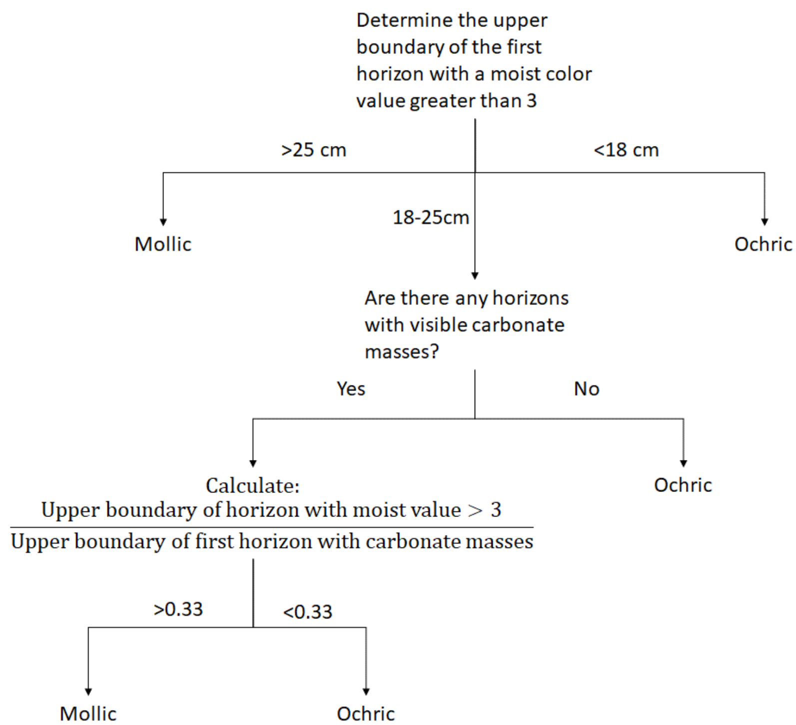
13. **Landform:** Select the one of the following choices: Upland, Floodplain, Terrace, Sandhill, Tableland. (REFER TO GLOSSARY for definitions)
14. **Parent material**: Select the appropriate parent material based on the landform and profile characteristics. <u>More than one may be required</u> if the profile contains distinct layers of different parent material (designated in the pre. column in section A). Choices are: Alluvium, Till, Loess, Eolian sand, Residuum. (REFER TO GLOSSARY for definitions)

15. **Slope:** measured between the stakes using the % scale
    i. Verify that top of stakes are the same height above ground before measuring
    ii. Use clinometer provided and record value
16. **Hillslope profile position**: Select one of the following: Summit, Shoulder, Backslope, Footslope, Toeslope . (REFER TO GLOSSARY for definitions.)

17. **Surface runoff:** see BLUE SHEET

Part D. Soil Classification

18. **Epipedon:** Surface diagnostic horizon. Typically corresponds to the A horizon(s) but may include upper part of B. In Nebraska, most epipedons are **mollic** or **ochric**. You can determine which one it is using the flow chart below.



19. Diagnostic subsurface horizons and features: Select all that apply.

Albic: A, B/E, or E/B horizon that meets all of the following:

- One of the following color criteria
    - Value 4 or 5 and chroma 1 or 2
    - Value 6 or 7 and chroma 1, 2, or 3

Argillic: May be either of the following

- Bt, Btk, Btg, Btn, Btss, or other morphologic horizon with clay films that meets one of the following criteria
    - If A or E has <15% clay: must have >3% more clay
    - If A or E has 15 to 40% clay: clay must increase by 1.2x
    - If A or E has >40% clay: must have >8% more clay

Cambic: Bw, Bg, Bk, Bss, or other morphologic horizon that meets all of the following:

- Does not occur in the same soil as an argillic, natric, or calcic horizon
- Texture of VFS, LVFS or finer
- Contains structure
- ≥15 cm thick
- Not part of Ap or epipedon
- If soil wetness class is 1, 2, or 3 meets one of the following
    - Higher chorma, higher value, redder hue, or higher clay content than an overlying or underlying horizon
    - Evidence of removal of carbonate or gypsum
    - E&Bt or Bt&E horizon with cumulative lamellae thickness of <15 cm
- If soil wetness class is 4 or 5 meets all of the following
    - Colors that do not change on exposure to air
    - One of the following

  - Value of 3 or less and chroma of 0
  - Value of 4 or more and chroma of 1 or less
  - Chroma of 2 or less and redox concentrations

Calcic: Bk, Btk, Ck, or other morphologic horizon that meets all of the following:

- $CaCO_3$ equivalent ≥ 15%
- One of the following
  - ≥5% more $CaCO_3$ equivalent than the C horizon
  - ≥5% visible $CaCO_3$ forms by volume

Natric: Btn horizon that meets all of the following:

- Meets requirements for argillic
- Meets on the follwoing
  - SAR ≥ 13 (or ESP ≥ 15) within upper 40 cm of argillic horizon
  - More Exch Mg+Na than Ca+Exch Acidity within upper 40 cm of argillic and SAR ≥ 13 (or ESP ≥ 15)
- ≥7.5 cm thick

Lithic contact: R horizon
Paralithic contact: Cr, Crk, Crkt, or other horizon composed of weathered bedrock
Slickensides: Bss, Btss, Btkss, or other horizon with polished and grooved surfaces on peds. Occurs in soils high in shrink-swell clays.
Abrupt texture change: Within a distance of 7.5 cm, clay percentage doubles or increases by >20% absolute.
Albic materials: A, B/E, or E/B horizon meeting the color requirement for albic horizon (may or may not meet volume requirement)
Lithologic discontinuities: Major change in texture or mineralogy. Usually a change in parent material but could also be 2 different alluviums. Select this option when a 2 is used in the prefix column.
Aquic conditions: Redox features within the upper 50 cm
None: Meets none of the above

20. Soil order: Use key below

Soils with a mollic epipedon and ≥50% base saturation at the shallowest of the following depths: 125 cm below the top of the argillic or natric horizon, 180 cm below the soil surface, or immediately above the Cr or R horizon…………………………………………….**Mollisols**

Other soils with argillic horizon……………………………………………………**Alfisols**

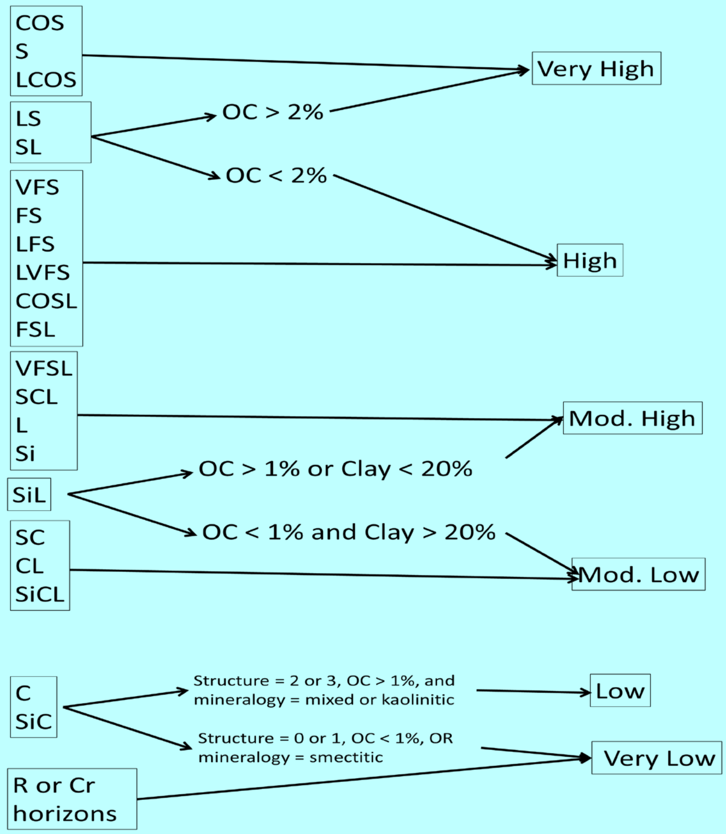
Other soils lacking mollic epipedon, but with a cambic horizon within 100 cm of the soil surface………… …….**Inceptisols**

Other soils……………………………………………………………………….**Entisols**

Part E. Site Interpretations: See BLUE SHEET

HYDRAULIC CONDUCTIVITY

- **Surface layer:** Determine hydraulic conductivity of the uppermost horizon using the chart below.
- **Limiting layer:** Determine the hydraulic conductivity of whichever horizon is most restrictive to water movement (e.g., rock or horizon with the most clay).



Note: OC and clay values indicated on this chart are general guidelines not rules.

SURFACE RUNOFF

- Use surface hydraulic conductivity and % slope to read chart below
- If there is good vegetation cover or an O horizon at the surface, select the next lower class to the one determined from the chart

Slope %	Saturated Hydraulic Conductivity Class					
	Very High	High	Moderately High	Moderately Low	Low	Very Low
< 2%	Negligible	Negligible	Negligible	Low	Medium	High
2 - 5%	Negligible	Very Low	Low	Medium	High	Very High
5 - 9%	Very Low	Low	Medium	High	Very High	Very High
9 - 18%	Very Low	Low	Medium	High	Very High	Very High
> 18%	Low	Medium	High	Very High	Very High	Very High

SITE INTERPRETATIONS

For each: determine suitability based on whichever criteria that places it in the most restrictive class.

1. Septic tank absorption fields

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
Hydraulic Conductivity of the most limiting layer (60 – 180 cm)	Moderately High, Moderately Low	---	Very High, High, Low, or Very Low
Wetness Class	1	2	3, 4, 5
Average Rocks > 7.5 cm diameter (60 – 180 cm)	< 15%	15 – 35%	> 35%
Depth to Bedrock	> 180 cm	100 – 180 cm	< 100 cm
Slope	< 9%	9 – 14%	> 14%
Flooding/Ponding	None	---	Any

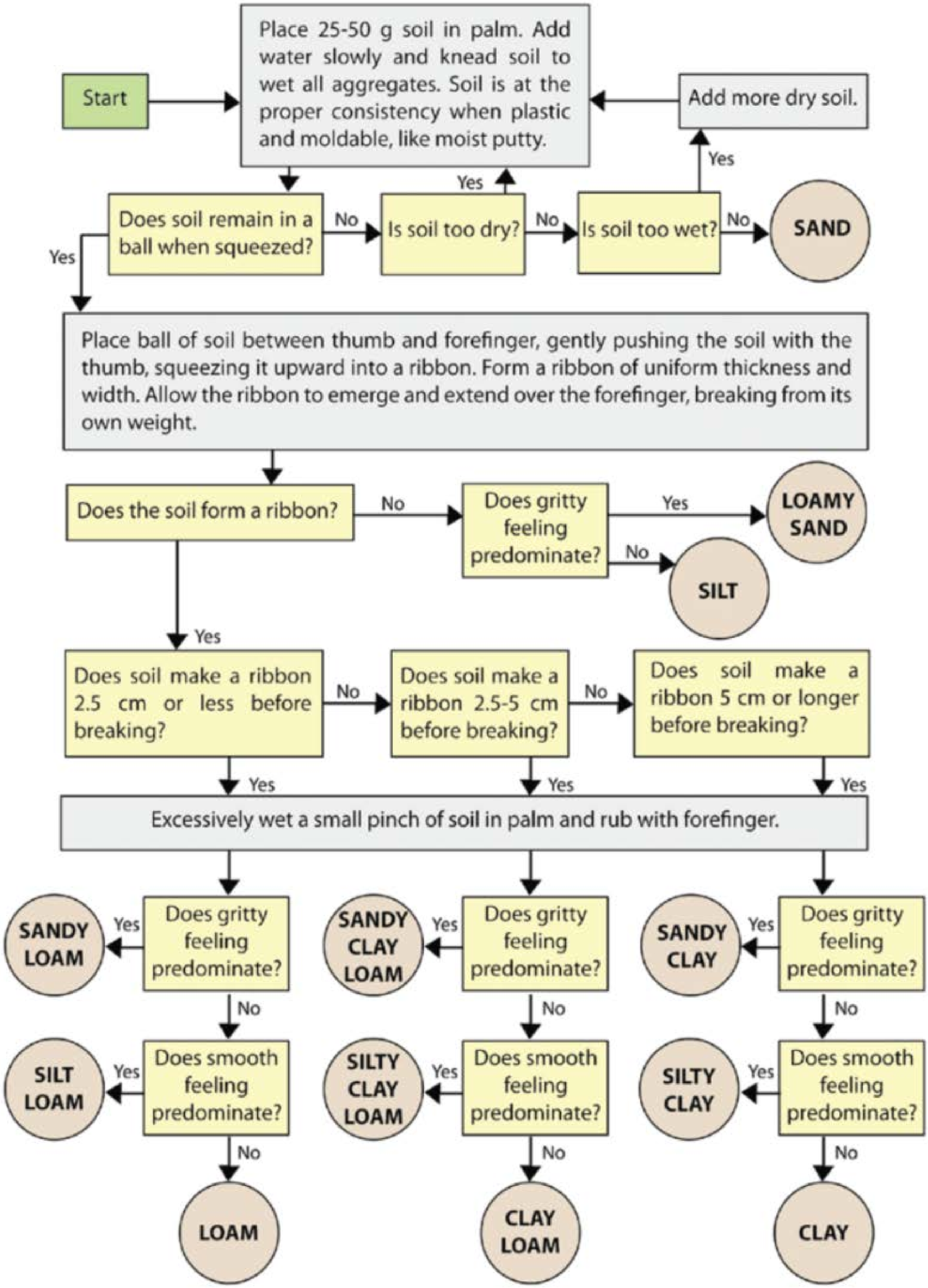
2. Local roads and streets

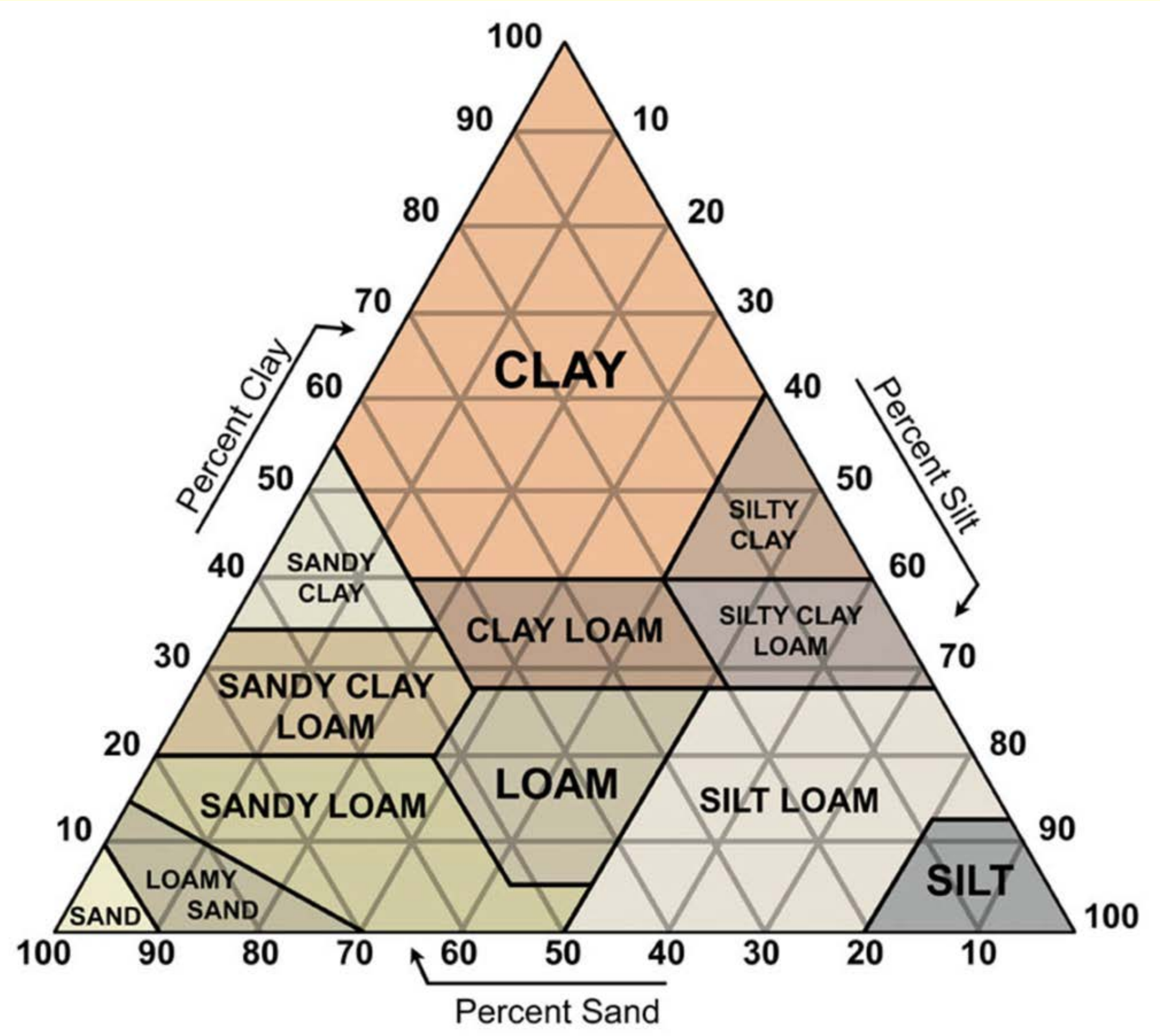
Criteria	Limitations		
	Slight	**Moderate**	**Severe**
Texture of the most limiting horizon (25 – 100 cm)	S, LS, SL	L, SCL	SI, SIL, SICL, SIC, CL, SC, C
Average Rocks > 7.5 cm diameter (60 – 180 cm)	< 25%	25 – 50%	> 50%
Wetness Class	1, 2	3, 4	5
Depth to Hard Bedrock (R)	> 100 cm	50 – 100 cm	< 50 cm
Depth to Soft Bedrock (Cr)	> 50 cm	< 50 cm	---
Slope	< 9%	9 – 14%	> 14%
Flooding/Ponding	None	Rare	Occasional or More

3. Dwellings with basements

Criteria	Limitations		
	Slight	**Moderate**	**Severe**
Texture of the most limiting horizon (25 – 100 cm)	S, LS, SL	L, SCL	SI, SIL, SICL, SIC, CL, SC, C
Average Rocks > 7.5 cm diameter (60 – 180 cm)	< 15%	15 – 35%	> 35%
Wetness Class	1, 2	3	4, 5
Depth to Hard Bedrock (R)	> 100 cm	50 – 100 cm	< 50 cm
Depth to Soft Bedrock (Cr)	> 50 cm	< 50 cm	---
Slope	< 9%	9 – 14%	> 14%
Flooding/Ponding	None	Rare	Occasional or More

Procedure for Analyzing Soil Texture by Feel

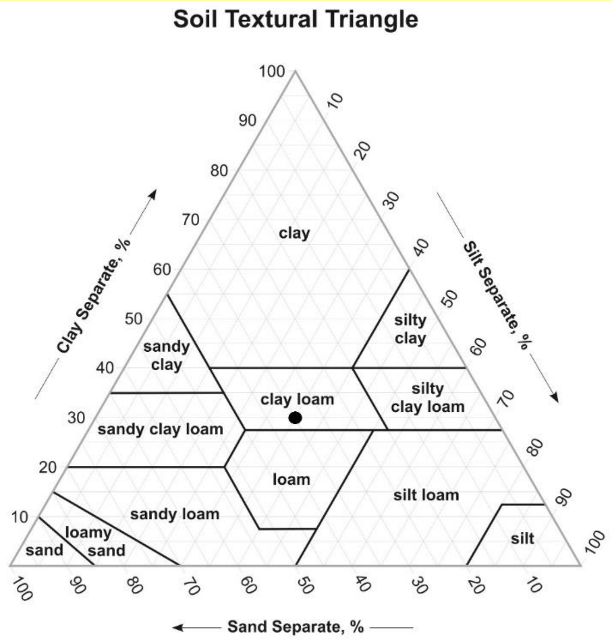




CLAY
SILTY CLAY
SANDY CLAY
CLAY LOAM
SILTY CLAY LOAM
SANDY CLAY LOAM
LOAM
SILT LOAM
SANDY LOAM
SILT
LOAMY SAND
SAND
Percent Clay
Percent Silt
Percent Sand
100
90
80
70
60
50
40
30
20
10

Correlation of Field Texturing Soils by Feel, Understanding Soil Laboratory Data, and Use of the Soil Textural Triangle

Example #1. You are given a soil texture sample that forms a ribbon that is 3 to 6.99 cm long that feels neither gritty nor smooth. When you follow the "Guide to Texture by Feel" flowchart you end up with Clay Loam. Clay loam is found on the Soil Textural Triangle below (black dot):



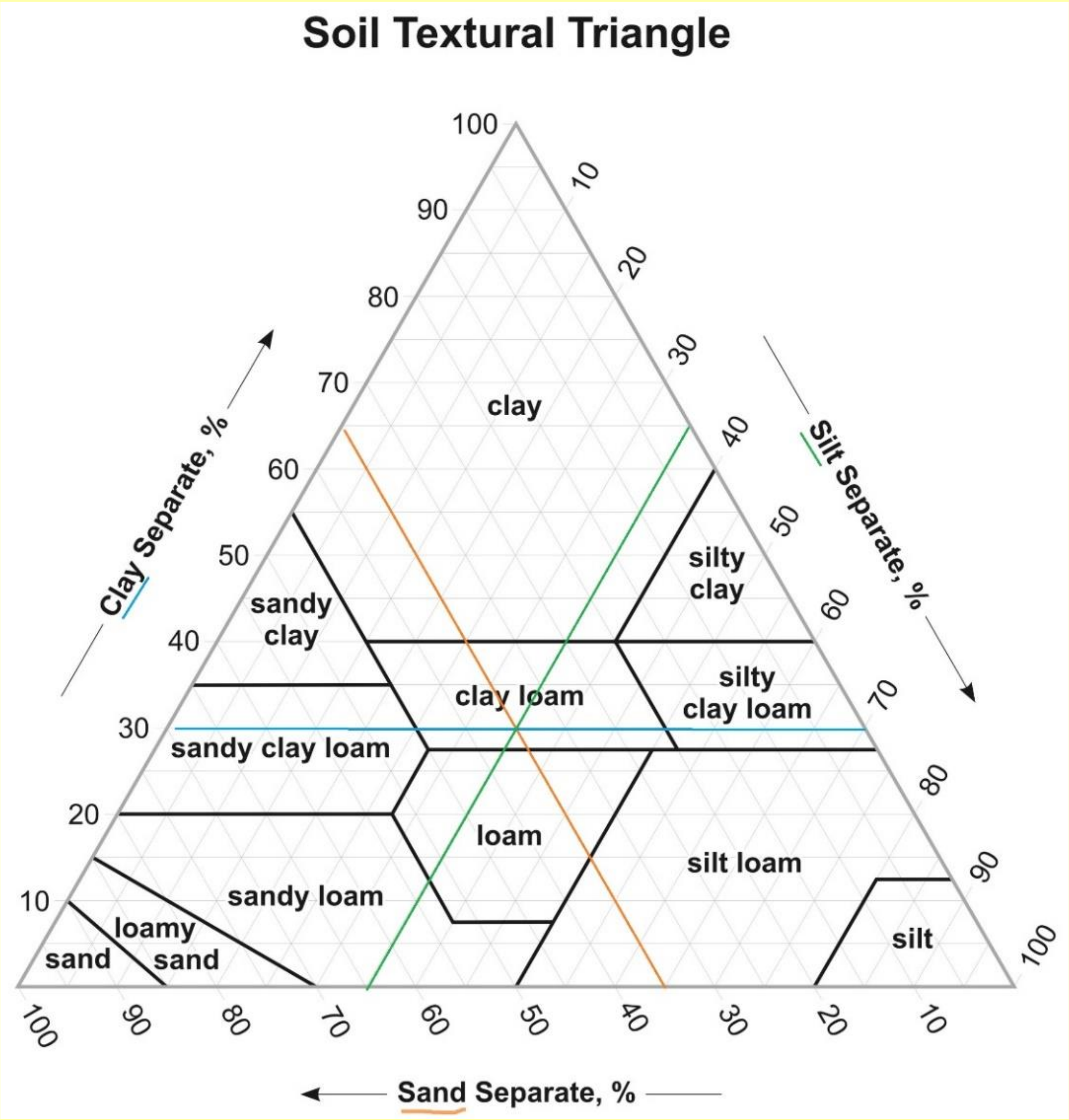
Example #2. You sent the soil sample above in for particle size analysis, it came back with 35% Sand, 35% Silt, and 30% Clay. These percentages of the soil separates always add up to 100%. To plot this information, we locate the intersection of three lines on the triangle.

Sand Separate percentage is chosen from the bottom of the triangle and follows the orange line.

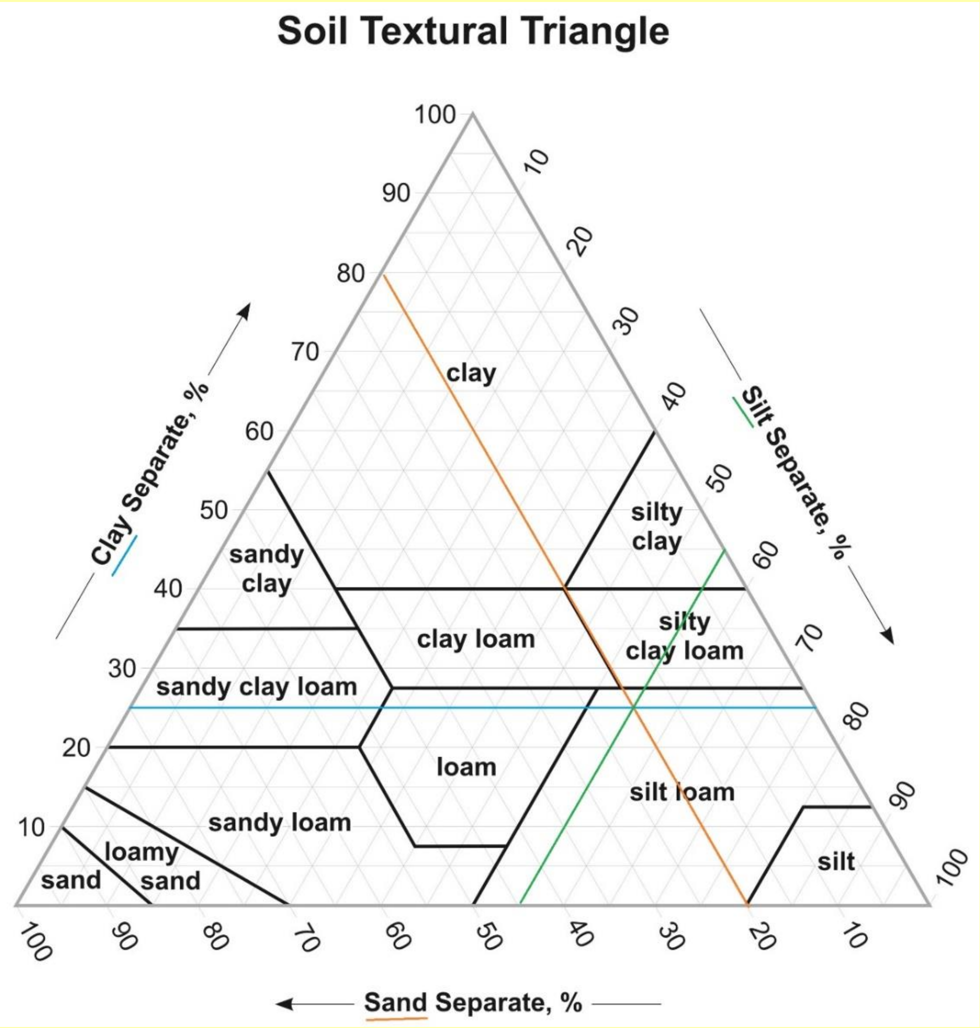
Silt Separate percentage is chosen from the upper right part of the triangle and follows the green line.

Clay Separate percentage is chosen from the upper left part of the triangle and runs horizontally following the blue line.

The intersection of these lines within the triangle will fall within one of the soil texture regions.



Example #3. You are given a soil textural triangle where the data is already plotted; what is the percentage of sand, silt, and clay?

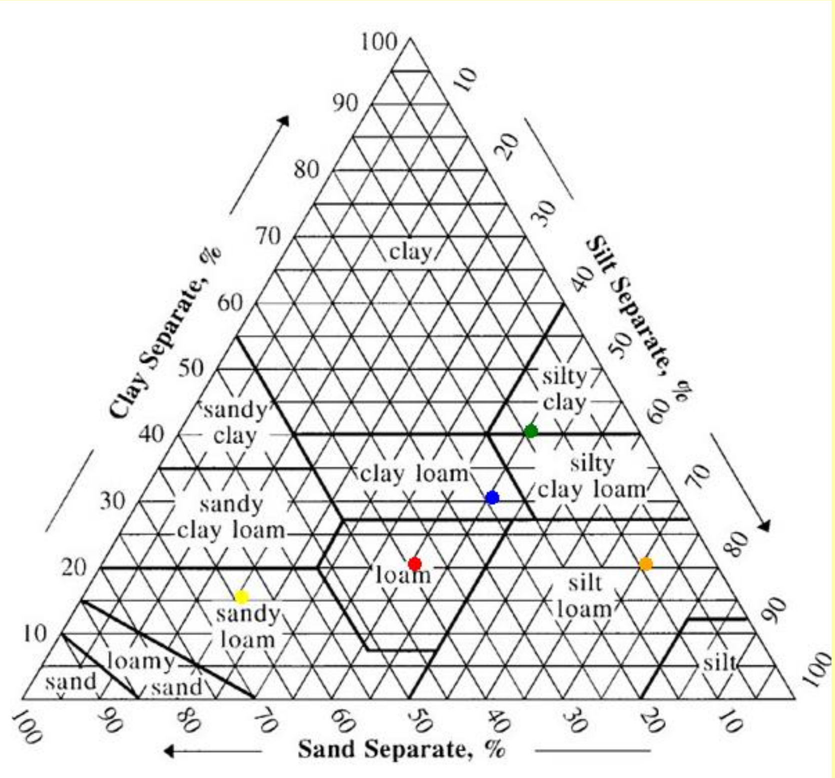


You should get 20% sand, 55% silt, and 25% clay.

Example #4. Lab results from soil samples from each horizon in a soil profile. Use the % of soil separates to find the soil texture for each horizon.

Depth cm	Texture	% Clay	% Silt	% Sand	Total	Rock Fragment >2mm	
0-20		20	40	40	100	0	RED
20-40		30	45	25	100	0	BLUE
40-60		15	20	65	100	0	YELLOW
60-80		40	45	15	100	0	GREEN
80-150		20	70	10	100	0	ORANGE

The lab data plotted on the textural triangle.



Depth cm	Texture	% Clay	% Silt	% Sand	Total	Rock Fragment >2mm
0-20	L	20	40	40	100	0
20-40	CL	30	45	25	100	0
40-60	SL	15	20	65	100	0
60-80	SIC	40	45	15	100	0
80-150	SIL	20	70	10	100	0

Tips for Measuring Percent Slope on Contour Maps

Excerpt from Forest Measurements by Joan DeYoung, 2018

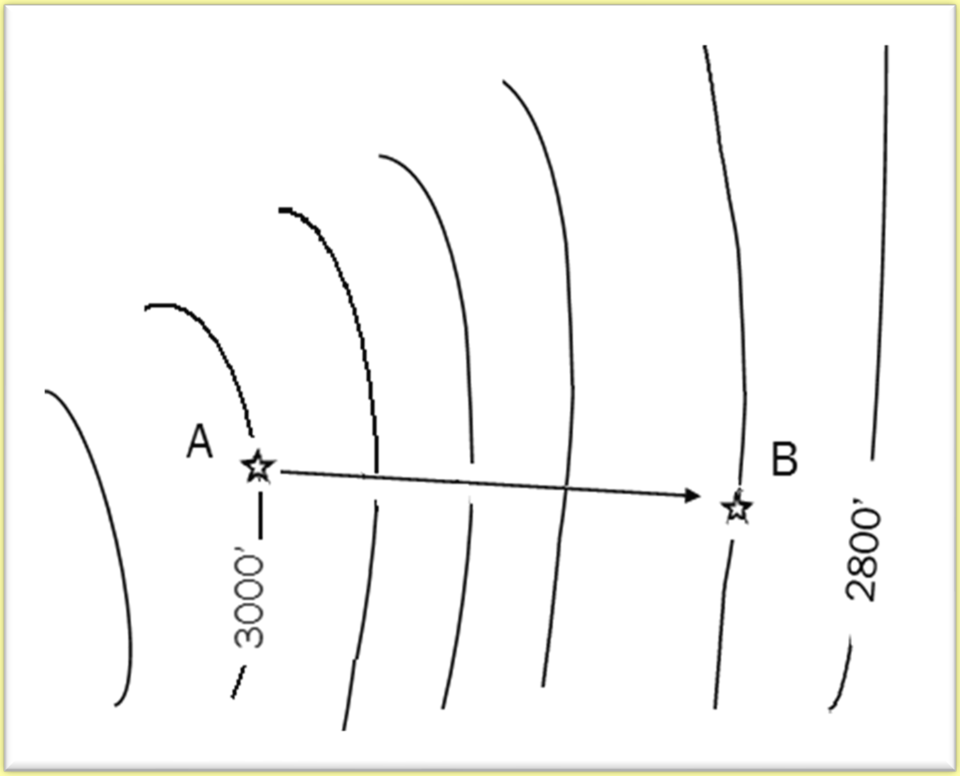
To calculate %slope of the land from contour maps, one still needs to determine the rise and run. On a map, the rise is the difference in elevation between two points. The run is the horizontal distance between two points. Map distance is always horizontal distance.

The rise is the difference in elevation between two points. Using the elevations printed on the map and the contour line interval, an elevation can be determined for the top and bottom of the slope in question. It generally works better to simply determine the elevation at each point and subtract rather than count the contour lines between two points. Doing the latter often results in rounding errors or double counting a contour line, which can throw slope readings off by 10 percent or more.

To determine the run, the map distance is measured between the two points and converted to the same units as the elevation. If difference in elevation is measured in feet, distance should also be calculated in feet. If difference in elevation is measured in meters, distance should also be calculated in meters.

Example:

An excerpt from a contour map is shown below. To determine the %slope from Point A to Point B, the rise and run must first be determined.



Rise:

If the map has 40-foot contour intervals, then Point A is located at 3,000 feet, and Point B is located at 2,840 feet. Therefore:

Rise = change in elevation = top (Point A elevation) minus bottom (Point B elevation):   3000' – 2840' = 160 feet

Run:

If the map scale is 1 inch = 500 feet, then the run is calculated as follows:

The map distanced measured 1.8 inches with an engineer's scale.

$$(1.8 \text{ in.})\left(\frac{500 \text{ ft.}}{\text{in}}\right) = 900 \text{ feet}$$

Percent Slope:

$$\left(\frac{rise}{run}\right)(100) = \%\text{slope}$$

$$\left(\frac{160}{900}\right)(100) \approx 18\%$$

From Point A to Point B, the slope is –18% (downhill); from B to A the slope is +18% (uphill).

Glossary

Parent Materials

alluvium - Unconsolidated, clastic material subaerially deposited by running water (channel flow), including gravel, sand, silt, clay, and various mixtures of these. Compare - colluvium. HP
ash [volcanic] - Unconsolidated, pyroclastic material less than 2 mm in all dimensions. Commonly called "volcanic ash”. SW & KST
bedrock - A general term for the solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface. Compare residuum. GG
colluvium - Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g. direct gravitational action) and by local, unconcentrated runoff. HP
eolian - Pertaining to material transported and deposited (eolian deposit) by the wind. Includes clastic materials such as dune sands, sand sheets, loess deposits, and clay. HP
eolian sands [soil survey] - Sand-sized, clastic material transported and deposited primarily by wind, commonly in the form of a dune or a sand sheet. SW
loess - Material transported and deposited by wind and consisting predominantly of silt-size particles. Commonly a loess deposit thins and the mean particle size decreases as distance from the source area increases. Loess sources are dominantly from either glacial meltwaters (i.e. “cold loess”) or from non-glacial, arid environments, such as deserts (i.e. ”hot loess”). [soil survey] Several types of loess deposits can be recognized based on mineralogical composition (calcareous loess, non-calcareous loess). SW & GSST
residuum - (residual soil material) Unconsolidated, weathered, or partly weathered mineral material that accumulates by disintegration of bedrock in place. HP
till [glacial] - Dominantly unsorted and unstratified drift, generally unconsolidated and deposited directly by a glacier without subsequent reworking by meltwater, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders; rock fragments of various lithologies are imbedded within a finer matrix that can range from clay to sandy loam. SW & GG

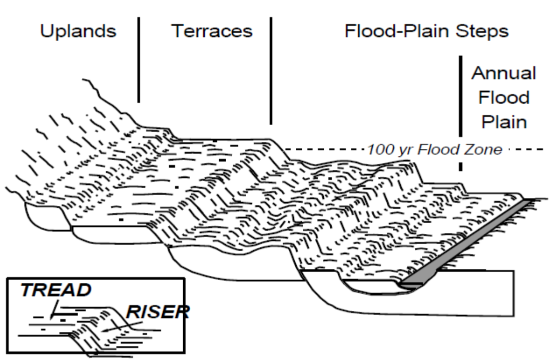
Landforms

alluvial fan - A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream (best expressed in semiarid regions) at the place where it issues from a narrow mountain or upland valley; or where a tributary stream is near or at its junction with the main stream. It is steepest near its apex which points upstream and slopes gently and convexly outward (downstream) with a gradual decrease in gradient. Compare –sideslope. GG
channel - (a) [stream] The hollow bed where a natural body of surface water flows or may flow. The deepest or central part of the bed of a stream, containing the main current and occupied more or less continuously by water. (b) (colloquial: western U.S.A.) The bed of a single or braided watercourse that commonly is barren of vegetation and is formed of modern alluvium. Channels may be enclosed by banks or splayed across and slightly mounded above a fan surface and include bars and mounds of cobbles and stones. (c) [Microfeature] Small, trough-like, arcuate or sinuous channels separated by small bars or ridges, caused by fluvial processes; common to flood plains and young alluvial terraces; a constituent part of *bar and channel* topography. GG, FFP, & SW.
flood plain - The nearly level plain that borders a stream and is subject to inundation under flood-stage conditions unless protected artificially. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams. HP
flood-plain step - An essentially flat, terrace-like alluvial surface within a valley that is frequently covered by flood water from the present stream (e.g., below the 100 year flood level); any approximately horizontal surface still actively modified by fluvial scour and/or deposition (i.e., cut and fill and/or scour and fill processes). May occur individually or as a series of steps. Compare – stream terrace. SW & RR
interdune - The relatively flat surface, whether sand-free or sand-covered, between dunes. GG
plain - A general term referring to any broad, flat, lowland area, large or small, of low relief. Specifically, any extensive region of comparatively smooth and level to gently undulating land. A plain has few or no prominent hills or valleys but sometimes has considerable slope, and usually occurs at low elevation relative to surrounding areas.

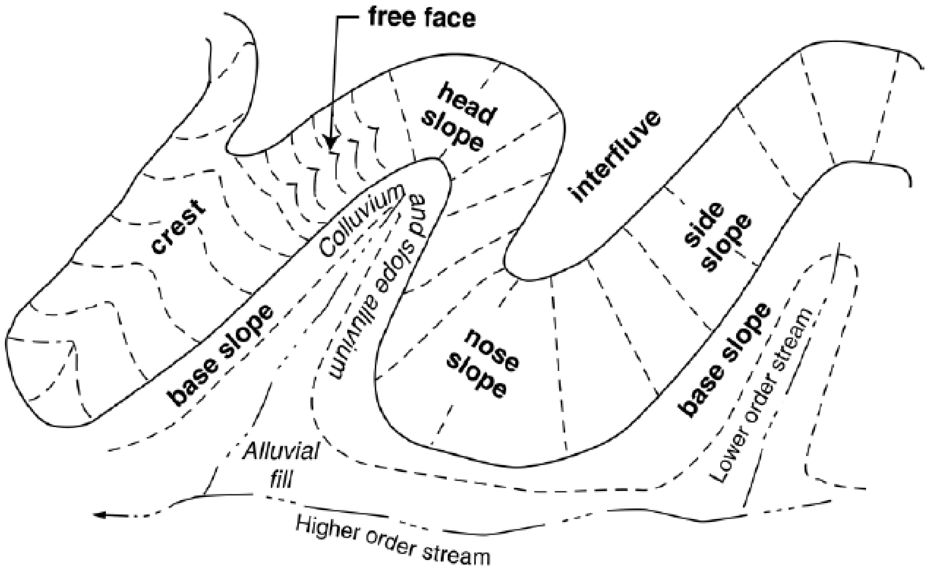
Where dissected, remnants of a plain can form the local uplands. A plain may be forested, cropped, grasslands or barren and may be formed by deposition or erosion. Compare - lowland, plateau. SW & GG
playa - The usually dry and nearly level lake plain that occupies the lowest parts of closed depressions, such as those occurring on intermontane basin floors. Temporary ponding occurs primarily in response to precipitation-runoff events. Playa deposits are fine grained and may or may not have high water table and saline conditions. HP
riser [geomorphology] **-** A geomorphic component of terraces**,** flood-plain steps, and other stepped landforms consisting of the vertical or steep side slope (e.g. escarpment) typically of minimal aerial extent. Commonly a recurring part of a series of natural, step-like landforms such as successive stream terraces. Characteristic shape and alluvial sediment composition are derived from the cut and fill processes of a fluvial system. Compare - tread. SW
sand sheet - A large, irregularly shaped, commonly thin, surficial mantle of eolian sand, lacking the discernible slip faces that are common on dunes. GG
sandhills - A region of semi-stabilized sand dunes or sandy hills, either covered with vegetation or bare, as in north-central Nebraska and the midlands of the Carolinas. GG
stream terrace - One, or a stepped series of flattopped landforms of alluvium in a stream valley, that flank and are parallel to the stream channel. Originally formed by a previous stream level, and representing the remnants of an abandoned flood plain, stream bed, or valley floor produced during a past state of fluvial erosion or deposition (i.e., currently very rarely or never flooded; inactive cut and fill and/or scour and fill processes). Erosional surfaces cut into bedrock and thinly mantled with stream deposits (alluvium) are called "strath terraces." Remnants of constructional valley floors thickly mantled with alluvium are called alluvial terraces. Compare - alluvial terrace. HP & SW
tableland - A general term for a broad upland mass with nearly level or undulating summit area of large extent and steep side slopes descending to surrounding lowlands (e.g. a large plateau) or broad, dominantly planar upland plains bounded **or** dissected by large streams or rivers. Compare - plateau, mesa, cuesta. SW & HP
terrace [geomorphology] - A step-like surface, bordering a valley floor or shoreline, that represents the former position of a flood plain, or lake or sea shore. The term is usually applied to both the relatively flat summit surface (tread), cut or built by stream or wave action, and the steeper descending slope (scarp, riser), graded to a lower base level of erosion. Compare - stream terrace, flood-plain step. HP.
till plain – An extensive, flat to gently undulating area underlain predominantly by till and bounded on the distal end by subordinate recessional or end moraines. SW
tread [geomorphology] - A geomorphic component of terraces, flood-plain steps, and other stepped landforms consisting of the flat to gently sloping, topmost and laterally extensive slope. Commonly a recurring part of a series of natural, step-like landforms such as successive stream terraces. It's characteristic shape and alluvial sediment composition is derived from the cut and fill processes of a fluvial system. Compare - riser. SW
upland [geomorphology] - An informal, general term for (a) the higher ground of a region, in contrast with a low-lying, adjacent land such as a valley or plain. (b) Land at a higher elevation than the flood plain or low stream terrace; land above the footslope zone of the hillslope continuum. HP& GG
valley - An elongate, relatively large, externally drained depression of the Earth's surface that is primarily developed by stream erosion or glacial activity. HP

2) TERRACES, STEPPED LANDFORMS :

	Code (*conventional*)	(*NASIS*)
riser	*riser*	*RI*
tread	*tread*	*TR*



Geomorphic

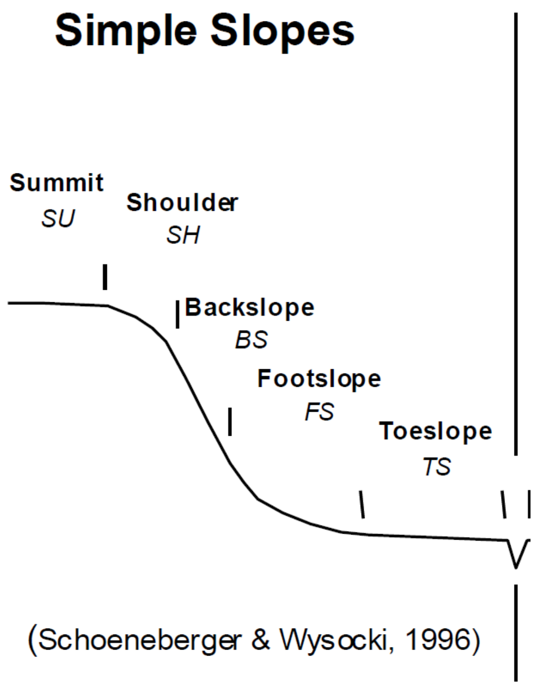


(adapted from Wysocki, et al., 1999)

base slope [geomorphology] - A geomorphic component of hills consisting of the concave to linear slope (perpendicular to the contour) which, regardless of the lateral shape is an area that forms an apron or wedge at the bottom of a hillside dominated by colluvial and slope wash processes and sediments Compare - head slope, side slope, nose slope, interfluve, free face. SW
crest [geomorphology] – A geomorphic component of hills consisting of the convex slopes (perpendicular to the contour) that form the narrow, roughly linear top area of a hill, ridge, or other upland where shoulders have converged to the extent that little or no summit remains; dominated by erosion, slope wash and mass movement processes and sediments (e.g., slope alluvium, creep). Commonly, soils on crests are more similar to those on side slopes than to soils on adjacent interfluves. Compare – interfluve, head slope, side slope, nose slope. SW
divide - A summit area or tract of high ground which can vary from broad to narrow, or a line of separation that constitutes a watershed boundary between two adjacent drainage basins; a divide separates the surface waters that flow naturally in one direction from those that flow in a different or opposite direction. Compare - interfluve GG
free face [geomorphology] – A geomorphic component of hills and mountains consisting of an outcrop of bare rock that sheds rock fragments and other sediments to, and commonly stands more steeply than the angle of repose of, the colluvial slope immediately below; most commonly found on shoulder and backslope positions, and can comprise part or all of a nose slope or side slope. Compare – interfluve, crest, nose slope, side slope, head slope, base slope. SW
head slope [geomorphology] - A geomorphic component of hills consisting of a laterally concave area of a hillside, especially at the head of a drainageway, resulting in converging overland water flow (e.g. sheet wash); head slopes are dominated by colluvium and slope wash sediments (e.g., slope alluvium); contour lines form concave curves. Slope complexity (downslope shape) can range from simple to complex. Headslopes are comparatively moister portions of hillslopes and tend to accumulate sediments (e.g., cumulic profiles) where they are not directly contributing materials to channel flow. Compare - side slope, nose slope, free face, interfluve, crest, base slope. SW.
interfluve [geomorphology] - A geomorphic component of hills consisting of the uppermost, comparatively level or gently sloped area of a hill; shoulders of backwearing hillslopes can narrow the upland (e.g., ridge) or merge (e.g., crest, saddle) resulting in a strongly convex shape. Compare – crest, side slope, head slope, nose slope, free face, base slope. SW
nose slope [geomorphology] - A geomorphic component of hills consisting of the projecting end (laterally convex area) of a hillside, resulting in predominantly divergent overland water flow (e.g., sheet wash); contour lines generally form convex curves. Nose slopes are dominated by colluvium and slope wash sediments (e.g., slope alluvium). Slope complexity (downslope shape) can range from simple to complex. Nose slopes are comparatively

drier portions of hillslopes and tend to have thinner colluvial sediments and profiles. Compare - head slope, side slope, free face, interfluve, crest, base slope. SW
side slope [geomorphology] - A geomorphic component of hills consisting of a laterally planar area of a hillside, resulting in predominantly parallel overland water flow (e.g., sheet wash); contour lines generally form straight lines. Side slopes are dominated by colluvium and slope wash sediments. Slope complexity (downslope shape) can range from simple to complex. Compare - head slope, nose slope, free face, interfluve, crest, base slope. SW; The slope bounding a drainageway and lying between the drainageway and the adjacent interfluve. It is generally linear along the slope width. RR

Hillslope



backslope - The hillslope profile position that forms the steepest and generally linear, middle portion of the slope. In profile, backslopes are commonly bounded by a convex shoulder above and a concave footslope below. They may or may not include cliff segments (i.e. free faces). Backslopes are commonly erosional forms produced by mass movement, colluvial action, and running water. Compare - summit, shoulder, footslope, toeslope. GSST&
footslope - The hillslope profile position that forms the concave surface at the base of a hillslope. It is a transition zone between upslope sites of erosion and transport (shoulder, backslope) and downslope sites of deposition (toeslope). Compare - summit, shoulder, backslope, and toeslope. SW
shoulder - The hillslope profile position that forms the convex, erosional surface near the top of a hillslope. If present, it comprises the transition zone from summit to backslope. Compare - summit, crest, backslope, footslope, and toeslope. SW & HP
summit - (a) The topographically highest position of a hillslope profile with a nearly level (planar or only slightly convex) surface. Compare - shoulder, backslope, footslope, and toeslope, crest. (b) A general term for the top, or highest area of a landform such as a hill, mountain, or tableland. It usually refers to a high interfluve area of relatively gentle slope that is flanked by steeper slopes, e.g., mountain fronts or tableland escarpments. HP
toeslope - The hillslope position that forms the gently inclined surface at the base of a hillslope. Toeslopes in profile are commonly gentle and linear, and are constructional surfaces forming the lower part of a hill-slope continuum that grades to valley or closed-depression floors. Compare - summit, shoulder, backslope, footslope, valley floor. HP

2021 NCF-Envirothon Nebraska
Soils and Land Use Study Resources

Key Topic #3: Soil Surveys and Interpretations

8. Interpret published and on-line soil survey reports and use that information.
9. Have the skill to start WebSoilSurvey, create and area of interest, create a soil map, generate soil interpretations and reports.
10. Make land use management decisions based on information obtained from a soil survey.

Study Resources

Getting Started with Web Soil Survey – *USDA NRCS, 2021* (Page 63-66)

Study Resources begin on the next page! ➡

Introduction to Soils

What is soil? (less technical)

Soil is a naturally occurring mixture of mineral and organic ingredients with a definite form, structure, and composition. The exact composition of soil changes from one location to another. The following is the average composition by volume of the major soil ingredients:

- 45% Minerals (clay, silt, sand, gravel, stones).
- 25% Water (the amount varies depending upon precipitation and the water- holding capacity of the soil).
- 25% Air (an essential ingredient for living organisms).
- 5% Organic matter or humus (both living and dead organisms).

A soil is composed primarily of minerals which are produced from parent material that is weathered or broken into small pieces. Beyond occasional stones, gravel, and other rock debris, most of the mineral particles are called sand, silt, or clay. These mineral particles give soil texture. Sand particles range in diameter from 2 mm to 0.05 mm, are easily seen with the unaided eye, and feel gritty. [One millimeter (mm) is about the thickness of a dime.] Silt particles are between 0.05 mm and 0.002 mm and feel like flour. Clay particles are smaller than 0.002 mm and cannot be seen with the unaided eye. Clay particles are the most reactive mineral ingredient in the soil. Wet clay usually feels sticky.

Water and air occupy the pore spaces—the area between the mineral particles. In these small spaces, water and air are available for use by plants. These small pore spaces are essential to the life of soil organisms, to soil productivity, and to plant growth.

The final ingredient of a soil is organic matter. It is comprised of dead plant and animal material and the billions of living organisms that inhabit the soil.

(From "Conserving Soil," NRCS)

What is soil? (more technical)

Soil is a natural body which consists of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: (1) horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or (2) the ability to support rooted plants in a natural environment. The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose.

Areas are not considered to have soil if the surface is permanently covered by water too deep (typically more than 2.5 meters) for the growth of rooted plants. The lower boundary that separates soil from the nonsoil underneath is most difficult to define. Soil consists of horizons near the earth's surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. For purposes of classification, the lower boundary of soil is arbitrarily set at 2 meters.

(From "Soil Taxonomy," second edition, 1999)

What are soil horizons?

Soils are deposited in or developed into layers. These layers, called horizons, can be seen where roads have been cut through hills, where streams have scoured through valleys, or in other areas where the soil is exposed.

Where soil-forming factors are favorable, five or six master horizons may be in a mineral soil profile. Each master horizon is subdivided into specific layers that have a unique identity. The thickness of each layer varies with location. Under disturbed conditions, such as intensive agriculture, or where erosion is severe, not all horizons will be present. Young soils have fewer major horizons.

The uppermost layer generally is an organic horizon, or O horizon. It consists of fresh and decaying plant residue from such sources as leaves, needles, twigs, moss, lichens, and other organic material accumulations. Some organic materials were deposited under water. The subdivisions Oa, Oe, and Oi are used to identify levels of decomposition. The O horizon is dark because decomposition is producing humus.

Below the O horizon is the A horizon. The A horizon is mainly mineral material. It is generally darker than the lower horizons because of the varying amounts of humified organic matter. This horizon is where most root activity occurs and is usually the most productive layer of soil. It may be referred to as a surface layer in a soil survey. An A horizon that has been buried beneath more recent deposits is designated as Ab.

The E horizon generally is bleached or whitish in appearance. As water moves down through this horizon, soluble minerals and nutrients dissolve and some dissolved materials are washed (leached) out. The main feature of this horizon is the loss of silicate clay, iron, aluminum, humus, or some combination of these, leaving a concentration of sand and silt particles.

Below the A or E horizon is the B horizon, or subsoil. The B horizon is usually lighter colored, denser, and lower in organic matter than the A horizon. It commonly is the zone where leached materials accumulate. The B horizon is further defined by the materials that make up the accumulation, such as the letter t in the designation Bt, which identifies that clay has accumulated. Other illuvial concentrations or accumulations include iron, aluminum, humus, carbonates, gypsum, or silica. Soil not having recognizable concentrations within B horizons but showing a color or structural difference from adjacent horizons is designated Bw.

Still deeper is the C horizon or substratum. The C horizon may consist of less clay, or other less weathered sediments. Partially disintegrated parent material and mineral particles are in this horizon. Some soils have a soft bedrock horizon that is given the designation Cr. C horizons described as 2C consist of different material, usually of an older age than horizons which overlie it.

The lowest horizon, the R horizon, is bedrock. Bedrock can be within a few inches of the surface or many feet below the surface. Where bedrock is very deep and below normal depths of observation, an R horizon is not described.

What is a soil survey?

One of the main tools available to help land users determine the potentials and limitations of soils is a soil survey. Soil surveys are available through the USDA, Natural Resources Conservation Service (NRCS). The surveys are made by NRCS in cooperation with other Federal, State, and local agencies. Our offices can provide this information, but more and more soil surveys are also available on the Internet. Web Soil Survey allows you to produce a customized soil survey for your own area of interest.

A soil survey generally contains soils data for one county, parish, or other geographic area, such as a major land resource area. During a soil survey, soil scientists walk over the landscapes, bore holes with soil augers, and examine cross sections of soil profiles. They determine the texture, color, structure, and reaction of the soil and the relationship and thickness of the different soil horizons. Some soils are sampled and tested at soil survey laboratories for certain soil property determinations, such as cation-exchange capacity and bulk density.

Like any tool, a soil survey is helpful only if you know what it can and can't do, and if you use it accordingly. The survey does not replace careful onsite investigation or analysis by a soil scientist

(Found in "From the Surface Down," NRCS)

Who uses a soil survey?

Soil surveys available from the Natural Resources Conservation Service are intended for many different users. They can help homebuyers or developers determine soil-related hazards or limitations that affect homesites. They can help land use planners determine the suitability of areas for housing or onsite sewage disposal systems. They can help farmers estimate the potential crop or forage production of his land. They can be used to determine the suitability and limitations of soils for pipelines, buildings, landfills, recreation areas, and many other uses.

Many people assume that soils are all more or less alike. They are unaware that great differences in soil properties can occur within even short distances. Soils may be seasonally wet or subject to flooding. They may be shallow to bedrock. They may be too unstable to be used as a foundation for buildings or roads. Very clayey or wet soils are poorly suited to septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

These soil properties and many others that affect land use are given in soil surveys. Each soil survey describes the properties of soils in the county or area surveyed and shows the location of each kind of soil on detailed maps.

What is a map unit?

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called non-contrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. The contrasting components are mentioned in the map unit descriptions. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

What is a consociation, complex, association, undifferentiated group, or miscellaneous area?

A ***consociation*** is a kind of map unit that consists of one major soil or miscellaneous area plus any components of minor extent. The major component is identified in the map unit name. "Consociation" is a coined term.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A ***complex*** consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas.

An ***association*** is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar.

An ***undifferentiated group*** is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them.

Miscellaneous areas have little or no soil material and support little or no vegetation.

What is an Official Series Description?

The Official Soil Series Descriptions (OSD) is a national collection of more than 20,000 detailed soil series descriptions, covering the United States, Territories, Commonwealths, and Island Nations served by USDA-NRCS. The descriptions, in a text format, serve as a national standard.

The soil series is the lowest category of the national soil classification system. The name of a soil series is the common reference term, used to name soil map units. Soil series are the most homogenous classes in the system of taxonomy. "Official Soil Series Descriptions" define specific soil series in the United States, Territories, Commonwealths, and Island Nations served by USDA-NRCS. They are descriptions of the taxa in the series category of the national system of soil classification. They serve mainly as specification for identifying and classifying soils. The descriptions contain soil properties that define the soil series, distinguish it from other soil series, serve as the basis for the placement of that soil series in the soil family, and provide a record of soil properties needed to prepare soil interpretations.

Farmers and Ranchers

As farmer or rancher you don't have time or capital to spend on elaborate agricultural research and experiments or on mapping and studying soils. But you are interested in the results of such studies if they can help you to manage more profitably.

Soil surveys contain detailed maps and descriptions of soils in your area. This information can contribute to the management of your farm or ranch. For specific sites and uses, an onsite investigation of the soils by a trained professional can determine if there are any soil hazards or limitations, and whether these can be overcome by corrective measures.

How soil surveys can help farmers

To stay in business, farmers have to evaluate important developments in agricultural management. A soil survey can play a major part in this aspect of managing a farm.

Management practices: Farm production depends largely on fitting soil management practices to the soil properties as accurately as possible. It is the right combination of a number of practices that gets optimum results.
Researchers try various combinations of fertilizers, tillage methods, water management, and conservation measures. Combinations that produce the greatest yields at the least cost on soils at experiment stations can be expected to give equally good results on similar soils elsewhere. Soil descriptions presented in the soil survey of your area can help you evaluate prospective changes in management of your soils.

New practices also are constantly on trial at state and other agricultural experiment stations. By comparing soils at such stations with those described in the soil survey of your area, you can estimate the likely success of new practices on your farm.

Special crops: You may want to know if new or special crops will work for you. The soil survey of your area describes soil properties that affect crop growth and provides information that could save you costly experiments in determining the best way to manage your land for unfamiliar crops.

Crop yields: Estimated yields of major crops under a high level of management are included in published soil surveys. The estimated yields can help you calculate approximately what returns to expect on your soils and determine whether a high level of management would increase yields enough to pay the extra cost.

Conservation plan: A soil survey can help you determine how intensively you can use your soils without damage. It also helps in determining what conservation measures are needed to control erosion and maintain or increase the productivity of your farm.

Reclaiming land: Some severely eroded soils respond readily to soil treatments, such as fertilizer, lime, and green manure, but other soils respond very poorly. A soil survey can help you decide whether added treatment to reclaim soils is likely to succeed.

Waste disposal: Feedlots, poultry and broiler plants, and dairy farms dispose of manure and other wastes into soils. A soil survey helps in determining how much waste the soils can absorb and in what form.

Recreation: A soil survey can help in selecting areas suitable for manmade ponds. It also can help in planning development of land for fee fishing, hunting, camping, and other recreation facilities used to supplement income.

How soil surveys can help ranchers

As a rancher, you want the greatest amount of high-quality forage from your range. Because forage yields depend in large part on soil properties, detailed knowledge of the soils on your ranch can help you manage your range more effectively.

Range potential: A soil survey provides detailed soil descriptions that can help you relate the kinds of soil on your ranch to the distinctive kind and amount of vegetation each soil can support. Soil texture, depth, wetness, available water, slope, and topographic position are among the important soil properties that affect range potential. Deep loamy soils on bottom lands may produce the most desirable range plants. On uplands where rainfall is moderate, medium-textured soils that take in water readily may produce desirable plants if grazing is controlled. In some dry areas sandy soils are more productive than clayey soils. Grouping the soils on your range according to their potential productivity helps you plan the kind of management needed to increase forage yields.

Range management: A soil survey can help you estimate the likely benefits of management practices. For example, the soil in an area of brush or mesquite may have such low potential productivity that the cost of chaining or chemical removal may not be worth the ultimate yield in forage. On the other hand, there may be rocky areas or hillsides where the soils are capable of producing more forage if properly managed. A soil survey can help you determine such natural differences in productivity.

Grazing management: If range is overgrazed, desirable plants decrease and less desirable plants may take over the site. A soil survey can help you identify soils that are producing at less than their potential. Each soil survey names the main species of desirable and undesirable range plants that grow on the soils and provide estimates of forage yields than can be expected under favorable and unfavorable conditions.

Pasture, hay, and silage: You may need to grow more winter feed or establish more pasture. A soil survey rates soil suitability for hay and pasture plants so that you can determine which areas will be most productive for this use.

Wildlife and recreation: To supplement income, many ranchers use their land for fee hunting or other kinds of recreation. A soil survey provides information that can help you manage your land for wildlife habitat or identify areas suitable for recreation development.

Conservation plan: A soil survey can help you plan conservation management of your range. Soil maps and soil descriptions help you identify problem areas, select suitable areas for stock ponds, and establish schedules for grazing and proper use of the soils on your range.

What soil data are available?

Soil surveys contain detailed maps and descriptions of soils and they provide interpretations of soil properties for farming and ranching where such land use is practiced. Among the soil properties that affect use of soils for farming and ranching are the content of sand, silt, and clay, acidity and alkalinity, flood hazard, depth to water table, natural drainage, erodibility, organic-matter content, and fertility. These and many other properties described in soil surveys provide basic information for managing soils on a farm or ranch.

To determine whether a soil survey of your area is available, call the local office of the Natural Resources Conservation Service. The soil conservationist or soil scientist will welcome an opportunity to discuss conservation management of your soils with you.

Cropland

Cropland is defined as a land cover or land use category that includes areas used for the production of adapted crops for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland is land that is used for either row crops or close-grown crops. Hayland or pastureland that is in a rotation with row crops or close-grown crops also is considered cultivated cropland. Noncultivated cropland includes permanent hayland and horticultural cropland.

Reference:
"2001 Annual NRI Glossary of Key Terms," National Resources Inventory, USDA, NRCS

Land capability classification

Determinations of land capability involve consideration of the risks of land damage from erosion and other causes and the difficulties in land use resulting from physical land characteristics and from climate. Land capability, as used in the USA, is an expression of the effect of physical land characteristics and climate on the suitability of soils for crops that require regular tillage, for grazing, for woodland, and for wildlife habitat.

Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The criteria used in grouping the soils do not include major and generally expensive landforming that would change slope, depth, or other characteristics of the soils, nor do they include possible but unlikely major reclamation projects.
Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, forestland, or engineering purposes.

In the capability system, soils are generally grouped at three levels: capability class, subclass, and unit.

Capability classes, the broadest groups, are designated by the numbers 1 through 8. Capability classes are determined for both irrigated and nonirrigated land. The numbers indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:
Class 1 soils have slight limitations that restrict their use.
Class 2 soils have moderate limitations that restrict the choice of plants or require moderate conservation practices.
Class 3 soils have severe limitations that restrict the choice of plants or require special conservation practices, or both.
Class 4 soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
Class 6 soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
Class 7 soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
Class 8 soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Capability subclasses are soil groups within one class. They are designated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, 2e. In class 1 there are no subclasses because the soils of this class have few limitations.
Class 5 contains only the subclasses indicated by *w*, *s*, or *c* because the soils in class 5 are subject to little or no erosion. These soils have other limitations that restrict their use to pasture, rangeland, forestland, wildlife habitat, or recreation. The significance of each subclass letter is described as follows:

Subclass letter e shows that the main problem is the hazard of erosion unless close-growing plant cover is maintained. The susceptibility to erosion and past erosion damage are the major soil-related factors affecting the soils that are assigned this subclass letter.

Subclass letter w shows that water in or on the soil interferes with plant growth or cultivation. In some soils the wetness can be partly corrected by artificial drainage. Ponding, a high water table, and/or flooding affect the soils that are assigned this subclass letter.

Subclass letter s shows that the soil has limitations within the root zone, such as shallowness of the root zone, a high content of stones, a low available water capacity, low fertility, and excessive salinity or sodicity. Overcoming these limitations is difficult.

Subclass letter c shows that the chief hazard or limitation is climate that is very cold or very dry. This subclass letter is used only in some parts of the United States.

Capability units are soil groups within a subclass. The soils in a capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, 2e-4 and 3e-6. The use of this category of the land capability classification is a state option. This category of the system is not stored in the soil survey database. For information about capability units, please contact the local NRCS State Soil Scientist. For locations of the offices of the State Soil Scientists, click on the State Contacts link in the upper portion of this window.

Reference:
"National Soil Survey Handbook," Part 622 (00-Exhibit 1), USDA, NRCS

Soil erosion and crop production

Soil erosion has long been considered detrimental to soil productivity. It is the basis for soil loss tolerance values. Considerable loss in productivity is likely to occur on most soils if they are eroded for several centuries at present soil loss tolerance levels. The cost of annual erosion-caused losses in productivity on cropland and pastureland in the United States approaches $27 billion. There is an additional cost of $17 billion for off-site environmental damage. Worldwide costs for erosion-caused losses and off-site environmental damage are estimated at $400 billion per year.

Soil erosion can significantly reduce crop yields, especially in years when weather conditions are unfavorable. As soil erosion continues, the soil is further degraded. Poor soil quality is reflected in decreases in the content of organic matter, aggregate stability, phosphorus levels, and the potential for providing plant-available water. The net result is a decrease in soil productivity.

Soil erosion occurs through either water or wind action. Erosion by water includes sheet, rill, ephemeral gully, classical gully, and streambank erosion. Each succeeding type is associated with the progressive concentration of runoff water into channels as it moves downslope.

Sheet erosion, sometimes referred to as "interrill erosion," is the detachment of soil particles by the impact of raindrops and the removal of thin layers of soil from the land surface by the action of rainfall and runoff.

Severe sheet and rill erosion on highly erodible soils in northwest Iowa after heavy rains. The

spring rains fell on the surface when the soils were not protected against erosion. (NRCS Photo Gallery NRCSIA99126)

Rill erosion is the formation of small, generally parallel channels caused by runoff water. It usually does not recur in the same place.

Rill erosion on highly erodible soils in Cass County, Iowa, after heavy rains. The field was not protected against erosion. (NRCS Photo Gallery NRCSIA99128)

Ephemeral gully erosion is the formation of shallow, concentrated flow channels in areas where rills converge. The channels are filled with soil by tillage and form again through subsequent runoff in the same general location.

A central Iowa field where ephemeral gully erosion has washed young corn plants from the ground and has removed topsoil and plant nutrients. (NRCS Photo Gallery NRCSIA99140)

Classical gully erosion is the formation of permanent, well defined, incised, concentrated flow channels in areas where rills converge. The gullies cannot be crossed by ordinary farm equipment.

Gully erosion caused by uncontrolled runoff in an area in Kansas. (NRCS Photo Gallery NRCSKS02008)

Streambank erosion is the removal of soil from streambanks by the direct action of streamflow. It typically occurs during periods of high streamflow.

The greatest deterrent to soil erosion by water is a vegetative cover, living or dead, on the surface. Supplemental erosion-control practices include contour farming, contour stripcropping, and terraces or diversions.

Wind erosion is generally the most common form of soil erosion on the Great Plains. Other major regions that are subject to damaging wind erosion are the Columbia River plains; some parts of the Southwest and the Colorado Basin; areas of muck and sandy soils in the Great Lakes region; and areas of sand on the Gulf, Pacific, and Atlantic seaboards. Wherever the soil surface is loose and dry, vegetation is sparse or does not occur, and the wind is sufficiently strong, wind erosion will occur unless erosion-control measures are applied.

Wind is an erosive agent. It detaches and transports soil particles, sorts the finer from the coarser particles, and deposits the particles unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yields. Abrasion by airborne soil particles damages plants and manmade structures. Drifting soil also causes extensive damage. Sand and dust in the air can harm animals, humans, and equipment.

A "black roller" moving across the plains, carrying soil blown from unprotected farmland during the Dust Bowl. (NRCS Photo Gallery NRCSDC01019)

References:
1957 Yearbook of Agriculture, USDA, NRCS. "National Agronomy Handbook," USDA, NRCS, 2002
Natural Resources Conservation Service Photo Gallery, USDA, NRCS "Soil Quality-Agronomy Technical Note 7," Soil Quality Institute, USDA, NRCS, 1998

Cropland management

Because of the impacts of both wind and water erosion on yields and soil quality, good cropland management is necessary to conserve and protect our soil, water, and air. Following is a discussion of several different kinds of cropland management practices. Generally, cropland management involves crop rotation, tillage or planting techniques, crop residue management, nutrient management, and pest management. Additional practices or treatments, where applicable, include irrigation water management (IWM), surface and subsurface water management, contour farming, buffer strips, filter strips, cover crops, cross wind strips, subsoiling, terraces and water- and sediment-control basins, and grassed waterways.

Crop rotation

How this practice works: A planned sequence of two or more different crops grown on the same land in successive years or seasons helps to replenish the soil; reduces the damaging effects of insects, weeds, and disease; and provides adequate feed for livestock. Crop rotations add diversity to an operation and often reduce economic and environmental risks. They are low-cost practices that often form the basis for other conservation practices. Crop rotations are common on sloping soils because of their potential for conserving soil. They can reduce the need for fertilizer when legumes, such as alfalfa or soybeans, replace some of the nitrogen that corn and other grain crops remove.

The major benefits of crop rotations include:

1. Reduced runoff and erosion
2. Increased content of organic matter
3. Improved soil tilth
4. Improved pest management
5. Better moisture efficiency
6. Higher yields
7. Improved esthetics and wildlife habitat

An effective crop rotation has three components:

1. The crop rotation must consist of two or more "unlike" crops planted on the same land in successive years or seasons, i.e., a corn-soybean rotation in which corn is planted on a field one year and soybeans planted in the same field the following year. In dryland situations, a crop rotation must have a subsequent crop of sufficient intensity to ensure maximum use of the effective precipitation.
2. The crop rotation must be diverse. Crop diversity promotes effective nutrient cycling and expanded disease- and weed-control strategies.
3. The crop rotation that has sufficient intensity and diversity must be managed properly. Proper management includes tillage and planting methods that reduce the extent of surface disturbance. It also includes dependence on cultural practices that minimize the need for costly technology.

How this practice helps:

Pest management: Crop rotations naturally reduce the incidence and severity of weeds, insects, and diseases in a cropping system, thereby reducing pesticide costs. When a different crop is grown each year, there is a different host crop that is usually not compatible with the pests that may have carried over from the previous year. As a result, different pest-management strategies can be used.

Erosion control: Rotations consisting of continuous row crops and excessive tillage have a higher potential for wind erosion or water erosion than rotations that include closely spaced row crops or perennial crops.

Surface residue: Surface residue is one of the most effective erosion-control measures available. If crops that produce high amounts of residue follow crops that produce low amounts of residue in the cropping sequence, higher levels of crop residue are maintained on the surface. Residue management practices, such as mulch tillage and no-till, can help to maximize the amount of crop residue on the surface during critical erosion periods.

Soil quality: Cropping sequences that include hay or pasture crops result in greater soil aggregate stability than rotations of continuous grain crops. Under all grain rotations, greater aggregate stability occurs with crops that produce higher amounts of residue. For example, a corn-soybean rotation results in greater organic carbon levels than a rotation of continuous soybeans.

Nutrient management: Rotations in which forage legumes or legume cover crops precede grain crops can reduce the need for nitrogen (N) fertilizer when the grain crops are grown.

Water management: Dryland rotations can take advantage of stored soil moisture by alternating shallow-rooted crops, such as winter wheat, and deep- rooted crops, such as safflowers.

Livestock feed production: For livestock operations, rotations that include hay and/or pasture can provide a major portion or, in some cases, all of the livestock forage and feed. Including hay or pasture in the rotation dramatically reduces the hazard of soil erosion and helps to protect water quality by keeping excess nutrients or chemicals from entering surface water.

Crop rotation (Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS)

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 "National Agronomy Handbook," USDA, NRCS, 2002

Crop residue management

Definition: Any tillage and planting system that uses no-till, ridge-till, mulch-till, or other systems designed to retain all or a portion of the previous crop's residue on the soil surface. The amount required depends on other conservation practices applied to the field and the farmer's objectives.

How this practice works: Leaving last year's crop residue on the surface before and during planting operations provides cover for the soil at a critical time of the year. The residue is left on the surface by reducing the number of tillage operations and the extent of tillage. Pieces of crop residue shield soil particles from rain and wind until plants can produce a protective canopy.

How this practice helps:

Soil temperature: Crop residue insulates the soil surface from the sun's energy. This insulation may be good or bad, depending on weather conditions at planting time. Cooler soil temperatures may delay planting and/or lead to poorer germination. Where cooler temperatures are a concern, planter attachments may be used to remove crop residue from the row area. Later in the growing season, the cooler soil temperature may improve crop growth and yields.

Allelopathy: This term refers to the toxic effects on a crop resulting from decaying residue from the same crop or a closely related crop. A proper crop rotation and use of planter attachments that remove the residue from the row area can eliminate this problem.

Moisture: When left on the soil surface, crop residue reduces the rate of water evaporation and increases the rate of water infiltration. Although it may be a disadvantage during planting in some areas, the extra soil moisture may increase yields if a dry period is encountered later in the growing season. Compared to conventional systems, no-till systems often result in more soil moisture later in the growing season and thus may increase yields.

Organic matter: Organic matter in soil tends to stabilize at a certain level for a specific tillage and cropping system. Each tillage pass aerates the soil, resulting in the breakdown of crop residue and organic matter. Crop residues left on the soil surface in no-till or ridge-till systems decompose slowly, thus increasing the content of organic matter in the upper few inches of the soil.

Soil density: All tillage systems have some effect on soil density. Systems that disturb the plow layer by inversion tillage or mixing and stirring temporarily decrease soil density. After the soil is loosened by tillage, however, the density gradually increases because of wetting and drying, wheel traffic, and secondary tillage operations. By harvest, the soil density has returned to almost the same density as before tillage operations started. Cropping systems that include several tillage operations can create a compacted layer at the bottom of the plow layer. If compaction is excessive, drainage is impeded, plant root growth is restricted, soil aeration is reduced, herbicide injury may increase, and nutrient uptake may be restricted. No-till systems result in a higher soil density at planting time than other systems because the plow layer is not disturbed when a seedbed is formed. This higher density seldom has any effect on germination, emergence, and subsequent crop growth. Many times, the crop benefits from the higher density because the soils retain more available moisture.

Stand establishment: Regardless of the tillage system, a uniform planting depth, good seed-to-soil contact, and proper seed coverage are needed for a good stand. Coulter and/or row cleaners may be needed to remove crop residue from the row area and thus ensure a good stand in areas where a no-till system is applied.

Fertilizer placement: Starter fertilizer (nitrogen and phosphorus) is generally recommended to help overcome the effects of lower soil temperatures at planting time. If fertility levels (P, K, and pH) are properly maintained before the tillage system is switched to a conservation tillage system, fertility should not be a problem. In a no-till system, surface application of phosphorus and lime will result in stratification of these nutrients, but this has not been shown to affect crop yields. For a no-till system, it is generally recommended that nitrogen be knifed into the soil or that a nitrogen stabilizer be used. Nitrogen that is applied on the surface may volatilize and be lost if a rain does not move the nitrogen into the soil profile shortly after application.

Weed control: Controlling weeds is essential for profitable production systems. With less tillage, herbicides and crop rotations become more important in obtaining adequate weed control. Weed identification, herbicide selection, application rates, and timing are important. A burn-down may be needed in no-till and ridge-till systems. A change in weed species can be expected in no-till and ridge-till systems. Perennials may become more evident but usually can be controlled with good management. The combination of post-applied herbicides and bioengineered crops has made weed control much easier, even in a no-till system.

Insect management: Regardless of the tillage system, effective insect- management guidelines and tactics are available. Different tillage systems may affect potential insect pressure, but management addresses this pressure.

Disease control: Crop residue on the soil surface can result in increased disease problems, but many disease-control strategies are available. Crop rotation or the selection of disease-resistant hybrids may nullify these potential problems.

Crop yields: Crop yields are more affected by weather than by the tillage system. Yields generally are higher when a crop rotation is used, especially in areas where a no-till system is applied.

Production costs: All of the costs associated with various tillage systems must be analyzed in an evaluation of profitability.

Machinery and labor costs: The total cost for machinery and labor per acre usually decreases as the amount of tillage is reduced. If the size of the power units can be decreased (in a no-till system), the savings can be even more dramatic. No-till equipment (planters, drills, and nutrient-injection equipment) may be more expensive than the conventional equipment. Because of increased efficiency, producers who use no-till systems have been able to farm more acres without additional labor than producers who use conventional tillage systems.

Large no-till planters used in Washington's Palouse region (Photo Gallery NRCSWA84002)

Ridge-till soybeans in corn residue (NRCS Photo Gallery NRCSIA99306)

"National Agronomy Handbook," USDA, NRCS, 2002
NRCS Photo Gallery, USDA, NRCS

Nutrient management

Definition: Management of the amount, source, placement, and form of plant nutrients and soil amendments applied to soils to obtain optimum yields and minimize the risk of surface- and ground-water pollution. This management also includes the timing of application.

Comprehensive Nutrient Management Plan (CNMP): A CNMP is a conservation plan that is unique to an animal-feeding operation (AFO). It is a group of conservation practices and management activities that, when implemented as part of a conservation system, will help to ensure that both production and natural resource protection goals are met. A CNMP incorporates practices that use animal manure and organic by-products as beneficial resources. It addresses the impacts that soil erosion, manure, and organic by- products may have on water quality. These impacts may derive from an AFO. A CNMP is developed to assist an AFO owner or operator in addressing all applicable local, tribal, State, and Federal water-quality goals or regulations. For nutrient-impaired stream segments or water bodies, additional management activities or conservation practices may be required to address these goals or regulations.

How this practice works: Soil samples are taken on a 2.5-acre grid and analyzed for nitrogen (N), phosphorus (P), potassium (K), and other micronutrients and pH. Realistic crop yield goals and the nutrient requirements for the crop rotation are set. Credits for contributions from the previous year's crop, animal waste, and biosolid applications are subtracted to determine the amount of nutrients and/or soil amendments to be applied. Nutrients are then applied at the proper time and by the proper method. Nutrient sources include animal manure, biosolids, and commercial fertilizers. Good nutrient management reduces the potential for nutrients to go unused and wash or infiltrate into water supplies.

CNMP development includes the documentation of:

- *Manure and wastewater handling and storage:* This element addresses the components and activities associated with the production facility, feedlot, and manure and wastewater storage and treatment structures and areas, including areas used to facilitate the transfer of manure and wastewater.
- *Land treatment practices:* This element addresses the evaluation and implementation of appropriate conservation practices on sites proposed for land application of manure and organic by-products from an AFO. On fields where manure and organic by-products are applied as beneficial nutrients, measures that minimize runoff and soil erosion are essential if plant uptake of the nutrients is to occur.
- *Nutrient management:* This element addresses the requirements for land application of all nutrients and organic by-products. Manure and organic by- products are commonly applied to the surface because of their content of nutrients and organic matter. Land application must be planned and implemented in a way that minimizes potential adverse impacts on the environment and on public health.
- *Record keeping:* This element documents implementation of activities associated with CNMPs. Documentation of implementation and management activities provides valuable benchmark information that the AFO can use to adjust the CNMP to meet production and natural resource conservation objectives.
- *Feed management:* This element may be used to reduce the nutrient content of manure. It may result in less land being required to effectively utilize the manure. Specific feed management activities that address nutrient reduction in manure may include phase feeding, amino acid supplemented low crude protein diets, or the use of low phytin phosphorus grain and enzymes, such as phytase or other additives.
- *Other utilization activities:* This element includes environmentally safe alternatives to land application of manure and organic by-products that could be part of the CNMP. These alternatives are needed where the nutrient supply exceeds the nutrient requirements of the crops and/or where land application would cause significant environmental risk. Examples are using manure for energy production, such as burning, methane generation, and conversion to other fuels. Reducing the weight or volume or changing the form can reduce transportation costs or create more valuable products.

How this practice helps: Sound nutrient management reduces input costs and protects water quality by preventing excessive application of commercial fertilizer and animal manure. Correct applications of manure and biosolids on all fields can improve soil tilth and increase the content of organic matter. Proper waste- storage facilities allow timely application of nutrients while protecting surface water and ground water.

Application of anhydrous ammonia fertilizer at planting time in Cedar County, Iowa (NRCS Photo Gallery NRCSIA99245)

A manure storage tank (part of a conservation plan) on a dairy farm in Lancaster County, Pennsylvania (NRCS Photo Gallery NRCSPA00020)

State-of-the-art lagoon waste management system for a 900- head hog farm. The facility is completely automated and temperature controlled (NRCS Photo Gallery NRCSGA02035)

References:

"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 "National Agronomy Handbook," USDA, NRCS, 2002

NRCS Photo Gallery, USDA, NRCS

Pest management

Definition: Use of environmentally sensitive prevention, avoidance, monitoring, and suppression strategies to manage weeds, insects, diseases, animals, and other organisms (including invasive and noninvasive species) that directly or indirectly cause damage or annoyance.

How this practice works: Crop rotations naturally reduce the incidence and severity of weeds, insects, and diseases in a cropping system, thereby reducing pesticide costs. The key components for pest management are:

1. Use integrated pest management principles to ensure that the techniques are environmentally sound.
2. Use crop rotations to break up pest cycles.
3. Use hand weeding or spot treatment when appropriate.
4. Use biological control and beneficial insects.
5. Scout fields, and apply chemicals at the correct time and dosage rate.

6. Consider the effects of repetitive use of the same chemicals on pesticide resistance.
7. Apply erosion-control measures to reduce runoff and associated pollution.
8. Use field borders and buffer strips to reduce the potential for pollution from runoff.
9. Become familiar with common pests, including their life cycles, and learn alternative control techniques.
10. Use chemicals safely.
11. Always follow label instructions.
12. Use extreme care in preparing tank mixes and rinsing chemicals from tanks.
13. Ensure that farm workers are properly trained in safety precautions.

Weeds

Weed shift: Changing tillage systems may result in a "weed shift" as new weed species appear because of a lack of tillage and a change in the mode of action for herbicides being used with no-till. Winter annuals may increase in extent, and small-seed weeds, which usually germinate at the surface of the soil, may become more dominant. Large-seed weeds, which generally germinate deeper in the soil, decrease in extent with no-till. Perennial weeds, including trees and shrubs in some areas, may also increase in extent under no-till.

Weed control: In a no-till system, a burn-down generally is needed to control existing weeds before planting. The perception exists that more herbicides are used in a no-till system. With the new chemicals available, however, about the same application rates are used. Mulch-till and no-till systems may involve one product or a combination of early preplant, preemergent, and post application products. Regardless of the tillage system, rotating modes of action help to prevent herbicide resistance in weeds.

Diseases

Four key factors are involved in disease management:

- A susceptible host crop
- A pathogen (disease-causing agent)
- An environment that favors the pathogen
- Adequate time for economic damage to occur

Integrated pest management is used as a preventative tool as well as a corrective action. In some areas lack of rotation causes increased disease pressure. Diseases have not been a major factor in the adoption of high-residue systems when a good crop rotation is used.

Insects

Insect problems and controls generally are no different for no-till than for other tillage systems. The exception is that early weed growth may attract some insects. Appropriate scouting and integrated pest management techniques can reduce the risk of insect damage.

How this practice helps: The importance of crop rotation for successful no-till or mulch-till implementation cannot be overemphasized. Generally, rotating a grass with a legume provides the most consistent results. Breaking the green bridge between living roots of older host plants that cause disease problems and the newly planted crops is critical in the rotation from one crop to the next.

Allelopathic crop effects

Some plants produce toxic material during the breakdown of residue. These chemicals may inhibit the germination or vigor of other plants. This effect can be detrimental or beneficial. For example, corn planted into corn residue, wheat into wheat residue, or alfalfa into an alfalfa stand may result in poor stand establishment because of autotoxicity, a specific type of allelopathy. Some varieties of these crops are more sensitive than others. On the other hand, soybeans planted into a rye cover crop may have little weed pressure because of the allelopathic effect produced by decaying rye residue on germinating weed seeds.

Crop consultant scouts field for pests as part of an integrated crop management system in northeast Iowa (NRCS Photo Gallery NRCSIA99289)

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS "National Agronomy Handbook," USDA, NRCS, 2002 NRCS Photo Gallery, USDA, NRCS

Irrigation water management (IWM)

Definition: IWM is the process of determining and controlling the amount of irrigation water and the timing and rate of its application so that crop moisture requirements are met at the same time that water losses and soil erosion are minimized.

How this practice works: IWM matches irrigation water application to the needs of the crop and the infiltration rate of the soil and thus helps to reduce surface runoff during irrigation and prevent excessive soil erosion and loss of nutrients. Properly timing the water application maximizes the beneficial effects of pesticides and yet reduces the chance of loss from leaching or runoff. Properly designed and managed irrigation and drainage systems remove runoff and leachate efficiently, control deep percolation, minimize the erosion caused by the applied water, and reduce adverse impacts on surface water and ground water.

The volume of irrigation water applied and the frequency of irrigation should be determined by crop needs and soil characteristics. Soil moisture should be monitored to determine when application is needed to prevent crop stress and limit deep percolation. The volume of irrigation water applied should match the water-holding capacity of the soil in the root zone of the crop. The application rate should not greatly exceed the absorption or infiltration rate of the soil. When fertigation or chemigation is used, wells must be equipped with check valves and anti-siphon devices to prevent well contamination, which can lead to contamination of the aquifer.

Pollution process: Pollution is the result of a series of factors. These can be categorized as availability, detachment, and transport. Water pollution is a hazard only when a pollutant is available in some form in the field, becomes detached, and is transported beyond the edge of the field, below the root zone, or above the crop canopy and toward a receiving water body.

Availability: A potentially polluting substance is available in some amount and in some place. The potential pollutant could be sediment from a highly erosive soil since soil is always available. Chemical compounds vary not only in quantity but also in the degree of their availability for movement. The amount available at the time of runoff or deep percolation is important. Nutrients from fertilizer in or on the soil or from mineralized crop residue, pesticides applied to the field, bacteria carried with an application of animal manure, or some other potentially harmful material have different forms and times of availability for movement.

Detachment: The potential pollutant or its environment is modified so that the substance can be moved from where it should be to where it should not be. The detachment process is either physical or chemical. Chemical pollutants can be grouped into three categories on the basis of their adsorption characteristics: (1) strongly adsorbed, (2) moderately adsorbed, and (3) nonadsorbed.

Detachment is dependent on:

- The type of compound and concentration
- The strength of bonding to the soil particles
- Quality and quantity of irrigation water
- The chemical, physical, and biological characteristics of the soil (pH, content of organic matter, porosity, and electrical conductivity)
- Climatic conditions (wind, temperature, and water movement)
- The properties of the chemical compound

Highly soluble compounds are easily detached when they dissolve into both surface runoff and percolating water. Strongly adsorbed compounds are sometimes not detached but are carried by soil particles that have been separated by water drop splash or surface runoff shear.

Transport: Transport is the movement of material from its natural or applied position. Agricultural pollutants are typically transported in water during periods of surface runoff or deep percolation, or they can be moved through wind drift and volatilization. The particular pathway by which a pollutant leaves the field depends on the soil type, the hydrology of the field, the type of irrigation system and its operational techniques, the timing and rate of nutrient and pesticide application, and the interaction of the compounds with water and soil as affected by management practices. Pollutants are generally transported to receiving water bodies by surface runoff and/or through deep percolation. Excess irrigation water application provides an opportunity for transport.

How this practice helps: IWM helps to effectively use available irrigation water as it manages and controls the moisture environment of crops and other vegetation. IWM minimizes soil erosion and the loss of plant nutrients and protects both the quantity and quality of water resources.

IWM basics

1. Determine when to apply water according to the rate of use by the plants at the various stages of crop or forage growth.
2. Measure or estimate the amount of water required for each irrigation run.
3. Determine the time needed for the soil to absorb the required amount of water.
4. Detect changes in the water intake rate.
5. Determine how and when to adjust the stream size, the application rate, and the time of irrigation to compensate for changes in the soil or topography that affect the water intake rate.
6. Recognize the erosion caused by irrigation.
7. Evaluate the uniformity of water application.

Source reduction: Maintain a surface cover to prevent excessive erosion and entrap potential pollutants. Provide the kind of conservation tillage, vegetative cover, and water management practices needed to reduce irrigation-induced soil erosion and runoff and thus reduce the amount of time that water is in contact with the potential contaminant. Nutrients, especially fertilizers, should be applied so that their availability matches the uptake needs of the plants as closely as possible. Matching application to plant requirements can reduce the amount of pollutants available for detachment and transport.

Reduction of availability: Optimize nutrient availability by managing the rate, timing, source, and method of application. Soil and plant testing monitors the buildup of available nutrients in the root zone of the crop. Incorporation of chemicals reduces their contact time with irrigation water. Improving the chemical, physical, and biological condition of the soil can help retain and degrade many of the chemical compounds in the root zone.

Reduction in detachment: For those nutrients that are strongly adsorbed to soil particles, detachment and transport off the field are major avenues of loss. For example, phosphorus is tightly bound to soil particles by aluminum, iron, and calcium minerals. Thus, it is readily transported only when soil becomes detached.

Reduction in transport: Because many nutrients and salts are strongly adsorbed to soil particles, the amount of these materials lost from the field is directly related to the amount of sediment carried from the field. Chemicals that dissolve readily are easily transported with excess irrigation water either from the edge of the field or from the bottom of the root zone. Applying the proper amount of irrigation water at the proper time is essential in reducing the potential for the transport of pollutants.

Salt: All irrigation water contains dissolved salts, which are added to the soil during each irrigation run. Fertilizer and animal manure also contain salts. Salts may stay in solution and move below the root zone, or they may precipitate within the root zone. Excessive or imbalanced dissolved salts can cause four types of production problems in irrigated areas:

- General yield declines
- Structure problems
- Toxicity
- Corrosion

General yield declines: Dissolved salts create an osmotic force that makes water unavailable for plant uptake. Excessive dissolved salts reduce the amount of plant-available water in the soil. The reduced amount of water can cause crop stress.

Structure problems: The total amount of dissolved salts in the soil may not be as important as the relative ratio of the different salts. If salt types are out of proportion, soil structure problems can result. The most significant salt imbalance occurs if there is too much sodium in relation to magnesium and calcium in the soil water. This problem usually leads to restricted permeability in the soil. As infiltration is reduced, the soil becomes hard, making root penetration difficult.

Toxicity: Some nutrient salts, while essential for plant growth in small amounts, are toxic in excessive amounts. Boron, for example, is toxic to plants and starts to restrict plant growth when irrigation water exceeds 1-ppm boron levels.

Corrosion: Salts can cause corrosion of irrigation equipment. Water must be handled and treated carefully because of the need to prevent disruption of water distribution, especially when drip irrigation systems are used.

Drainage and runoff

The removal of excess soil water by drainage systems has greatly increased agricultural production. These systems not only remove the gravitational water from the soil but also allow freer exchange of soil air with atmospheric air.
Changing the water and air status of the soil impacts the fate and transport of agrochemical compounds. Foremost, drainage water carries with it any dissolved materials from the soil. Soluble carbon, nitrates, potassium, phosphorus, and pesticides move with drainage water. This water is transported to subsurface drain outlets, seeps and springs, open channels, and fissures in bedrock and can become part of the surface water. Some of the drainage water moves downward through the soil, does not resurface, and becomes part of the ground water.

Some irrigation water must pass through the root zone of the crop if soil salinity is to be maintained at a desirable level. Deep percolation is required to remove salts from the root zone. The key questions are: *How much deep percolation is required?* and *Where does it go?* Leaching should be done when residual soil nitrate levels are at the lowest.

If insufficient drainage occurs, as is the case when impermeable rock or clay is relatively near the soil surface, percolating water backs up and creates a saturated zone in the soil. Under these conditions, natural drainage cannot remove the excess water fast enough and plant roots are adversely affected by a lack of oxygen in the soil. Artificial drainage systems are needed to carry away the excess soil water. These systems generally consist of perforated, polyethylene tubes buried at various depths and intervals at or near the bottom of the root zone of the crop. Soil water enters the perforations and is carried by gravity to a surface outlet or is pumped to the surface for disposal.

Water level control

Water level control is the manipulation of soil moisture to create a suitable soil and plant environment for control of vegetative growth, reduction of such compounds as nitrate nitrogen, or promotion of soil micro and mesa fauna. This control is accomplished by changing the aeration or water status of the soil pores. Such crops as rice respond favorably to saturated soil conditions and can grow better than other vegetation under these conditions.

Water management planning accounts

Two types of water management planning accounts are available. A "water budget" is a projected accounting of the water supply in the soil for a general area and a general period of time. It indicates where the water comes from and where it goes. A "water balance" is the daily accounting of the water supply for a specific field (soil and crop type) during a specific time.

Methods of controlling irrigation-induced soil erosion

In-field soil erosion in areas of furrow irrigation systems can be controlled by:

- Using proper inflow streams
- Reducing irrigation grades
- Maintaining crop residue on the soil surface
- Using a soil-stabilizing compound, such as polyacrylamide (PAM)
- Using crop rotation
- Off-field sediment movement can be controlled by:
- Establishing vegetative filters at the lower edge of the field
- Controlling runoff, thereby reducing water velocity
- Installing sediment-detention basins
- Collecting and redistributing tailwater

Siphon tubes used for furrow irrigation in an area of romaine lettuce near Yuma, Arizona (NRCS Photo Gallery NRCSAZ02010)

A handline sprinkler irrigation system (NRCS Photo Gallery NRCSID00003)

An area in the Colorado River Basin, where salinity is a challenge for landowners and resource professionals (Photo Gallery NRCSUT03052) (NRCS Photo Gallery NRCSUT03053)

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS NRCS Photo Gallery, USDA, NRCS

Contour farming

Definition: Tilling and planting across the slope, following the contour of the land, as opposed to farming up and down hills.

How this practice works: Farming on the contour creates small ridges that slow runoff water, and it increases the rate of water infiltration, reduces the hazard of erosion, and redirects runoff from a path directly downslope to a path around the hillslope. Farming on the contour rather than up and down the slope reduces fuel consumption and is easier on equipment.

- Contour farming is often used in combination with other practices, such as terraces, water- and sediment-control basins, and stripcropping.
- Longer, steeper slopes may require stripcropping rather than just contour farming, which is less effective in preventing excessive erosion on the steeper or longer slopes.
- Irregular slopes may require more than one key contour line. Some fields may be too steep and/or irregularly shaped for contour farming.

- Strips of row crops should be roughly the same width as strips of hay or small grain crops. The desirable acreage of row crops should be considered. Hay strips will rotate to row crops over time. The width of the strip depends on slope, equipment, and management.
- A hand level or contour gauge can be used to establish a key line around the hill.
- All tillage and planting operations should be parallel to the key contour line.
- Rotating strips from corn to legumes allows corn to use the nitrogen added to the soil by the legumes.
- Herbicide carryover may be a problem.
- Replacing end rows with grasses or legumes reduces the hazard of erosion and makes turning equipment easier.
- Grassed waterways are needed where runoff concentrates.
- The grade of the contour key line generally should not exceed 2 percent. Within 100 feet of an outlet (i.e., a waterway), however, the grade can be 3 percent.
- Where curves in contour lines are too sharp for farm equipment, grass strips may serve as sites where the equipment can turn.

How this practice helps: Contour farming can reduce soil erosion by as much as 50 percent compared to farming up and down hills. It promotes better water quality by controlling sedimentation and runoff and increasing the rate of water infiltration.

Contour farming in northeast Iowa (NRCS Photo Gallery NRCSIA99176)

References:

"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 "Contour Farming and Stripcropping," USDA, NRCS, Wisconsin http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/? cid=nrcs142p2_020785
NRCS Photo Gallery, USDA, NRCS

Contour stripcropping

How this practice works: Contour stripcropping is used with contour farming. Crops are arranged so that a strip of meadow or small grain is alternated with a strip of row crops. Not more than half of a field can be planted to row crops.
Meadow slows runoff, increases the rate of water infiltration, traps sediment, and provides surface cover. Ridges formed by contoured rows slow waterflow and reduce the hazard of erosion. Rotating the strips from corn to legumes allows nutrient-needy crops to benefit from the nitrogen added to the soil by the legumes. Contour stripcropping combines the beneficial effects of contouring and crop rotation. It may be combined with terraces to provide additional erosion control and stormwater management.

How this practice helps: Contour stripcropping can reduce soil erosion by as much as 50 percent compared to farming up and down hills. The cost of fertilizer can be reduced if legumes, such as alfalfa or clover, are planted in the meadows. Contour stripcropping improves water quality by controlling sedimentation and runoff and increasing the rate of water infiltration.

Alternating strips of alfalfa and corn grown on the contour in northeast Iowa (NRCS Photo Gallery NRCSIA99355)

Aerial view of contour stripcropping in central Wisconsin (NRCS Photo Gallery NRCSUT03035)

Contour stripcropping

Reference:
Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS

Cover crops

Definition: Growing a crop of grass, small grain, or legumes primarily for seasonal protection and soil improvement.

How this practice works: Cover and green manure crops, including cereal rye, oats, clover, hairy vetch, and winter wheat, are grown on cropland and in orchards, vineyards, and certain recreation and wildlife areas to temporarily protect the ground from wind erosion and water erosion during times when the land is not adequately protected. These crops are usually plowed under or desiccated to accommodate the primary crop being produced on the site.

How this practice helps: Cover crops are used to control erosion, improve fertility by adding organic matter to the soil, trap nutrients, improve soil tilth, improve water infiltration and aeration in the soil, and control weed competition. These crops also are designed to increase bee populations for pollination purposes. They have beneficial effects on water quantity and quality. Cover crops also filter sediment, pathogens, and dissolved and sediment-attached pollutants.

A cover crop in a field in Black Hawk County, Iowa (Photo Gallery NRCSIA99177)

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS NRCS Photo Gallery, USDA, NRCS

Grassed waterways

Definition:A grassed waterway is a natural or constructed channel that is shaped or graded to carry surface water at a nonerosive velocity to a stable outlet. The required dimensions are those needed for the waterway to convey runoff from the design storm, generally the 10-year, 24-hour storm. The grassed waterway is designed to ensure that the velocity of runoff water is not excessive.

How this practice works: The primary purpose of a grassed waterway is to convey runoff from terraces, diversions, or other areas of water concentration without causing erosion or flooding. Another purpose is to improve water quality. Grassed waterways are natural drainageways that are graded and shaped to form a smooth, bowl-shaped channel. They are seeded to sod-forming grasses. Runoff water that flows down the drainageway flows across the grass rather than tearing away soil and forming a larger gully. An outlet is commonly installed at the base of the drainageway to stabilize the waterway and to keep a new gully from forming.

The most critical time for successful installation of a grassed waterway is immediately following construction, when the channel is bare and unprotected from runoff. Waterways are generally planted to perennial grass and then mulched with straw. In some areas silt fences or straw bales in the waterway reduce the velocity of the runoff, thereby reducing the risk of gully formation in the new waterway.

How this practice helps: A grassed waterway provides a vegetative strip that benefits the environment in several ways in addition to the primary benefit of providing a nonerosive waterway. These additional benefits include diversity of wildlife habitat, corridor connections, vegetative diversity, noncultivated strips of vegetation, and improved esthetics. An additional grassed width on each side of the grassed waterway allows the waterway to better serve as a conservation buffer.

Functions: The primary function of a grassed waterway is to transport water and sediment. Nearly all grassed waterways are located topographically so that runoff enters the waterways either as sheet or concentrated flow. Because of high water velocities, little or no sediment deposition occurs within the waterway. Therefore, suspended sediment entering the grassed waterway will most likely exit the waterway at its outlet to the possible detriment of the receiving water body. The function of a grassed waterway is not to reduce sediment loading in runoff.
Providing enough additional grassed width on each side of the waterway to serve as filter strips, however, reduces the sediment load entering the waterway and thus enhances the quality of water bodies.

A grassed waterway in Fayette County, Iowa (NRCS Photo Gallery NRCSIA99447)

Grassed waterways in a corn field in northeast Iowa (NRCS Photo Gallery NRCSIA99509)

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 Farmland Protection Program NEPA Documents, Appendix B FPP Practice Effects: Practice Photos, Descriptions and Network Diagrams, USDA, NRCS NRCS Photo Gallery, USDA, NRCS

Terraces

How this practice works: Terraces break long slopes into shorter ones. They generally follow the contour. As water makes its way down a hill, terraces serve as small dams that intercept and guide the water to an outlet. There are two basic types of terraces: storage terraces and gradient terraces. Storage terraces collect water and store it until it can infiltrate into the ground or be released through a stable outlet. Gradient terraces are designed as a channel to slow runoff water and carry it to a stable outlet, such as a grassed waterway.

How this practice helps: Terraces improve both water quality and soil quality. Terraces with grassed frontslopes or backslopes can provide nesting habitat and other cover for wildlife.

Grassed-back terrace in Iowa (NRCS Photo Gallery NRCSIA03005)

Contour terraces in Kansas (NRCS Photo Gallery NRCSKS02026)

Reference:
NRCS Photo Gallery, USDA, NRCS

Buffer strips

How this practice works: Conservation buffers are areas or strips of land where a permanent cover of vegetation is maintained to help control pollutants and manage other environmental problems. Buffer vegetation may produce alternative commodities to diversify farm income. These include lumber, fuel wood, fiber, hay, seeds, and ornamental, medicinal, and food products.

How this practice helps: Buffers are strategically located on the landscape to accomplish many objectives. They reduce the hazard of erosion by slowing the velocity of water or wind, trap sediment or other pollutants, and may provide wildlife habitat. Following is a description of 10 different kinds of buffers.

Alley cropping

Alley cropping is the planting of trees or shrubs in two or more sets of single or multiple rows with agronomic, horticultural, or forage crops cultivated in the alleys between the rows of woody plants. Alley cropping is used to enhance or diversify farm products, control surface runoff and wind and water erosion, improve the utilization of nutrients, improve crop production by modifying the microclimate, increase the diversity of wildlife habitat, and enhance the beauty of the area.

Contour buffer strips

Contour buffer strips are strips of perennial vegetation alternated with wider cultivated strips that are farmed on the contour. Contour buffer strips slow runoff and trap sediment. The amount of sediment, nutrients, pesticides, and other contaminants in runoff is reduced as the runoff passes through the buffer strips.

Grassed contour buffer strips in Iowa (NRCS Photo Gallery NRCSIA00031)

Cross wind trap strips

Cross wind trap strips are areas of herbaceous plants that are resistant to wind erosion and as nearly as possible are grown perpendicular to the prevailing wind direction. These strips catch wind-borne sediment and other pollutants, such as nutrients and pesticides, from the eroded material before it reaches water bodies or other sensitive areas. They filter the wind-borne material.

Field borders

Field borders are bands or strips of perennial vegetation established on the edge of a cropland field. They help to control sheet, rill, and gully erosion at the edge of fields; trap sediment, chemicals, and other pollutants; are turning areas for farm equipment; and provide habitat for wildlife.

A field border in Iowa (NRCS Photo Gallery NRCSIA99192)

Filter strips

Filter strips are areas of grass or other permanently established vegetation used to reduce the amount of sediment, organic material, nutrients, pesticides, and other contaminants from runoff and to maintain or improve water quality. They slow the velocity of water, filter suspended soil particles, and increase infiltration of runoff and soluble pollutants and adsorption of pollutants on soil and plant surfaces.

Conservation filter strips in Illinois (NRCS Photo Gallery NRCSIL001) Grassed waterway/vegetated filter

A grassed waterway/vegetated filter system is a natural or constructed vegetated channel that is shaped and graded to carry surface water at a nonerosive velocity to a stable outlet. It spreads the flow of water before the water enters a vegetated filter.

Herbaceous wind barriers

Herbaceous wind barriers consist of tall grasses and other nonwoody plants established in one- to two-row, narrow strips spaced across the field, perpendicular to the normal wind direction. These barriers reduce wind velocity across the field and intercept wind-borne soil particles.

Riparian forest buffers

Riparian forest buffers are areas of trees and shrubs adjacent to streams, lakes, ponds, and wetlands. They intercept contaminants from surface runoff and shallow subsurface waterflow.

Buffers along a stream in an area of rangeland in California (NRCS Photo Gallery NRCSCA00026)

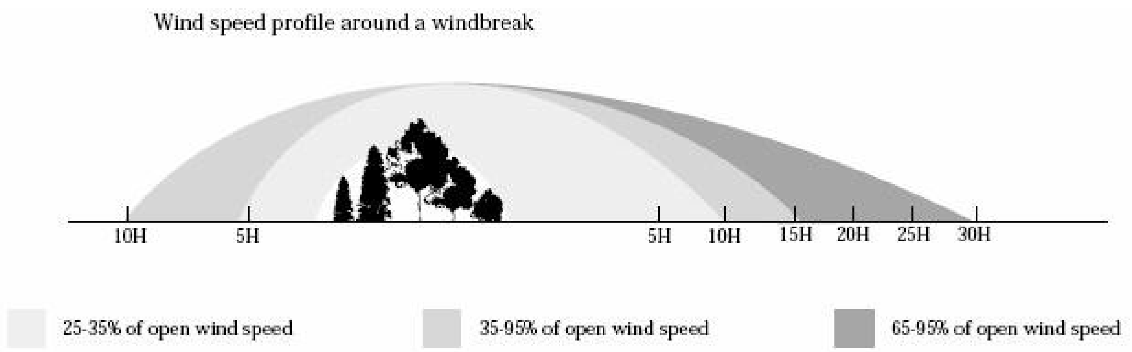
Vegetated barriers

Vegetated barriers are areas of narrow, permanent strips of stiff-stemmed, erect, tall, dense perennial plants established in parallel rows and perpendicular to the dominant slope of the field. These barriers provide help to control water erosion on cropland and offer an alternative to terraces where the soil might be degraded by terrace construction.

Windbreaks or shelterbelts

Windbreak or shelterbelts consist of a single row or multiple rows of trees or shrubs that protect the soil from wind erosion, protect sensitive plants, manage snow, improve irrigation efficiency, protect livestock and structures, and create or enhance wildlife habitat.

Field windbreaks in North Dakota (NRCS Photo Gallery NRCSND99001)



Wind speed profile around a windbreak

References:
"Core4 Conservation Practices Training Guide," USDA, NRCS, 1999 NRCS Photo Gallery, USDA, NRCS

Rangeland

What is rangeland?

Rangeland is a kind of land on which the historic climax vegetation was predominantly grasses, grasslike plants, forbs, or shrubs. Rangeland includes land revegetated naturally or artificially to provide a plant cover that is managed like native vegetation. Rangelands include natural grasslands, savannas, most deserts, tundra, alpine plant communities, coastal and freshwater marshes, and wet meadows.

Rangelands provide numerous products and have many values and uses. Rangelands are a primary source of forage for domestic livestock and for wildlife. Rangelands provide water for urban, rural, domestic, industrial, and agricultural use.

They provide wildlife habitat, areas for natural recycling, purification of the air, and carbon sequestration. Rangelands have aesthetic value, provide open space, and act as buffers for urban areas. They are a vital link in the enhancement of rural social stability and economic vigor.

Reference: "Range and Pasture Handbook," Section 600.0202(a) page 2-2

What is range management?

Range management is the art and science founded on ecological principles and dealing with the use of rangelands and range resources for a variety of purposes. These purposes include use as watersheds, wildlife habitat, grazing by livestock, recreation, and aesthetics.

What is an ecological site?

An ecological site is a distinctive kind of land with specific physical characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation. Landscapes are divided into ecological sites for the purposes of inventory, evaluation, and management.

An ecological site is the product of all the environmental factors responsible for its development, and it has a set of key characteristics that are included in the ecological site description. Ecological sites have characteristic soils and hydrology that have developed over time throughout the soil development process. The factors of soil development are parent material, climate, living organisms, topography or landscape position, and time. These factors lead to soil development or degradation through the processes of loss, addition, translocation, and transformation.

Most ecological sites evolved with a characteristic kind of herbivory (kinds and numbers of herbivores, seasons of use, and intensity of use). Herbivory directly influences the vegetation and soil, both of which influence the hydrology.

Ecological sites evolve with a characteristic fire regime. Fire frequency and intensity contribute to the characteristic plant community of the sites.

Reference: "Range and Pasture Handbook," Section 600.0300 (a) page 3.1-1

What is an ecological site description?

An ecological site description is prepared for each ecological site. These descriptions contain information regarding the physiographic features, climate, soils, water features, and plant communities associated with each ecological site. Plant community dynamics, annual production estimates, growth curves, associated wildlife communities, and interpretations for use and management of the site are also included in each site description.

Ecological site descriptions provide the foundation information to assist land managers in making timely, well informed resource management decisions.

Example: "National Range and Pasture Handbook," Exhibit 3.1-3 page 3.1 ex-3

What is a historic climax plant community?

The historic climax plant community for a site in North America is the plant community that existed at the time of European immigration and settlement. It is the plant community that was best adapted to natural disturbances, such as drought, fire, grazing of native fauna, and insects. The historic climax plant community was in dynamic equilibrium with its environment.

The historic climax plant community of an ecological site is not a precise assemblage of species for which the proportions are the same from place to place or from year to year. In all plant communities, variability is apparent in productivity and occurrence of individual species. Boundaries of the plant communities can be recognized by characteristic patterns of species composition, association, and community structure.

Reference: "National Range and Pasture Handbook," Section 600.0301 pages 3.1-2

What is a similarity index?

Similarity index is the comparison of the present plant community on an ecological site to any other plant communities that may exist on the site.

The purpose for determining similarity index is to provide a benchmark for future comparisons evaluating the extent and direction of changes that have occurred in the plant community because of a specific treatment or management.

Reference: "National Range and Pasture Handbook," Section 600.0402(b) page 4-17

How is similarity index calculated?

To determine the present plant community's similarity index to a specific plant community, the specific plant community must be adequately described in the ecological site description. The specific plant community must be described by species and the expected range of production by weight by species or by groups of species as well as the expected normal total annual production. This range of production becomes the allowable production to be counted when determining similarity index.

The existing plant community must be inventoried by recording the actual weight, in pounds, of each species present. The annual production by species of the existing plant community is then compared to the production of individual species in the desired plant community. All allowable production is then totaled. It is important to remember that if the similarity index is calculated when plants are still growing, then the plant productions should be reconstructed to reflect the total production for the year.

The relative similarity index to the desired plant community is calculated by dividing this total weight of allowable production by the total annual production in the desired plant community. This evaluation expresses the percentage of the desired plant community present on the site. For example, if the current inventory reflects only 65% of the allowable plants compared to the desired plant community, then the current plant community has a 65% similarity index to the desired plant community.

Reference: "National Range and Pasture Handbook," Section 600.0402(b)(2) page 4-17

What is trend?

Trend is a rating of the direction of plant community changes that may be occurring on a site. The plant community and the associated components of the ecosystem may be either moving toward or away from the historic climax plant community or some other desired plant community. At times, it can be difficult to determine the direction of change. Usually trend is determined by two evaluations over time.

Trend provides information necessary for the operational level of management to ensure that the direction of change meets the objectives of the manager. The present plant community is a result of a sustained trend over a period of time.

Trend is an important and required part of a rangeland resource inventory. It is significant when planning the use, management, and treatment needed to affect desired change in the rangeland resource.

Reference: "National Range and Pasture Handbook," Section 600.0402(a) page 4-14

How is range trend determined?

The plant community and the associated components of the ecosystem may be either moving toward or away from the historic climax plant community or some other desired plant community (rangeland trend or planned trend). The kind of trend (rangeland trend or planned trend) being evaluated must be determined.

Rangeland trend is defined as the direction of change in an existing plant community relative to the historic climax plant community. It is described as:
Toward: Moving towards the historic climax plant community.

Not apparent: No change detectable.
Away from: Moving away from the historic climax plant community.

Planned trend is defined as the change in plant composition within an ecological site from one plant community type to the desired plant community. It is described as:
Positive: Moving towards the desired plant community.

Not apparent: No change detectable.
Negative: Moving away from the desired plant community.

Most ecological sites evolved with a characteristic kind of herbivory (kinds and numbers of herbivores, seasons of use, and intensity of use). Herbivory directly influences the vegetation and soil, both of which influence the hydrology.

Trend is determined by evaluating changes in plant composition, abundance of seedlings and young plants, plant residue, plant vigor, and condition of the soil surface.

Reference: "National Range and Pasture Handbook," Section 600.0402(a) page 4-14

What is rangeland health?

The rangeland health assessment is an attempt to look at how the ecological processes on an ecological site are functioning. Ecological processes include the water cycle (the capture, storage, and redistribution of precipitation), energy flow (conversion of sunlight to plant and animal matter), and nutrient cycle (the cycle of nutrients, such as nitrogen and phosphorus, through the physical and biotic components of the environment).

Qualitative assessments of rangeland health provide land managers with information that can be used to identify areas that are potentially at risk of degradation and provide early warnings of resource problems on upland rangelands.

This procedure has been developed for use by experienced, knowledgeable land managers. It is not intended that this assessment procedure be used by individuals who do not have experience or knowledge of the rangeland ecological sites they are evaluating. This approach requires a good understanding of ecological processes, vegetation, and soils for each of the ecological sites to which it is applied.

Reference: "National Range and Pasture Handbook," Section 600.0402(c) pages 4-23

How is rangeland health evaluated?

Ecological processes functioning within a normal range of variation support specific plant and animal communities. Direct measures of site integrity and status of ecological processes are difficult or expensive to measure because of the complexity of the processes and their interrelationships. Therefore, biological and physical attributes are often used as indicators of the functional status of ecological processes and site integrity.

Three closely interrelated attributes are evaluated:

Soil/site stability: The capacity of the site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic function: The capacity of the site to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant) to resist a reduction in this capacity and to recover this capacity following degradation.

Integrity of the biotic community: Capacity of a site to support characteristic functional and structural communities in the context of normal variability, to resist loss of this function and structure because of a disturbance, and to recover following such disturbance.

Reference: "National Range and Pasture Handbook," Section 600.0402(c)(2) pages 4-24

2021 NCF-Envirothon Nebraska
Soils and Land Use Study Resources

Key Topic #4: Soil Biology and Land Management

11. Explain the importance of biological diversity and how it is important for soil health, environmental health, and human health.
12. Describe how the hydrologic, carbon, and nutrient cycles impact soil management.
13. Apply the concepts of soil ecology to the management of soils in various contexts.
14. Identify predominant types of organisms (flora and fauna) in a soil ecosystem and explain their roles (decomposition, nutrient cycling, soil color i.e. redox features).

Study Resources

Soil Biology and Land Management – *Soil Quality – Soil Biology: Technical Note No. 4, USDA NRCS, 2004* (Page 68-87)

Study Resources begin on the next page! ➡

Be able to read and use reports from Web Soil Survey to answer questions on the test. Understand the tables, interpretations, and soil descriptions, and know how to make inferences from the data presented.

Getting Started With Web Soil Survey

Soil surveys are being completed and published in printed form on an ongoing schedule. As time passes, the data in printed surveys can become out of date. The up-to-date official information about the soils in a given area is now available in electronic form for each of the Soil Survey Areas. Web Soil Survey provides interactive access to the most current information for a user-defined Area of Interest. Click the following link to go to the Web Soil Survey home page: Web Soil Survey Home Page. If spatial soil data are available for your Area of Interest, Web Soil Survey also generates soil maps. Web Soil Survey also provides the capability to download official Soil Survey Geographic Database (SSURGO) soil data for whole soil survey areas. Generalized soil data (State Soil Geographic Database or STATSGO2) can also be downloaded in individual state datasets or the whole U.S.

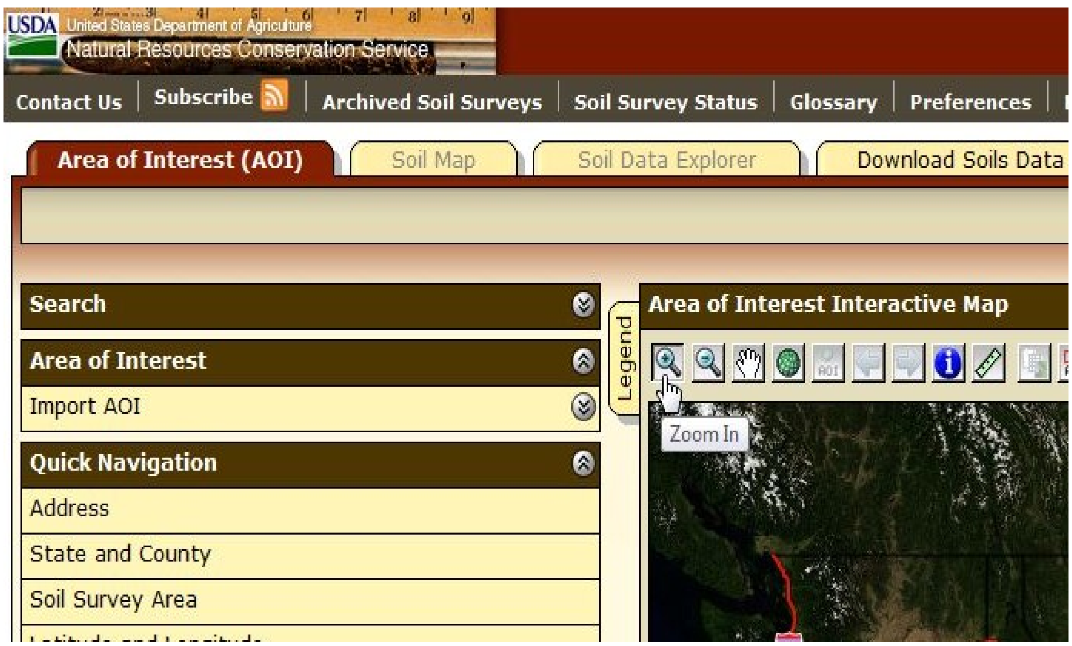
Information about how to use Web Soil Survey, including a link to this **Getting Started** document, is available on the Web Soil Survey home page. Look on the right side of the home page in the **I Want To...** and **I Want Help With...** sections.

4 Basic Steps:

1. **Define:** Use Area of Interest (AOI) tab to define your area of interst.
2. **View:** Click the Soil tab to view or print a soil map and detailed descriptions of the soils in your AOI.
3. **Explore:** Click the Soil Data Explorer tab to access soil data on suitability of soils for a particular use.
4. **Check Out:** Use the Shopping Cart tab to get your custom printable report immediately or download it later.

Here's a brief overview to get you started using Web Soil Survey:

1. Browse to the Web Soil Survey home page at the following link: Web Soil Survey Home Page.
2. To start the application, click the large round green button labeled **Start WSS**.
3. To work with Web Soil Survey interactively, jump to step 4 below. To download soils data for a full survey area or for State Soil Geographic Database (STATSGO2) data, click the **Download Soils Data** tab.
4. After the map refreshes, you can use the **Zoom In** map tool. Click on the **Zoom In** tool to put the map in **Zoom In** mode. Then either click on the map to zoom in, or click and drag the map to zoom to the rectangle you've drawn. Zoom in as close as you need.
5. Or alternatively, on the left side of the browser window, in the **Quick Navigation** panel, click on one of the forms — **Address**, **State and County**, **Soil Survey Area**, etc. Enter the information, and click **View**.



6. Before you can view any soil data, you must define your Area of Interest or AOI. You can set your AOI by drawing a rectangle or a polygon on the map, or you can set your AOI to a whole Soil Survey Area. You can also create a multi-part AOI using the Create AOI from Shapefile or Create AOI from Zipped Shapefile options under the Import AOI menu. AOIs created using the **AOI Rectangle** and **AOI Polygon** tools are limited to a maximum of 100,000 acres, but Soil Survey Area AOIs are not.

- To set your AOI to a rectangle, click the **AOI Rectangle** map tool. Then click and hold the left mouse button, and drag a rectangle on the map. When you release the mouse button, the rectangle you've drawn will be set as your Area of Interest.

- To set your AOI to a polygon, click the **AOI Polygon** map tool. Then click points on the map to define your AOI. To finish, either double click the last point, or hold down the Control key while clicking the last point.
- To set your AOI to a whole Soil Survey Area, in **Quick Navigation**, open the **Soil Survey Area** form. Choose a state and Soil Survey Area using the dropdowns. Then click **Set AOI**.

7. Once you have set your AOI, click the **Soil Map** tab to see the soil map and map unit information.
8. To create a printable document containing the map and information on the **Soil Map** tab, click the **Printable Version** button, and then click the **View** button.
9. To run soil ratings or soil reports, click the **Soil Data Explorer** tab, then the one of the inner tabs: **Suitabilities and Limitations for Use**, **Soil Properties and Qualities**, or **Soil Reports**.
10. On the left side of the browser window, click the **Open All** button to expand all the folders, or click an individual folder to list the items within it.
11. Click one of the items to open the form, then set options as desired, and click **View Rating** or **View Soil Report**. This will show the data in tabular form and, for the Ratings, in color-coded map form. Click the Legend tab at the left side of the map to see a legend of the Rating values.
12. To create a printable version of the soil data, click **Printable Version** or **Add to Shopping Cart**:
    - **Printable Version** generates a Portable Document Format (PDF) document containing the rating or report that you just ran.
    - **Add to Shopping Cart** adds the report or map to the shopping cart. You can add multiple ratings and reports to the shopping cart and then create a Portable Document Format (PDF) document containing all the items you added to it. The AOI soil map and the list of map units and their descriptions are added to the shopping cart by default. Once you're done adding content to the shopping cart, click the **Shopping Cart (Free)** tab, and then click the **Check Out** button. This will generate a single Portable Document Format (PDF) document containing all the items you added. By default, the **Soil Map** content is automatically included in your Portable Document Format (PDF) document. For best results, limit the number of items you add to the shopping cart to ten or fewer.

13. There is a **Search** function that you can use to search for where specific keywords occur in the application. The **Search** form is located in the upper left corner of each tab. Set your Area of Interest, then click **Search** and enter keywords, such as “hydric rating” or “KCl”, and then click the **Search** button. The search results are links that navigate to the place in the application where the keywords were found.
14. After you have defined your AOI, you can also click the **Download Soils Data** link to download tabular and spatial soils data for your AOI. You will need Microsoft Access software to make use of the tabular data, and ArcGIS software to make use of the spatial data.
15. Throughout Web Soil Survey, context-specific help is available by clicking the following question mark icon: ?. For more information, see "How can I get help using Web Soil Survey?" on the Frequently Asked Questions page by clicking the following link: How can I get help using Web Soil Survey?
16. For assistance with specific soil data questions, you may click the following Contact Us link: Contact Us. The Contact Us link is also located beneath the USDA logo in the upper-left corner of Web Soil Survey.

For further assistance, you can also click the following email link: soilshotline@lin.usda.gov.

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Study Resources

Soil Biology and Land Management – *Soil Quality – Soil Biology: Technical Note No. 4, USDA NRCS, 2004* (Page 67-86)

<u>Study Resources begin on the next page!</u> ➡

United States
Department of
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Natural
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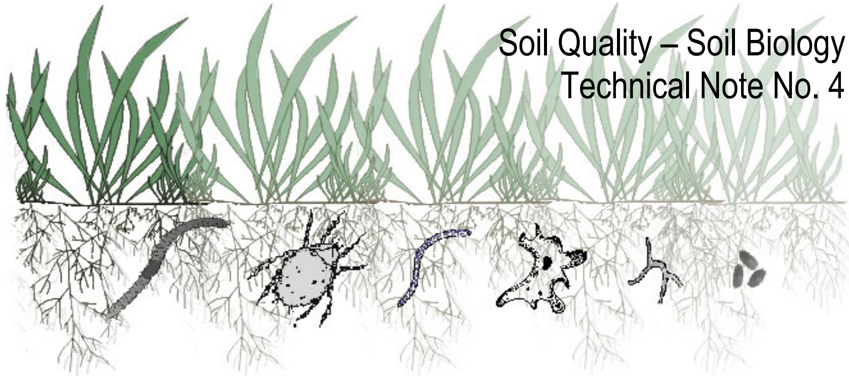


Soil Biology and Land Management

Soil Quality – Soil Biology
Technical Note No. 4

January 2004

NRCS file code: 190-22-15

Other titles in this series:
#1 Soil Biology Primer
#2 Introduction to Microbiotic Crusts
#3 Soil Biology Slide Set

NRCS Soil Quality
http://soils.usda.gov/sqi

Table of contents

Introduction

The purpose of this technical note is to provide information about the effects of land management decisions on the belowground component of the food web. It points out changes in soil biological function that land managers should look for when changing management practices. This information is not a set of prescriptive guidelines, but is designed to increase awareness and prompt field trials.

The goal of soil biology management

The goal of managing the soil biological community is to improve biological functions, including forming and stabilizing soil structure, cycling nutrients, controlling pests and disease, and degrading or detoxifying contaminants.

Research shows that management practices and disturbances impact soil biological functions because they can 1) enhance or degrade the microbial habitat, 2) add to or remove food resources, or 3) directly add or kill soil organisms. Although management practices are known to impact soil biology, there is limited knowledge to support the development of detailed management strategies. A particular practice may have the desired result in one situation but have little effect in another because biological communities respond to the interaction of multiple factors including food sources, physical habitat, moisture, and impacts of historical land use. Therefore, before a new product or practice is applied to a large parcel of land, it should be tested on a limited area and results should be monitored in comparison to an untreated plot.

Why should land managers understand soil biology?

Energy and the food web

Through agriculture, the sun's energy is converted into food, feed, and fiber. However, most of the solar energy captured by plants is not directly harvested when crops are gathered; instead, it feeds the belowground food web. Feeding the "underground livestock" is essential to productive forests, rangeland, and farmland. Figure 1 shows how energy is recycled repeatedly through belowground soil organisms. The soil food web is part of energy, nutrient, and water cycles. The energy cycle begins when the sun's energy is captured by the plant-based (aboveground) food web. Nutrient availability is governed by the detritus-based (belowground) food web. The water cycle is also influenced by the interaction of plants, soils, and soil organisms.

Functions of the soil food web

Nutrient cycling

In a healthy soil ecosystem, soil biota regulates the flow and storage of nutrients in many ways. For example, they decompose plant and animal residue, fix atmospheric nitrogen, transform nitrogen and other nutrients among various organic and inorganic forms, release plant available forms of nutrients, mobilize phosphorus, and form mycorrhizal (fungus-root) associations for nutrient exchange. Even applied fertilizers may pass through soil organisms before being utilized by crops.

Soil stability and erosion

Soil organisms play an important role in forming and stabilizing soil structure. In a healthy soil ecosystem, fungal filaments and exudates from microbes and earthworms help bind soil particles together into stable aggregates that improve water infiltration, and protect soil from erosion, crusting, and compaction. Macropores formed by earthworms and other burrowing creatures facilitate the movement of water into and through soil. Good soil structure enhances root development, which further improves the soil.

Water quality and quantity

By improving or stabilizing soil structure, soil organism dynamics help reduce runoff and improve the infiltration and filtering capacity of soil. In a healthy soil ecosystem, soil organisms reduce the impacts of pollution by buffering, detoxifying, and decomposing potential pollutants. Bacteria and other microbes are increasingly used for remediation of contaminated water and soil.

Plant health

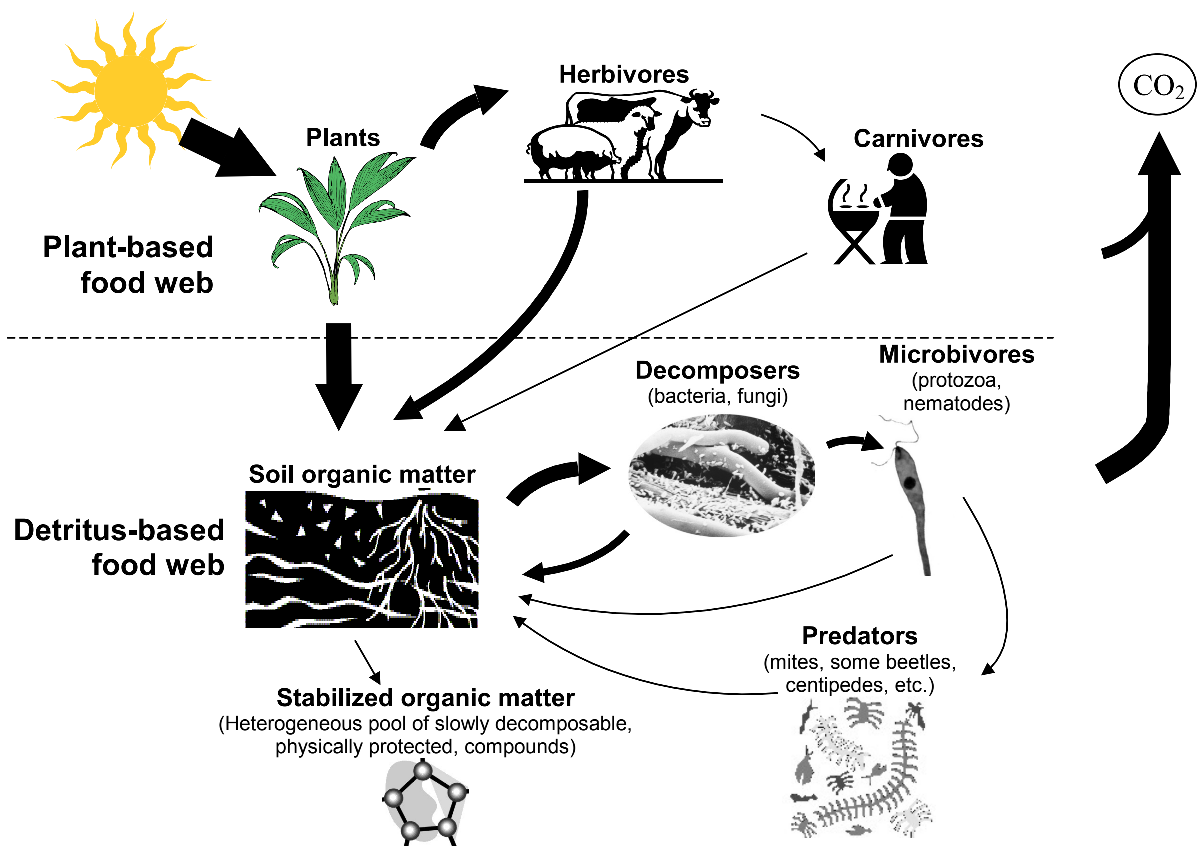
A relatively small number of soil organisms cause plant disease. A healthy soil ecosystem has a diverse soil food web that keeps pest organisms in check through competition and predation. Some soil organisms release compounds that enhance plant growth or reduce disease susceptibility. Plants may exude specific substances that attract beneficial organisms or repel harmful ones, especially when they are under stress, such as grazing.

For more information about what lives in the soil and how they function, see the "Soil Biology Primer" (Tugel and Lewandowski, 1999), and the soil biology glossary on the NRCS Soil Quality web site.

Complexity and function

Many soil biological functions emerge from the complex interactions of soil organisms and are not predictable by adding up the activity of individual soil organisms. How well the soil community performs each of these functions depends in part on the complexity of the biological community. Complexity is a factor of both the number of species and the different kinds or functions of species. Greater complexity may imply more diversity of functions and more redundancy of functions, and therefore more stability. For example, when multiple populations of microbes convert ammonium to nitrate, even if one population dies out, the function (nitrification) will continue to be performed. Functional redundancy is the underlying idea behind the "insurance hypothesis," which states that biodiversity insures ecosystems against declines in function.

Figure 1. The plant-based (aboveground) and detritus-based (belowground) food webs. Arrows represent energy flow (commonly measured in carbon units). Of the aboveground organic matter entering the pool of soil organic matter, 60%-80% of the carbon is eventually lost as CO_2. (Based on Chapin et al., 2002, Fig. 11.12.)



The underground community

Soil organisms can be grouped by size as shown in figure 2, or by functions as described below (Wardle, 2002; Coleman & Crossley, 1996).

Decomposers

Bacteria, actinomycetes (filamentous bacteria), and saprophytic fungi degrade plant and animal residue, organic compounds, and some pesticides. Bacteria generally, but not exclusively, degrade the more readily decomposed (lower C:N ratio) materials, compared to fungi, which can use more chemically complex materials. (See boxes on pages 7 and 8.) Bacteria often degrade what they can of a particular material; then fungi decompose the remainder.

Grazers and predators

Protozoa, mites, nematodes, and other organisms "graze" on bacteria or fungi; prey on other species of protozoa and nematodes; or both graze and prey. Grazers and predators release plant-available nutrients as they consume microbes. Often organisms specialize in one type of prey, such as either bacteria or fungi. Certain collembolans (springtails) even specialize on specific species of fungi. Other organisms are generalists and will feed on any microbial species they encounter.

Litter transformers

Arthropods are invertebrates with jointed legs, including insects, spiders, mites, springtails, centipedes, and millipedes. Many soil arthropods shred and consume plant litter and other organic matter, increasing the surface area accessible to decomposers. The organic matter in their fecal pellets is frequently more physically and chemically accessible to microbes than was the original litter. Some litter transformers, especially ants, termites, scarab beetles, and earthworms, are "ecosystem engineers" that physically change the soil habitat for other organisms by chewing and burrowing through the soil. Microbes (decomposers) living within their guts break down the plant residue, dung, and fecal pellets consumed along with the soil.

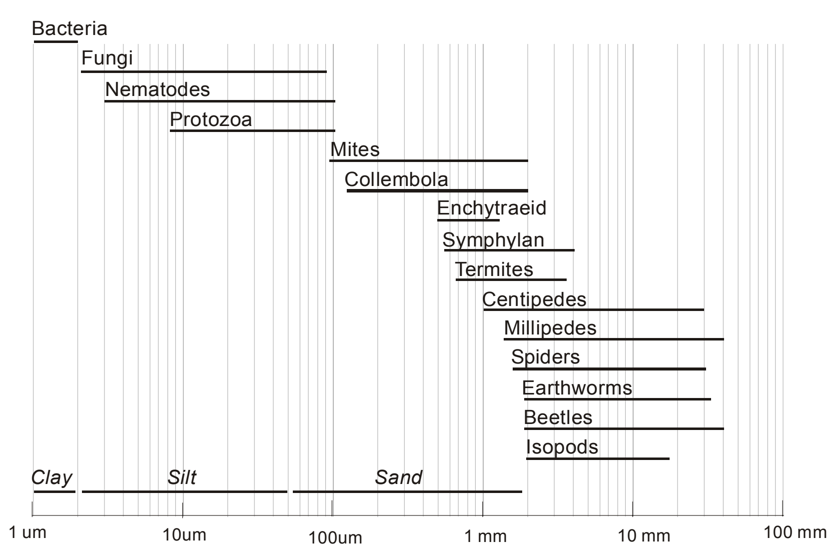
Mutualists

Mycorrhizal fungi, nitrogen-fixing bacteria, and some free-living microbes have co-evolved together with plants to form mutually beneficial associations with plants. Mycorrhizae are associations between fungi and plant roots in which the fungus supplies nutrients and perhaps water to the plant, and the plant supplies food to the fungi. These fungi can exist inside (endomycorrhizae) or outside (ectomycorrhizae) the plant root cell wall. The common arbuscular mycorrhizae (AM or VAM fungi) are endomycorrhizae.

Pathogens, parasites, and root feeders

Organisms that cause disease make up a tiny fraction of the organisms in the soil, but have been most studied by researchers. Disease-causing organisms include certain species of bacteria, fungi, protozoa, nematodes, insects, and mites.

Figure 2. Body width of soil organisms (Swift et al., 1979).



What controls soil biology?

People can adapt management strategies to affect the factors that control soil biological communities. Soil biological activity is determined by factors at three different levels. 1) At the scale of *individual organisms*, biological activity is determined by conditions such as temperature and moisture in the microbial habitats. 2) At the scale of *populations*, biological activity is determined by the amount of habitat diversity, the types of habitat disturbances, and the diversity and interactions among various soil populations.
3) At the scale of *biological processes*, functions such as nutrient cycling or pest control are affected by the interaction of biological populations with physical and chemical soil properties.

For example, consider the effect of tillage on earthworms at each of these scales. At the scale of individual organisms, a single tillage event may kill as many as 25 percent of individual earthworms. At the scale of populations, a single tillage pass may have little effect after a few months as the earthworms reproduce and rebuild their population. At the scale of soil processes, tillage will weaken soil structure over time and reduce the amount of surface residue available to fungi and earthworms. As fungal and earthworm activity declines, soil stability declines and alters the microhabitats for other organisms.

Microscale factors

The following environmental factors affect the types and activity levels of soil organisms. These factors may vary over short distances in the soil. Consider how each factor is impacted by climate, soil texture, time of day or season, and management practices including tillage, crop rotation, and irrigation.

Food (nutrients and energy)

All organisms require a source of food that supplies nutrients and energy. "Primary producers" are organisms that use photosynthesis to make their own food from sunlight and CO_2. "Consumers" are organisms that use organic compounds from other organisms as their source of both carbon and energy. A small group of bacteria get their energy from inorganic nitrogen, sulfur, or iron compounds, rather than from sunlight or organic compounds. These bacteria are important in cycling some nutrients required by plants. Soil organisms also require varying amounts of macronutrients (N, S, and P) and micronutrients (e.g. Fe, Cu, Zn). The amount of all these nutrients and the quality of nutrient sources will favor some organisms over others, depending on each species' requirements and preferences.

Oxygen

Animals and most soil organisms are obligate aerobes, meaning they require oxygen. Some bacteria are obligate anaerobes, meaning they require oxygen-free conditions to function. Many organisms are facultative anaerobes, meaning they can switch metabolic pathways and function as either aerobes or anaerobes depending on environmental conditions. Anaerobes use nitrate, sulfate, or iron instead of oxygen as an electron acceptor. Aerobic respiration is the most common form of metabolism and typically produces ten times more energy per unit of organic matter than that generated through anaerobic metabolism. Anaerobic conditions and anaerobic microbes dominate in marshes and other saturated soils. However, even well-drained soils can have anaerobic and aerobic microsites within millimeters of each other. See box (next page) for a list of processes performed by aerobic and anaerobic organisms.

Anaerobic soil biological processes

Fermentation – Conversion of sugar to alcohol.
Denitrification – Reduction of nitrate to gaseous nitrogen.
Methane production – Reduction of CO_2 to methane (CH_4) in marshes and rumens.
Sulfur reduction – Reduction of sulfate to hydrogen sulfide or sulfur.
Iron reduction

Aerobic soil biological processes

Respiration – The conversion of oxygen eventually to carbon dioxide and water.
Ammonification – The creation of ammonia from organic compounds. May also occur anaerobically slowly.
Nitrification – The oxidation of ammonium to nitrite and then nitrate.

Other physical factors

Moisture, temperature, light, pH, and electrical conductivity (salinity) are other critical factors determining the level of biological activity within an ecosystem. Each species has different optimal conditions, but overall bacterial activity is highest at temperatures between 20°C and 40°C, at pH levels between 6 and 8, and when pore spaces are about 60% water-filled. Soil texture and porosity determine the amount of space available for soil organisms and for the movement of air and water through the soil. Thus, porosity, aeration, and moisture levels are linked. Relatively larger organisms, such as nematodes and small mites (figure 2), require large pore spaces to move. Many organisms, including protozoa and nematodes, are essentially aquatic and require water films.

Community-scale factors

The microscale factors listed above directly affect soil organisms. However, to understand soil biological function we also have to consider large-scale factors such as heterogeneity of habitat, disturbances, and biological interactions.

Heterogeneity of resources

Heterogeneity can refer to variation in food sources or any of the other microscale conditions listed above. Heterogeneity of soil habitats creates diversity and complexity in the structure of the soil food web. Plant diversity is an important means for creating heterogeneity because plants affect the food sources, the physical habitat (e.g. root structures and soil structure), and the chemical attractants and deterrents for soil organisms.

Disturbance

All human land uses, especially agriculture, are subject to natural and human disturbances including fire, harvest, tillage, compaction, overgrazing, disease, or pesticide applications. The frequency, severity, and timing of disturbances determine their effect on soil biological activity. According to the intermediate disturbance hypothesis, the greatest level of biological diversity and stability occurs with a "Goldilocks" amount of disturbance – not so much that processes are continually disrupted, and not so little that just a few species gain dominance. Conventional cropping systems are highly disturbed systems. Low-input, conservation tillage systems with crop rotations may be an example of an intermediately disturbed ecosystem.

Interactions with other organisms

Soil populations are affected by interactions with other soil organisms. One type of biotic interaction is *competition* for limited food and habitat. A second type is *predation* by larger organisms, such as nematodes and mites. A third type is *mutualism* – interactions beneficial to both parties, such as those involving mycorrhizae, symbiotic nitrogen fixers, many rhizosphere microbes, and microbes living in earthworm guts. When land management practices disproportionately affect one group of organisms over another, they impact the interactions among soil organisms.

General management strategies

Four broad management strategies are presented below. The diversity and functioning of a soil biological community are likely to improve when these strategies are used. Management plans should consider both the timing of management practices and disturbances, and the duration and degree of their effects on soil biology. The effects of management and disturbances vary by season, and the capacity of the soil community to recover from a particular practice or disturbance ranges widely.

1) Manage organic matter.

Regular inputs of organic matter are essential for supplying the energy that drives the soil food web. Each source of organic matter favors a different mix of organisms. (See boxes, this page and next.) Thus, a variety of sources may support a variety of organisms. The location of the organic matter—whether at the surface, mixed into the soil, or as roots—also affects the type of organisms that dominate in the food web.

Under any land use, organic matter inputs to the soil can be increased by improving plant productivity and increasing annual biomass production. In particular, good root growth is important for building soil organic matter. High biomass production should be combined with other organic matter management practices including minimizing residue removal and tillage, growing cover crops, and adding manure, mulch, or other amendments.

Components of organic matter

Organic matter is composed of a heterogeneous mix of compounds with various chemical bonding and branching characteristics. Each organism has the necessary enzymes for decomposing some compounds but not others. For example, lignin is a recalcitrant organic compound that can only be broken down by white and brown rot fungi.

The composition of organic matter from plants varies considerably, but generally comprises 60-70% carbohydrates (polysaccharides),
15-20% lignin, and 15% other compounds including proteins, nucleic acids, lipids, waxes, and pigments.

2) Manage for diversity.

The diversity of plant assemblages across the landscape and over time promotes a variety of microbial habitats and soil organisms. Up to a point, soil biological function generally improves when the complexity or diversity of the soil biological community increases.

Many types of diversity should be considered, such as diversity of land uses (buffers, forest, row crops, grazing land), plant types (perennial, annual, woody, grassy, broadleaf, legume, etc.), root structures (tap, fibrous, etc.), and soil pore sizes. Diversity is desirable over time as well as across the landscape. Land managers can increase diversity with appropriate grazing management, patchy or selective tree harvest (in contrast to broad clear-cutting), vegetated fencerows, buffer strips, strip cropping, and small fields. These landscape features provide refuges for beneficial arthropods. Diversity over time can be achieved with crop rotations. Rotated crops put a different food source into the soil each year, encouraging a wide variety of organisms and preventing the build-up of a single pest species.

3) Keep the ground covered.

Ground cover at or near the surface moderates soil temperature and moisture; provides food and habitat for fungi, bacteria, and arthropods; and prevents the destruction of microbial habitat by erosion. Minimize the length of time each year that soil is bare by maintaining a cover of living plants, biological crusts, or plant residue at the surface.

Living plants are especially important as cover because they create the rhizosphere—that area within one or two millimeters of living roots where soil biological activity is concentrated.

Microbes around roots take advantage of plant exudates and sloughed-off root cells. Maintaining a rhizosphere environment is one of the important benefits of using cover crops. In addition to preserving microbial habitat, cover crops help build and maintain populations and diversity of arthropods by preserving their habitat for an extended portion of the growing season.

4) Manage disturbances.

Some soil perturbations are a normal part of soil processes, or are a necessary part of agriculture and other land uses. However, some disturbances significantly impact soil biology and can be minimized to reduce their negative effects. These disturbances include compaction, erosion, soil displacement, tillage, catastrophic fires, certain pesticide applications, and excessive pesticide usage.

Carbon-to-nitrogen ratio

The carbon-to-nitrogen ratio (C:N) of organic matter can vary from about 4:1 (low carbon, high nitrogen) for bacteria to more than 200:1 to 600:1 for woody materials. Ratios for wheat straw are about 80:1, and young legumes may be 15:1. The C:N ratio of soil organic matter in agricultural soils averages 10:1. Fungi have a fairly constant C content of 45%, but N levels vary, resulting in C:N ratios of 15:1 to 4.5:1.

Low N materials have a low nutritional quality for microbes. When organic materials are added to soil, the carbon triggers microbial growth. If the amount of N in the added material is inadequate to support the increased growth, the microbes will absorb nitrogen from the soil and immobilize it in their tissues, thus depriving plants of nitrogen, at least temporarily. As a rule-of-thumb, materials with C:N ratios less than 25 or 30:1 will not trigger this N deficiency in plants. Materials with lower C:N ratios tend to decompose quickly. Materials with higher C:N ratios are slow to decompose and can lead to carbon storage or sequestration in the soil when accompanied by additional nitrogen inputs in reduced tillage systems.

C:N ratios of soil organic matter provide clues about the microbial community. For example, higher ratios tend to support more fungi compared to bacteria. A labile pool of soil organic matter with a low C:N ratio implies that the SOM consists of a high proportion of microbes.

Compaction

Ideally, soils are approximately 50 to 60% pore space comprising a variety of pore sizes and lengths. The size and continuity of pores controls whether larger microbes, such as protozoa, can prey upon bacteria and fungi. Compaction reduces the diversity of pore sizes and the amount of space and pathways available for larger organisms (figure 2) to move through the soil. This favors bacteria and small predators over fungi and the larger predators. Arthropods are severely affected by compaction. Among nematodes, the predatory species are most sensitive to compaction, followed by fungal-feeders, then bacterial-feeders. Root-feeding nematodes are least sensitive to compaction—perhaps because they do not need to move through soil in search of food. Compaction changes the movement of air and water through soil, can cause a shift from aerobic to more anaerobic organisms, and may increase losses of nitrogen to the atmosphere (denitrification). Rooting depth may be limited in highly compacted soils. This restricts the depth of the rhizosphere environment that supports microbes.

Erosion and sedimentation

Most soil organisms – especially larger ones – live in the top few inches of soil. Erosion disrupts and removes that habitat. Sedimentation buries the surface habitat and deprives organisms of space and air.

Soil displacement and tillage

Displacement and mixing of the soil occur during many activites including tillage, land leveling, grading, intense grazing, and site preparation and harvesting on forestlands. Some soil displacement can be useful such as tillage for seedbed preparation in cropland, limited disturbances in highly productive grassland systems, and soil scarification to ensure success of some types of reforestation. However, soil disturbances significantly change the biological habitat of the soil. If the extent of the disturbance is limited to small areas, the overall impact will also be limited. Broadly applied practices such as tillage, grazing, or clear-cutting can impact large areas. Even a single tillage or compaction event can significantly affect the location and quantity of the food supply and the physical habitat of soil organisms. If enough nitrogen is present, tillage and other practices that mix the soil usually lead to a flush of microbial activity and nutrient release, and loss of soil organic matter via CO_2 respiration. Where there is a loss of soil organic matter, microbial activity will eventually drop to a rate that is lower than the initial rate. Over time, tillage shifts the food web from being dominated by fungi to being dominated by bacteria.

Pesticides and herbicides

All pesticides impact some non-target organisms. Heavy pesticide use tends to reduce soil biological complexity. Total microbial activity often increases temporarily as bacteria and fungi degrade a pesticide. However, effects vary with the type of pesticide and species of soil organism. Labels generally do not list the non-target organisms affected by a product. In fact, few pesticides have been studied for their effect on a wide range of soil organisms. Pesticides that kill aboveground insects can also kill beneficial soil insects. Foliar insecticides applied at recommended rates have a smaller impact on soil organisms than fumigants or fungicides. Herbicides probably affect few organisms directly, but they affect the food and habitat of soil organisms by killing vegetation. A pulse of dead vegetation may trigger a flush of biological activity and decomposition. Crop rotations are useful for breaking pest cycles, reducing pesticide application rates, and for varying the families of pesticides used.

Considerations for specific land uses

The effects of management practices, operations, and natural disturbances often are specific to particular land uses, such as those discussed in this section. Each of the considerations below relates to the general management strategies described in the previous section.

Cropland

The highly disturbed soils of cropland may have as many bacteria and protozoa as other ecosystems, but tend to have far fewer fungi, nematodes, and arthropods. Reduced tillage and perennial cropping systems will support more of these larger soil organisms.

Crop biomass additions

Roots and surface residue from crops are convenient and valuable sources of soil organic matter and food for soil organisms. Corn harvested for grain will generate 3 to 4 tons of surface residue per acre and 1 to 2 tons of root biomass. Dense, sod-type crops produce generous amounts of root biomass. Recent research suggests that root contributions are more significant for building soil organic matter than are contributions from aboveground plant residue.

Surface residue encourages the decomposers—especially fungi—and generally increases food web complexity. Residue provides food and habitat for surface-feeding organisms, such as some earthworms, and for surface-dwellers, such as some arthropods. It also changes the moisture and temperature of the soil surface, and protects soil organic matter from erosion. The residue will increase some pathogens and reduce others. Soybeans, peanuts, and many vegetables leave little surface residue and should be rotated with high residue crops or cover crops.

Animal manure

Dung pats provide food and habitat for a variety of larger soil organisms. Manure in any form is a significant source of nutrients. Manure application substantially changes the mix of organisms in the soil compared to plant sources of organic matter. The implications of these differences are not clear, but they probably affect disease levels and nutrient cycling. Over-application of N or P (whether from organic amendments or synthetic fertilizer) can suppress certain soil organisms, especially mycorrhizal fungi, as well as lead to degradation of air and water quality.

Compost

Compost can be used to inoculate the soil with a wide variety of organisms and to provide a high quality food source for them. Composts have also been credited with reducing the incidence of plant disease (Ceuster and Hoitink, 1999). Some species thrive in both compost and soil, but many prefer one or the other. For example, the redworms (*Eisenia fetida*) commonly used to make vermicompost do not survive well in soil. The quality of compost varies substantially depending on the material used, peak temperature during the composting process, and the level of aeration. Organic materials decomposed with little oxygen (e.g. liquid manure) will contain a very different set of organisms and compounds than well-aerated compost. (For information about how to make compost, see NRCS conservation practice standard #317, Composting Facilities.)

Sewage sludge

Like manure, sludge can be an excellent food source for organisms. However, high levels of metals or salts in some sludge kill or reduce the activity of some organisms.

Cover crops

Cover crops have several positive effects on soil communities. Most soil organisms live in the rhizosphere – the area directly around living roots. By planting cover crops (also called green manure) the rhizosphere environment is available to soil organisms for a longer portion of the year. Cover crops typically increase the amount and diversity of roots and aboveground growth that become part of soil. Because of each crop's unique physiology, populations of specific soil organisms will increase or decline depending on the crop. For example, some cover crops exude compounds that inhibit disease-causing organisms.

Inorganic fertilizers

Fertilizer provides some of the nutrients needed by soil organisms and will favor those species that can best utilize the forms of nutrients found in fertilizers. The effect of acidity, alkalinity, or salt of some fertilizers (e.g. ammonium nitrate, ammonium sulfate, and urea formaldehyde) tends to reduce populations of fungi, nematodes, and probably protozoa. It is not clear how persistent these population reductions are in various situations.

Judicious fertilizer use can be positive for overall biological activity because it increases plant growth and organic matter inputs to the soil.

Genetically modified (GMO) crops

Each type of GMO is likely to have a different effect on soil biology. For example, Bt crops seem to have little direct effect on the composition of the soil biological community, yet decomposition rates of the crop residue differ from that of other corn varieties – perhaps because of changes in plant lignin composition, which may indirectly affect soil organisms via changes in food resources. (Lignin is a plant compound that is highly resistant to microbial attack.) However, soil type and crop variety seem to be more important than the presence of the Bt gene in determining decomposition rates (Saxena and Stotzky, 2001a, b).

Drainage

Improved water drainage tends to improve microbial activity by increasing oxygen availability. Poorly drained soils have a high level of anaerobic microsites and therefore a higher rate of denitrification (conversion of nitrate to gaseous nitrogen) compared to well-drained soils.

Irrigation and salt build-up

Where irrigation increases plant yield, it increases biomass production and soil organic matter, and therefore tends to increase biological activity and to alter the biological community structure. However, irrigation water can contain salts. To prevent salt accumulation that can reduce biological activity and crop yield, additional water must be applied to leach these salts from the root zone. Some irrigation techniques, such as furrow irrigation, require extreme soil disturbance that is detrimental to biological habitat. When the disturbance is a one-time event (i.e., intense but infrequent), as with installation of subterranean irrigation pipes, the disturbance is less likely to do lasting damage.

Soil inoculants and compost tea

Some commercially available inocula are intended to increase populations of specific soil organisms. Some products have a long track record of effectiveness, including nitrogen-fixing bacteria and some pest predators, such as bacteria, nematodes, or insects. Some products are unproven or unpredictable.

Inoculants will have little effect or only a temporary effect if the organisms cannot compete in their new environment. Because they must have supplies of organic matter as a food source, soils low in organic matter will not see long-lasting results unless a recurring supply of organic matter is added to the system. Furthermore, many functions performed by soil organisms result from the interactions of organisms, not from a few individual species.

When considering using inoculants, ask the following questions:

- Do you have assurances that the organisms claimed to be in the product are viable?
- Will the organisms survive in your soil environment long enough to have the desired effect?
- If you achieve positive results, was the change caused by the inoculated organisms or by associated management

practices, such as changes in tillage or added organic matter?

Before committing a whole farm to a new product, test it on a small area and compare results to a control strip managed identically but without application of the product. Monitor both short- and long-term effects.

Land leveling

Land leveling may have effects similar to erosion and sedimentation because biologically active surface soil is removed from some areas and deposited in other parts of the field. It may also expose subsoil with a less desirable texture or lower organic matter levels. This effect can be reduced by intense soil building practices after land leveling or by removing and stockpiling the topsoil just prior to land leveling and then spreading it over the newly leveled surface.

Terraces and grassed waterways

Permanent vegetative structures add diversity to a landscape and thus can enhance the biodiversity of the area. They serve as a refuge for larger soil organisms such as arthropods and pest predators. However, like land leveling, the soil movement involved during construction of terraces can significantly disrupt soil biological habitat.

Tillage and no-till

Tillage enhances bacterial growth in the short-term by aerating the soil and by breaking apart soil aggregates to expose organic matter that had been protected from microbial decay. The bacterial activity increases the loss of carbon respired as CO_2, and triggers population explosions of bacterial predators such as protozoa. Ultimately, recurrent tillage reduces the amount of soil organic matter that fuels the soil food web.

The mechanical action of tillage tends to temporarily reduce populations of fungi, earthworms, nematodes, and arthropods. Over the long term with repeated tillage, these populations are likely to decline because of the lack of surface residue rather than because of the mechanical action of tillage.

The environment for soil organisms can differ significantly in no-till compared to conventionally tilled soils. For example, because the surface soil structure is not regularly disrupted, no-till soils are more likely to have:

- Anaerobic micro-environments,
- Cooler spring soil temperatures because of greater surface cover,
- More macropores to facilitate infiltration,
- Greater soil moisture and carbon near the surface, and
- Uneven distribution of organic matter throughout the topsoil.
- In addition, surface compaction may be a problem if compaction was present before the conversion to no-till, and if biomass inputs are low or traffic patterns are not controlled.

Organic matter decomposition rates are lower in no-till vs. conventionally tilled soils because of the lower level of soil disturbance. The lack of disturbance and the presence of surface residue encourage fungi and large organisms such as arthropods and earthworms. No-till soils generally have a higher ratio of fungi to bacteria.

Fallow periods

Because microbes concentrate around living roots, fallow periods of even a few weeks at the beginning or end of a growing season reduce an important microbial habitat. During long fallow periods, most arthropods will emigrate or die of starvation. Some organisms can form cysts, allowing them to lie dormant until conditions become more favorable. Mycorrhizal fungi also “starve” during a fallow period and take time to recover after the fallow period ends. Growing non-mycorrhizal plants is equivalent to a fallow year from the perspective of mycorrhizal fungi. Plants that do not support mycorrhizae include brassicas (mustard, broccoli, canola) and chenopods (beets, lamb’s-quarters, chard, spinach). (See section on mutualists, page 4, for more information about mycorrhizae.)

Forestland

Forest soils have high ratios of fungi relative to bacteria, especially under coniferous forests. The fungi are predominately ectomycorrhizae that infect tree roots and then extend their hyphae into the soil. This greatly increases the tree's effective root zone, allowing access to a greater area of soil from which to extract water and nutrients. The mantle created by mycorrhizae around the root also prevents pathogenic fungi and bacteria from attacking the root system.

Arthropods can be quite numerous in forests because the soil is rarely disturbed. Earthworms are common in deciduous forests, but rare among conifers. Where non-native earthworms (e.g., fishing bait) have been introduced into deciduous forests, significant changes in understory vegetation have been observed (Minnesota DNR, 2004).

Tree harvesting

Tree harvesting removes nutrients from the area, reduces the total uptake of nutrients by plants, and can accelerate biological activity and decomposition. Tree harvest can change the activity, amount, and diversity of the microbial community. The degree of site disturbance during harvesting and the amount of slash remaining after harvest determines the effects on soil organisms. Techniques that minimize soil disturbance and compaction will have the least detrimental effect on soil organisms. Tractors, wheeled skidders, and mechanized harvesting equipment disturb the soil surface and can cause compaction that restricts biological activity. Cable, helicopter, and horse logging produce the least disturbance. Soil surface displacement and mixing of soil, duff, and slash temporarily increase microbial activity and may interfere with arthropod activity.

Clear-cutting generally has a negative effect on soil biological activity. The large number of roads, skid trails, and landings compact soil and are particularly susceptible to erosion. When erosion and loss of mycorrhizal host plants is severe mycorrhizal fungi may be lost from the ecosystem. Compared to soil under trees, bacteria and actinomycetes, such as streptomyces, are more prominent in clear-cut areas, between trees in thinned areas, and between intact forest patches. When reclaiming clear-cut forests it is beneficial to inoculate new tree seedlings with mycorrhizal fungi, forest soils, or litter containing these fungi. Retaining patches of intact forests among clear-cut areas provides a source of soil organisms to re-inoculate the harvested areas.

Thinning and fuel management

Thinning of forests has a positive effect on soil biological diversity, especially in single-age stands. Thinning increases the diversity of understory vegetation and thus creates more diversity of habitats and food sources for soil organisms. (This is an example of the intermediate disturbance hypothesis described on page 6.) However, excessive compaction and soil displacement can have negative effects.

Roads, trails, and landings

Compaction created under roads, skid trails, and landings compresses soil particles together and reduces pore sizes. This restricts the habitat for soil organisms, especially the nematodes and larger arthropods. The use of designated skid trails and restoration of landings after harvest minimizes the amount of forestland affected.

Slash piling and woody debris

Machine or hand piling of slash concentrates nutrient-rich branches, foliage, and sometimes topsoil. This increases soil organism populations and activity locally. Excessive nutrient leaching can occur in areas where microbial activity increases. Windrowing of slash has severe detrimental effects on areas between windrows because topsoil rich in soil organisms is scarified and placed in the windrows. Runoff may also erode nutrient-rich surface soil and organic matter from slash areas, potentially degrading water quality of nearby streams and lakes.

Wind damage increases the amount of dead wood available for soil organisms. Woody debris can enhance biological function because dead wood mitigates environmental extremes, such as heat and cold, in the microclimate of a disturbed area. In forests, downed logs serve as centers for biological activity including mycorrhizal hyphae, nitrogen-fixing bacteria, other microbes, arthropods, and even small mammals. In some systems, fungi extract water from large rotting logs and supply the water to growing trees during times of moisture stress. Downed logs also serve as natural dams to help reduce erosion and increase infiltration and thus improve recolonization by desirable species in highly disturbed areas.

Fire

Stand replacement fires – Stand replacement fires are common in single age stands of fire-adapted tree species such as lodgepole pine, jack pine, longleaf pine and black spruce. Fire is an integral part of the ecology of these forests. The microbial community tends to drop back to its previous level of activity after an initial flush of activity after a fire.

Cool or patchy fires – Frequent ground fires are an integral part of some forest ecosystems, such as ponderosa pine stands. These fires are not hot enough to burn the overstory trees, but the understory trees and brush are killed. A short, cool fire rarely eliminates any group of organisms. If the fire is cool, nitrogen will not be volatilized, and the nitrogen in ash may stimulate plant growth and diversity of species. Arthropods will repopulate readily after a patchy fire.

Catastrophic wildfire – Hot, long-duration fires will kill most organisms, including microbes at or near the soil surface. The ignition of litter and duff as well as erosion after the fire reduces food available to soil organisms. The mineralization and subsequent leaching of nitrogen can significantly decrease soil fertility. Hydrophobic layers formed during hot fires can restrict the penetration of water into the soil for several years. This restricts plant and root growth thus reducing the food supply for soil organisms.

Insects and disease

The reduction of fire in some forests, such as Ponderosa pine forests, has led to an increase in insect infestations and disease. Diseased or dead trees increase the amount of woody debris that serves as fuel for hotter-burning, potentially catastrophic fires.

An invasion or increase of less disease-resistant tree species will make a forest stand more susceptible to insect infestation and disease.

Rangeland

Soil biological activity in rangelands may vary greatly over short distances. Activity may be high under shrubs and grasses and almost none in the bare spaces between plants.

Some seemingly bare spots are actually encrusted with soil organisms, such as cyanobacteria. Biological soil crusts are important for nutrient and water cycling, particularly in arid and semi-arid environments.

When plant assemblages change dramatically over time, for example, from grass- to shrub-dominated, the character of the soil biology may change to the extent that it may be difficult to convert the system back to the original plant assemblage with its associated soil community.

Grazing and vegetation management

Grazing and vegetation management are the most important tools for maintaining the benefits of the soil food web. Timely grazing, the proper frequency of grazing, and control of the amount of vegetation removed will maintain or enhance plant production and the supply of organic matter. Both overgrazing and non-grazing reduces root growth and thus the amount of organic matter inputs to the soil. Grazing stimulates root growth and production of root exudates, but overgrazing reduces the amount of leaf surface for photosynthesizing. (This is another example of the intermediate disturbance hypothesis. See page 6.) With reduced food supplies, biological activity decreases along with important soil functions, including nutrient cycling, water infiltration, and water storage. As these functions decline, the ability of the plant and soil biological communities to replenish soil organic matter also declines. Heavy grazing can reduce the abundance of nitrogen-fixing plants, causing a decrease in the nitrogen supply for the entire plant community. Where biological crusts provide important functions such as protection from erosion, the timing and intensity of grazing should be managed to minimize damage to crusts. Ensuring even manure distribution is another mechanism by which good grazing management enhances soil biological activity.

Fire

Prescribed burning in grassland communities generally produces cool temperature fires that have little or no direct effect on soil organisms. There can be short-term losses of habitat or food sources, but patchy fires leave refuges for larger soil organisms in adjacent unburned litter and grass.

Absence of fire or an increased length of time between fires commonly promotes vegetation shifts from grass-dominated to shrub- or tree-dominated plant communities. Such vegetation shifts affect the soil organisms through the change in residue composition and the depth of root zones that contribute food sources. Woody residue and roots will increase fungal populations. Bare soil between shrubs provides little food and will result in a decline in soil organism populations.

Catastrophic fire is likely to occur in dense shrub- or tree-dominated plant communities. The resinous wood and longer burn times promote hot fires that can effectively scorch the upper few inches of the soil. This will kill some soil organisms and reduce their food supply while also increasing the availability of some nutrients.

Invasive weeds

Invasive weeds can cause a shift in the types of soil organisms present because the quantity and quality of plant residue and root exudates will change. Weeds that cause increased litter buildup tend to promote more fungal dominance in soil. The encroachment of annuals into perennial plant systems will cause changes in organism community composition because soil biological activity corresponds with plant growth stages and periods of litter fall and root die-off.

Shrub removal

Removing shrubs by chaining, thinning, or applying herbicides promotes a shift to a different plant community and affects food sources for soil organisms. Less woody material and more herbaceous material will promote bacterial increases compared to fungi. Arthropod species will also change to those supported by the new plant community. As with tillage, the soil displacement and mixing that occurs during chaining will enhance bacterial decomposition of soil organic matter and residues. Compaction and herbicide effects, as described in “General Management Principles” above, may also be an issue during shrub removal.

Plowing and seeding

Plowing and seeding disturbances are related to the degree of soil mixing. Tillage that completely mixes or inverts the topsoil will result in a sudden, drastic change in habitat, increased organic matter decomposition rates, and thus reduced food sources for soil organisms. It also destroys larger pores and some macrohabitats. Use of a seed drill minimizes soil mixing and is much less of a disturbance to soil biology. Changes in the amount of residue either from plowing or the establishment of the seeded species will alter the food sources for soil organisms. Loss of residue can reduce or eliminate habitats for larger organisms in the food web, such as insects and arthropods.

Compaction from traffic

Grazing animals and vehicles may cause compaction, especially when traffic is concentrated in small areas or soil is too wet. See “General management strategies” for a description of the implications of compaction on soil biology.

Erosion

Off-road vehicle traffic or heavily used trails can create ruts that compact soil and channel water. The resulting accelerated erosion, rills, and gullies can strip or bury topsoil and have a negative effect on soil organisms. Erosion associated with vegetation shifts often results in the redistribution of topsoil, organic matter, resources, and habitat across short distances. At the shrub-intershrub scale, bare areas between shrubs provide the least habitat and resources for soil organisms. Areas of grass, shrubs, or trees have more diversity of soil organisms.

Assessment and monitoring

In contrast to soil physical and chemical parameters, there are few specific guidelines for managing soil biological properties. Thus, it is especially important that land managers track changes in soil biological functions over time to monitor the effects of management choices.

Monitoring is the identification of trends by systematically collecting quantitative data over time from permanently marked locations. Objectives for monitoring soil biological function include:

- Evaluation and documentation of the progress toward management goals,
- Detection of changes that may be an early warning of future degradation, and
- Determination of the trend for areas in desired condition, at risk, or with potential for recovery.

Assessment is the estimation of the current functional status of soil biological processes. It requires a standard for comparison. Objectives of assessments can be:

- Selection of sites for monitoring,
- Gathering of inventory data,
- Identification of areas at risk of degradation, and
- Targeting management inputs.

Techniques for measuring soil biological properties range from informal, qualitative observations to quantitative laboratory techniques. These techniques can be useful for learning about organisms' resource requirements and functions. However, soil biological tests can be difficult to interpret, and thus provide limited support for making specific management decisions. More information may be gleaned by assessing and monitoring properties affected by soil biological activity including soil surface stability (aggregate stability and slake tests), water infiltration rates (ring infiltrometer and rainfall simulation tests), decomposition rates, pest activity, and soil nitrate and carbon levels (microbial biomass and total organic carbon tests). These measures of soil properties assess the soil functions of interest to a land manager. However, they are likely to change more slowly than biological measures and thus are more delayed indicators. When deciding what to assess or monitor, keep in mind the objectives and the time and resources available.

For more about planning appropriate soil quality assessments see "Guidelines for Soil Quality Assessment in Conservation Planning" (NRCS, 2001c).

Types of tests

As discussed in the Soil Biology Primer, a variety of approaches can be used to describe the soil community, including 1) counting soil organisms or measuring biomass, 2) measuring their activity, or 3) measuring diversity, such as diversity of functions (e.g., biolog plates) or diversity of chemical structure (e.g. cell components or DNA). Each approach provides different information.

Methods for measuring biomass identify either the total number of organisms or only those that are active. A pitfall trap or Berlese funnel (NRCS, 2001b) can be used to collect larger organisms living in litter from a forest floor, pasture, or cropland.

Activity measurements provide a better understanding of soil biological function than do biomass measurements. One measure of biological activity is testing for various microbial enzymes (Dick, 1997). By choosing the appropriate enzyme, an enzyme assay can be used to assess the rate of carbon, nitrogen, or phosphorus cycling, or overall microbial activity. Enzyme assays have potential as a useful indicator and can be done with the equipment found in typical soil analysis labs, but most labs do not yet offer these tests.

Respiration, or the amount of CO_2 produced from the soil, is another measure of biological activity. The test can be done in the field (NRCS, 1998), but results are difficult to interpret. Respiration rates are extremely variable hourly, seasonally, and by region and soil type, so baseline or reference data are nearly meaningless. Furthermore, high respiration may indicate a healthy and active biological community, or it may indicate recent disturbance, such as tillage, that has triggered a flush of activity. High respiration represents a loss of soil carbon to the atmosphere, which is counter to the goal of carbon sequestration. Yet there are no guidelines for determining how much is too much. For these reasons, soil respiration tests can be useful in side-by-side demonstrations, but are of limited value as a soil biological indicator.

Cotton strip tests (NRCS, 1998 and 2001b) and a few other techniques measure decomposition rates over days or weeks, and therefore are not confounded by short term variation as much as are respiration tests. However, results are still difficult to interpret and require a standard or control for comparison.

With any of these measures of the soil biological community, refer to a specialist for help interpreting test results.

Get to know your community

To gain a general awareness of soil organisms and their effects, try these simple methods. Choose a few places to take a close look at what lives in your soil. Look under a shrub, in the woods, along a fence line, in a meadow, in a field, etc. Take time to examine the litter on the surface and look for organisms that move. Look for biotic crusts, burrows, fungal hyphae, and other evidence of soil organisms. Over the seasons, look for birds picking out earthworms behind a tillage implement. Observe the rate that dung pats decompose. Notice the amount of runoff or ponding after a rain.

Collecting samples for laboratory analyses

A small number of commercial labs will test soil biological properties. Typical measures are microbial biomass and direct counts of soil microbes. When choosing a lab and soil biology tests, consider the following.

- What quality control measures does the lab use to ensure reliable results?
- What is the significance of each test in terms of soil function?
- How will the test assist in your management decisions?
- Do interpretations of results consider your specific soil type and cropping systems?

The biomass (total amount of organisms) changes seasonally, but does not change drastically from day to day. However, activity levels (e.g., respiration) can change quickly, so note the time of year and the temperature and moisture conditions when sampling, and sample under similar conditions for future observations.

Samples should be placed in sealed bags and chilled (but not frozen) immediately.

Summary

Soil organisms are integral to soil processes, including nutrient cycling, energy cycling, water cycling, processing of potential pollutants, and plant pest dynamics. These processes are essential to agriculture and forestry, and for protecting the quality of water, air, and habitat. Therefore, land managers should consider the effects of their actions on the health and function of the soil biological community.

Despite the well-known importance of soil biological processes, the development of monitoring and management guidelines is in its infancy. However, land managers can learn the general principles of how their choices affect biological processes and can monitor changes in soil function.

Soil biological health generally improves when the following management practices are applied:

- Regularly adding adequate organic matter,
- Diversifying the type of plants across the landscape (in all land uses) and though time (in cropping systems),
- Keeping the ground covered with living plants and residue,
- Avoiding excessive levels of disturbances including soil mixing or tillage, compaction, pesticides, heavy grazing, and catastrophic wildfires.

References and further resources

Atlas, Ronald M. and Richard Bartha. 1981. Microbial Ecology, Fundamentals and Applications. Addison-Wesley Publishing Company, Inc.

Chapin, F.S.III; P.A. Matson, H.A. Mooney. 2002. Principles of Terrestrial Ecosystem Ecology. Springer-Verlag, New York.

Coleman, D.C., D.A. Crossley. 1996. Fundamentals of Soil Ecology. Academic Press, San Diego.

Ceuster, T.J.J. de. and H.A.J. Hoitink. 1999. Using compost to control plant diseases. Biocycle. 40(6):61-64.

Dick, R.P. 1997. Soil enzyme activities as integrative indicators of soil health. *In:* Biological Indicators Of Soil Health. New York : CAB International. P. 121-156.

Gilkeson, L., P. Peirce, M. Smith. 1996. Rodale's Pest and Disease Problem Solver. Rodale Press, Emmaus.

Gliessman, Stephen R. 1998. Agroecology: Ecological Processes in Sustainable Agriculture. Sleeping Bear Press.

Liebig, Mark and Tom Moorman. 1999. Soil Biology for the Northern Great Plains. USDA ARS and NRCS. Mandan, ND and Ames, IA.

Madigan, Michael T., John M. Martinko, Jack Parker. 1997. Brock Biology of Microorganisms, Eighth edition. Prentice Hall, Upper Saddle River, NJ.

Minnesota DNR. 2004. Invasive Earthworms [Online]. http://www.dnr.state.mn.us/exotics/terrestrialanimals/earthworms/index.html (verified 20Jan2004).

NRCS. 1997. Introduction to Microbiotic Crusts. http://soils.usda.gov/sqi/

NRCS. 1998. Soil Quality Test Kit Guide. http://soils.usda.gov/sqi/
The NRCS Soil Quality Test Kit Guide includes instructions and interpretations for tests of biological activity, aggregate stability, water infiltration and more.

NRCS. 2001a. Agricultural management effects on earthworm populations. Soil Quality─Agronomy Technical Note No. 11. http://soils.usda.gov/sqi

NRCS. 2001b. Soil Biology Classroom Activities. http://soils.usda.gov/sqi/ Describes methods for the pitfall trap, Berlese funnel, and cotton strip decomposition tests.

NRCS. 2001c. Guidelines for Soil Quality Assessment in Conservation Planning. http://soils.usda.gov/sqi/

NRCS. 2003. Glossary of Soil Biology Terms [Online]. http://soils.usda.gov/sqi/soil_quality/soil_biology/sbglossary.html (verified 19Jan2004).

NRCS. 2003. Conservation Practice Standards [Online]. http://www.ftw.nrcs.usda.gov/practice_stds.html (verified 19Jan2004).

Paul, E.A. and F.E. Clark. 1989. Soil Microbiology and Biochemistry. Academic Press, Inc., San Diego California.

Perry, David A. 1994. Forest Ecosystems. The Johns Hopkins University Press, Baltimore.

Reeder, J.D., C.D. Franks, and D.G. Milchunas. Root biomass and microbial processes. In: Follett, R.F., J.M. Kimble and R. Lal eds. The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. Lewis Publishers.

Saxena, D., G. Stotzky. 2001a. BT corn has a higher lignin content than non-BT corn. American Journal of Botany. 88(9): 1704-1706.

Saxena, D., G. Stotzky. 2001b. Bacillus thuringiensis (Bt) toxin released from root exudates and biomass of Bt corn has no apparent effect on earthworms, nematodes, protozoa, bacteria, and fungi in soil. Soil Biology and Biochemistry. 33(9):1225-1230.

Swift, M.J., O.W. Heal, and J.M. Anderson. 1979. Decomposition in terrestrial ecosystems. University of California Press, Berkeley.

Tugel, A.J. and A.M. Lewandowski, eds. 1999. *Soil Biology Primer*. NRCS Soil Quality Institute, Ames, IA.
The Soil Biology Primer is a colorful and easy-to-read introduction to the organisms that live in the soil and why they are important to agriculture and environmental quality. Copies are available through the Soil and Water Conservation Society at www.swcs.org or 1-800-THE-SOIL.

Wardle, David A. 2002. Communities and Ecosystems: Linking the Aboveground and Belowground Components. Princeton University Press. Princeton, New Jersey.

2021 NCF-Envirothon Nebraska
Soils and Land Use Study Resources

Key Topic #5: Nebraska and Its Place in the Great Plains

15. Describe the defining characteristics of the Great Plains.
16. Identify the ecological challenges associated with this part of the United States.
17. Describe how soil changes across the plains and why.
18. Describe the various soil regions within the state.
19. Explain how the different areas of the state differ in topography and parent material.

Study Resources

Encyclopedia of the Great Plains – *David J. Wishart, editor; University of Nebraska – Lincoln, 2011* (Page 89-95)

Center for Great Plains Studies – *University of Nebraska – Lincoln, 2021* (Page 96)

Nebraska Maps – *Excerpts from: Resource Report Number 2, May 1969, Soils of Nebraska by John A. Elder, Published by University of Nebraska Conservation and Survey Division, Lincoln. Pages 4-7., 1969; and Soil Areas of Nebraska, Nebraska Natural Resources Conservation Service, 2010* (Pages 97-99)

Holdrege: Nebraska State Soil – *Soil Science Society of America, 2021* (Pages 100-104)

<u>Study Resources begin on the next page!</u> ➡

Encyclopedia of the Great Plains

David J. Wishart (editor), University of Nebraska - Lincoln, 2011

PHYSICAL ENVIRONMENT

Soils

People in an overwhelmingly urban society naturally have a hard time grasping subjects like topography and climatology or geology and biogeography, for all these things are increasingly removed from daily life. They have an almost impossible time, however, trying to muster any interest in soil and soil geography, for these are subjects inescapably linked with pejorative terms like dirt. Like all soils, however, the soils of the Great Plains reflect all the other elements of the physical environment, which can at least in large part be deduced from the crumbly or sandy, moist or dry, warm or cold soil mantle that rests on the earth.

The grass of the Great Plains, after all, is responsible for the dark color that is one of the two diagnostic traits of Great Plains soils. The other diagnostic trait of these soils arises from the climate of the Great Plains and is an alkaline layer, usually calcium carbonate, which occurs at the lowest level in the soil that is seasonally saturated. The two traits overlap. Dark color extends well east of the Great Plains, but the alkaline layer is typical of arid climates and extends well to the west. Hence the logic underlying the statement of Curtis F. Marbut, a pioneer soil scientist, that the Great Plains is simply that part of the country where these two traits overlap.

In a monograph published in 1935 as a part of the USDA's great *Atlas of American Agriculture*, Marbut went on to develop this idea: he pointed out that there is an inverse relationship between light soil color and deep layers of carbonate accumulation. The darkest soils, that is, are found in the wetter east, where the zone of carbonate accumulation lies at a depth of about six feet. Farther west, soil colors are lighter because there is less soil moisture and therefore less organic matter. Here, however, the zone of alkaline accumulation is much closer to the surface. On the High Plains, it is so well developed that it forms an impervious layer of so-called caliche. Marbut mapped parent material and on this basis distinguished three groups of soils based on where they were formed: glacial deposits, windborne deposits, and from bedrock–the latter lying chiefly in Kansas and the non-panhandle parts of Oklahoma and Texas. Yet when Marbut came to formally classify the soils of the Great Plains, he chose to ignore parent material and instead focus on those two diagnostic criteria we have already noted.

The eastern edge of the Great Plains thus became for Marbut the line beyond which there was enough precipitation that soil moisture percolated through the entire soil profile; there was no permanently dry zone here, and therefore no zone of carbonate accumulation. West of that line, however, one came to what Marbut, using Russian nomenclature, called the chernozems: black soils, though much thinner than the chernozems of Russia. Marbut distinguished a belt of these chernozems centered roughly along the 100th meridian from the eastern Dakotas through central Kansas, western Oklahoma, and Texas as far south as the Rio Grande. East of these chernozems generally lay forested and acidic podsols in the north and "prairie soils" to the south–soils formed under grass but so humid that the soils were degraded. West of the chernozems lay lighter-colored "dark brown" soils that graded on the west into patches of "brown" soils, which occurred in the driest parts of the Plains.

In Canada, soil taxonomists still use this nomenclature, so that most Canadian prairie soils are mapped as chernozems in the wetter and encircling savanna but dark brown and brown in the drier core along the international boundary. In the United States, however, the soil taxonomy used by Marbut was replaced in 1960 by another system, one that introduced an entire lexicon of neologisms and which is therefore exceedingly difficult for all but experts to use comfortably. This new classification system distinguishes between Great Plains soils neither by parent material nor by color but chiefly by soil temperature and moisture. The Great Plains soils of the United States are thus now classed chiefly as mollisols, or soils formed under a cover of grasses and forbs. Subdivisions are then made on the basis of soil temperature, so that the soils of the Dakotas, where the mean annual soil temperature is below 47ºF, are recognized as borolls, while moister soils to the south are recognized generally as udolls or, in Texas, where mean annual soil temperature exceeds 72ºF, as thermic udolls. Further subdivision is made on the basis of soil moisture. East of the Missouri Coteau, for example, the soil is recognized as a udic boroll, while to the west the soil is classified as a typic boroll. Similarly, the soils of the Central Plains are divided into udolls when they have sufficient moisture for plant growth much of the year; where moisture is lacking for long periods, the soils are labeled as ustolls; where, as in southeastern Colorado, soils are usually dry and therefore low in organic matter, they are called ustic aridosols. Some soils, lacking profile horizons, are mapped instead as entisols: the most extensive areas are the Sandhills and the gray soils developed on the thin glacial debris of southeastern Montana.

It is easy for the layman to despair in the face of such verbal arcana, but there is one final point about soils that is easy to grasp. Like the groundwater and vegetation of the Plains, the soils of the Great Plains have not fared well in the last century. Estimates are that soil losses under range conditions on the Plains today average two tons per acre annually, while losses on cropland are twice that or more. The Southern and Central Plains have been hurt most, both by wind erosion on the High Plains south of the Arkansas River and by severe sheet erosion and gullying in the deep loess south of the Sandhills and in the once extensive cotton lands of Oklahoma. Nearly a century after Willard Johnson's warnings, the question of proper land use remains an open one in the Great Plains, and for all the work of the Soil Conservation Service since its creation in the 1930s, one can still drive for mile after mile across Oklahoma and see the deep and unhealed red scars etched by farmers a lifetime ago.

Author: Bret Wallach, University of Oklahoma

Sources:

Atwood, Wallace W. *The Physiographic Provinces of North America*. New York: Ginn, 1940.
Bostock, H. S. "Physiographic Regions of Canada," Map 1254A of the Geological Survey of Canada, 1970.
Fenneman, Nevin M. *Physiography of Western United States*. New York: McGraw-Hill, 1931.
Flores, Dan. "Bison Ecology and Bison Diplomacy: The Southern Plains from 1800 to 1850." *The Journal of American History* 78 (1991): 465-85.

Great Plains Flora Association. *Flora of the Great Plains*. Lawrence: University Press of Kansas, 1986.
Hammond, Edwin. "Analysis of Properties in Land Form Geography: Application to Broad-scale Land Form Mapping." *Annals*, Association of American Geographers 54 (1964): 11-19.
Kuchler, August Wilhelm. *Potential Natural Vegetation of the Coterminous United States*. New York: American Geographical Society, 1964.
U.S. Department of Agriculture. *Atlas of American Agriculture*. Washington DC: Government Printing Office, 1936.
U.S. Department of Agriculture. *Climate and Man*. Washington, DC: Government Printing Office, 1941.
U.S. Geological Survey. *The National Atlas of the United States of America*. Washington DC: Government Printing Office, 1970.
Visher, Stephen Argent. *Climatic Atlas of the United States*. Cambridge: Harvard University Press, 1954.
Weaver, J. E. *Prairie Plants and Their Environment*. Lincoln: University of Nebraska Press, 1968.

IRRIGATION

Center-pivot sprinkler irrigation system, Alberta

In response to moisture deficiency, farmers irrigate more than 20 million acres in the Great Plains. Plains irrigation gives water stability to agriculture, permits a wider diversity of crops than possible with rain-fed cultivation, and promotes economic growth through increased productivity and associated processing and livestock feeding activities. Irrigation is most commonly used in the western reaches of the region, where it is drier and there is available groundwater and rivers sustained by Rocky Mountain meltwaters.

Small-scale irrigation in the nineteenth century involved diverting water onto fields or using windmills to pump water from shallow aquifers. By 1900 community and corporate ditch irrigation enterprises were expanding on the Platte and Arkansas Rivers, and, through the efforts of Mormon settlers and railroads, along various rivers in southern Alberta. Windmills were commonly used to pump water for people, stock, and gardens from Texas north to the Dakotas and Manitoba. A huge windmill near Garden City, Kansas, provided enough water to irrigate fifteen acres.

In the American Great Plains large-scale irrigation began with the Reclamation Act of 1902 that authorized the secretary of the interior to construct reservoirs, diversion dams, and distribution canals in the West, including the Plains states. Subsequently, pump technologies of the 1930s made it possible to lift water from the Ogallala and other formations of the High Plains Aquifer. In the Prairie Provinces, the federal government of Canada and provincial government of Alberta passed legislation supporting irrigation. The Alberta Irrigation District Act of 1915 enabled farmers to organize into districts that could raise capital to finance construction of dams, canals, and other irrigation works.

The Canadian irrigation districts and American reclamation projects provide water to farmers through a system of dams on rivers, on- and off-stream storage reservoirs, diversion canals, and smaller ditches that lead directly to fields. Gravity flow is most common, but in some newer districts in Saskatchewan and rehabilitated facilities elsewhere, water is provided under pressure. Farmers receive a specified amount of water at a set price, with the district or project maintaining the diversion, storage, and distribution system. Farmers from Nebraska south to Texas pump groundwater directly from the Ogallala Aquifer. Each farmer holds the right to use a given amount of water, measured in acre-feet (the volume of water needed to cover one acre to a depth of one foot). Allocations usually range between two and three acre-feet a year. The depth to the aquifer varies greatly, but a majority of irrigators pump their water from between 100 and 200 feet. Electricity, diesel fuel, or natural gas power most of the pump engines. Alternative sources of water for irrigation, such as effluent from livestock operations or urban areas, provide water in limited areas.

Most Plains farmers apply water to their fields using either surface or sprinkler methods. The main form of surface irrigation is furrow, whereby furrows are plowed between crop rows along which water flows from a pipe with holes called gates. Furrow irrigation is employed when the land is relatively flat and the soils absorb water slowly. The leading form of sprinkler irrigation is the center pivot. It is a lateral pipe–with spray nozzles, often suspended on drop tubes and mounted on wheeled structures called towers–that is anchored at the center of the field and automatically rotates in a circle. A typical center pivot has a one-quarter-mile radius and waters approximately 130 acres. More or less ground can be irrigated by adding or subtracting pipeline and towers. Center-pivot systems require more capital investment than furrows, but they take less labor to operate and can water uneven terrain and fast absorbing soils.

Irrigation is most developed in areas of good soils where the saturated thickness is greatest or where irrigation districts and reclamation projects have diverted river flow. In 1998 Nebraska led the Plains states with more than 6.3 million irrigated acres, followed by Texas with more than 4.4 million irrigated acres in the Plains part of the state. Next in importance were Kansas (2.7 million acres), Colorado (1.7 million acres in the Plains), and Alberta (1.5 million acres). Montana, Oklahoma, New Mexico, South Dakota, Saskatchewan, Wyoming, and North Dakota each had between 180,000 and 800,000 irrigated acres; Manitoba irrigated some 32,000 acres. Most of the irrigated land in Nebraska, Texas, and Kansas relies on water from the High Plains

Aquifer system. At the beginning of the twenty-first century irrigated acreage continued to increase in nearly all areas.

A wide array of crops is irrigated in the Great Plains. Corn occupies about two-fifths of the irrigated land. Nebraska irrigates more than 4.7 million acres of corn and Kansas nearly 1.2 million acres. Hay, grown throughout the region, accounts for nearly 12 percent of the acres irrigated. It is relatively most important in Wyoming and Montana, where irrigated pasture is also significant. Irrigated wheat is most important in Oklahoma, Kansas, Alberta, and Texas. Grain sorghum is irrigated on about 1.4 million acres, nearly two thirds of which is in Texas, where feed grains are replacing once-dominant cotton. The irrigated area for all these crops is expanding, as it is also for soybeans, sugar beets, and potatoes.

The sustainability of irrigation in the Great Plains is threatened by soil salinization and by groundwater depletion. Most irrigation-induced soil salinity results from water losses in transport, where seepage from canals raises the water level and brings natural salinity nearer to the surface and within the root zone of crops. Lining irrigation canals and ditches reduces the problem, but it can be very expensive. In Alberta much of the 4,500 miles of canals in the conveyance system has been rehabilitated in this way. Poor on-farm management of irrigation water also can cause salinity, especially in low-lying areas where water ponds and soil become salinized after evaporation. Soils with saliency programs can be reclaimed if the water table is brought below the root zone and the excess salts are leached out of the soil. The depletion of the High Plains Aquifer concerns farmers, as saturated thickness (the vertical extent of the watered zone in the aquifer) is limited in many areas, especially in Texas and New Mexico, and recharge is minimal. In some areas there is not enough water remaining to support irrigation. The distance to the water increases as irrigation lowers the water table, and lifting water becomes too costly when energy prices are high. There also is concern for groundwater quality when agricultural chemicals reach an aquifer.

In response to groundwater depletion, the desire to increase irrigation, and competing demands for water, irrigation efficiency has become a priority for most Plains irrigators. Water-saving practices have been widely adopted by farmers. Furrow irrigation has become less water-consumptive through the use of surge flow, whereby water is intermittently released from the gated pipes to discharge in surges that achieve relatively even watering along the entire length of a row. Center-pivot sprinklers are being fitted with low-energy precision application (LEPA) systems that use low-pressure emitters on drop tubes to apply the water directly on or near the soil. Drip irrigation, wherein water drips or trickles from perforations in a low-pressure pipe placed alongside the base of a row of plants, and subsurface drip irrigation, with the water carried directly to the root of the plants, have moved from experimentation to actual field use. Most farmers employ some form of irrigation scheduling to apply only the water required by a crop under different evaporative conditions. Water-saving innovations extend the available water supplies to assure the continuance of irrigation in the Great Plains.

Author: David E. Kromm, Kansas State University

Sources:
Green, Donald E. Land of the Underground Rain: Irrigation in the Texas High Plains, 1910–1970. Austin: University of Texas Press, 1973.

Kromm, David E., and Stephen E. White, eds. Groundwater Exploration in the High Plains. Lawrence: University Press of Kansas, 1992.

DUST BOWL

Dust cloud rolling over western Kansas town, February 21, 1935

The Dust Bowl was an area of drought and severe wind erosion in southwestern Kansas, southeastern Colorado, northeastern New Mexico, and the panhandles of Oklahoma and Texas during the 1930s. This area extended approximately 400 miles from north to south and 300 miles from east to west, although the boundary was never precise because of fluctuations in annual precipitation.

The area was first given the name "Dust Bowl" by Robert E. Geiger, a reporter for the Washington DC Evening Star, who used the term in an article following a severe dust storm, known as a black blizzard, on April 14, 1935. Soon, the Soil Conservation Service and the public were using the phrase Dust Bowl to identify the area of the Southern Great Plains that experienced the worst drought, wind erosion, and dust storms.

Although drought and dust storms are natural phenomena in the Great Plains, it was the rapid expansion of wheat production following World War I that destroyed soil-holding native grasses and created the Dust Bowl. After drought ruined the wheat crop during the autumn of 1931, the prevailing winds began to lift the soil and plague the region with dust storms by late January 1932.

As the drought and dust storms worsened during the mid-1930s, the federal government responded to the economic and technical needs of the drought-stricken farmers in the Dust Bowl with a host of programs. The Agricultural Adjustment Administration provided funds to farmers who agreed to limit wheat and cotton production, while the Commodity Credit Corporation offered price supporting loans on these crops. The Soil Conservation Service demonstrated terracing, strip cropping, and grass seeding techniques that prevented wind erosion and provided financial assistance that enabled farmers to apply these techniques. The Resettlement Administration and the Farm Security Administration furnished loans to the most destitute farmers who could not receive credit from other lending institutions to sustain their families and agricultural operations. The Farm Security Administration also purchased wind-eroded lands from farmers and returned those areas to grasslands. Originally known as land utilization projects, they are now identified as national grasslands.

In 1935 the Resettlement Administration filmed the documentary The Plow That Broke the Plains, hoping to gain public and congressional support for its program to resettle people from the worst of the eroded lands. In 1937 Life magazine published several paintings by Alexandre Hogue that depicted conditions in the Dust Bowl. Residents of the Dust Bowl criticized these works because they seemed to place the blame for the dust storms on the farmers and their new laborsaving technology, such as tractors and combines, rather than on drought. In 1940, Congress ordered the film withdrawn from circulation.

In 1938 wind erosion began to diminish with the return of near-normal precipitation to many areas of the Dust Bowl. By 1940 the drought on the Southern Great Plains had ended. The federal programs that had helped farmers remain on the land, practice soil conservation, and endure the economic crisis of the Great Depression were not without their critics. Given the problems of drought, dust, and economic depression, however, these programs provided essential assistance at a time when abnormal climatic conditions and poor farming practices created unprecedented wind erosion and earned the Southern Great Plains its reputation as the Dust Bowl.

Author: R. Douglas Hurt Iowa State University

<u>Sources:</u>

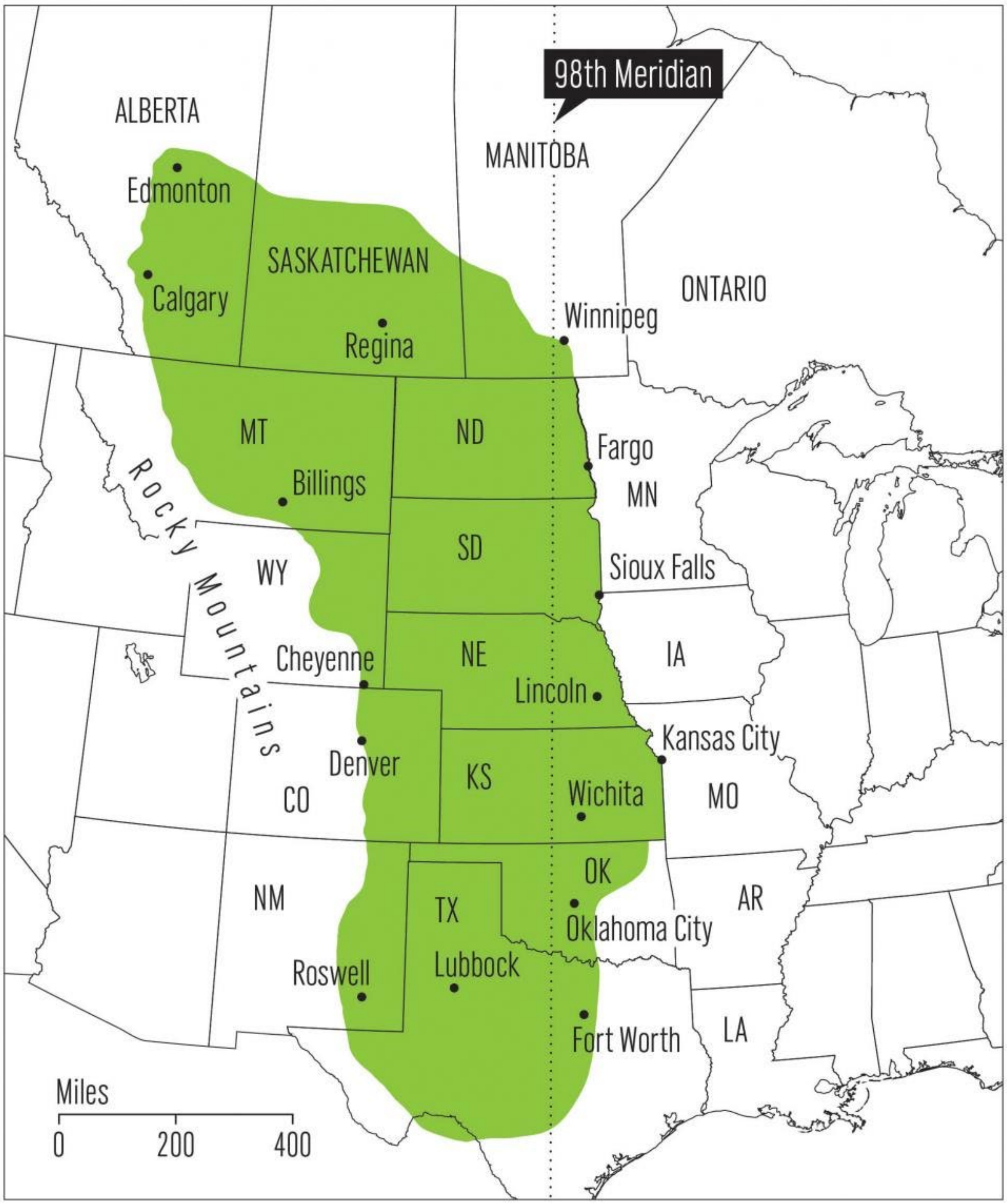
Hurt, R. Douglas. The Dust Bowl: An Agricultural and Social History. Chicago: Nelson-Hall, 1981.

Riney-Kehrberg, Pamela. Rooted in Dust: Surviving Drought and Depression in Southwestern Kansas. Lawrence: University Press of Kansas, 1994.

Worster, Donald. Dust Bowl: The Southern Plains in the 1930s. New York: Oxford University Press, 1979.

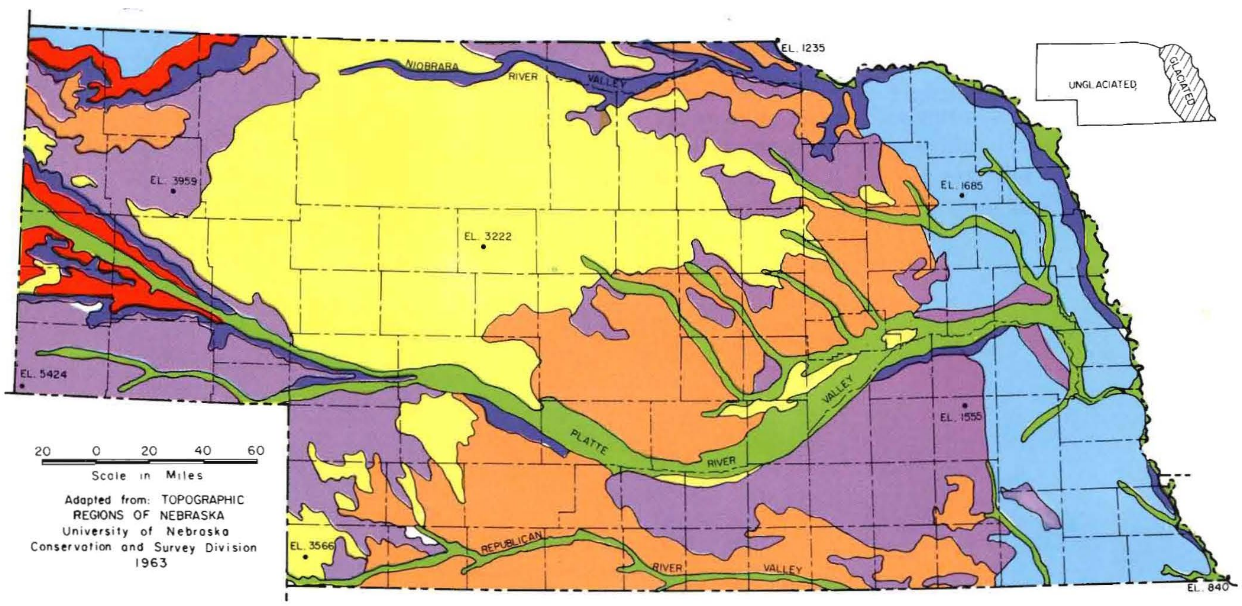
Center for Great Plains Studies

University of Nebraska – Lincoln, 2021
https://www.unl.edu/plains/about/map.shtml



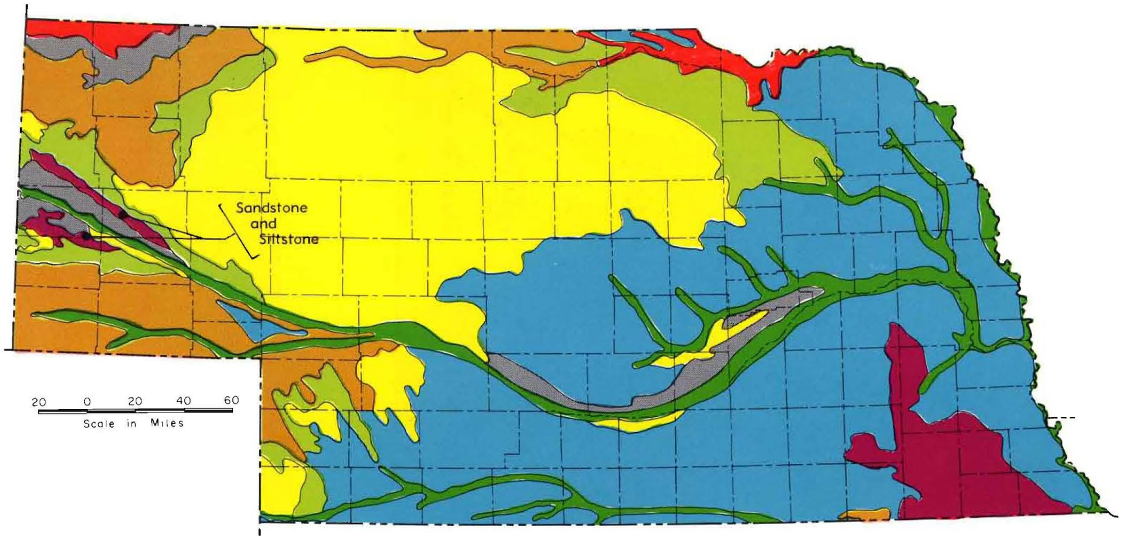
Nebraska Maps

Excerpts from: Resource Report Number 2, May 1969, Soils of Nebraska by John A. Elder, Published by University of Nebraska Conservation and Survey Division, Lincoln. Pages 4-7., 1969; and Soil Areas of Nebraska, Nebraska Natural Resources Conservation Service, 2010



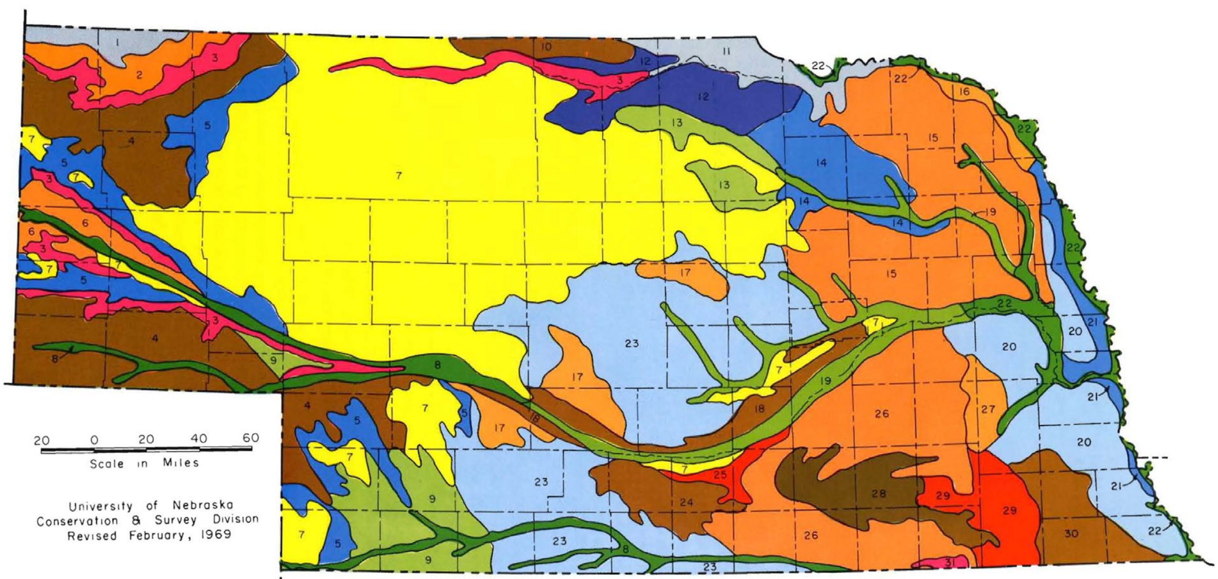
TOPOGRAPHIC REGIONS OF NEBRASKA

VALLEYS
DISSECTED PLAINS
ROLLING HILLS
VALLEY-SIDE SLOPES
PLAINS
SANDHILLS
BLUFFS & ESCARPMENTS
•EL. ELEVATIONS



SOIL PARENT MATERIALS

SHALE	SAND AND SILT	ALLUVIUM	LOESS AND DRIFT
SANDSTONE	SAND	LOESS	LOESS AND ALLUVIUM

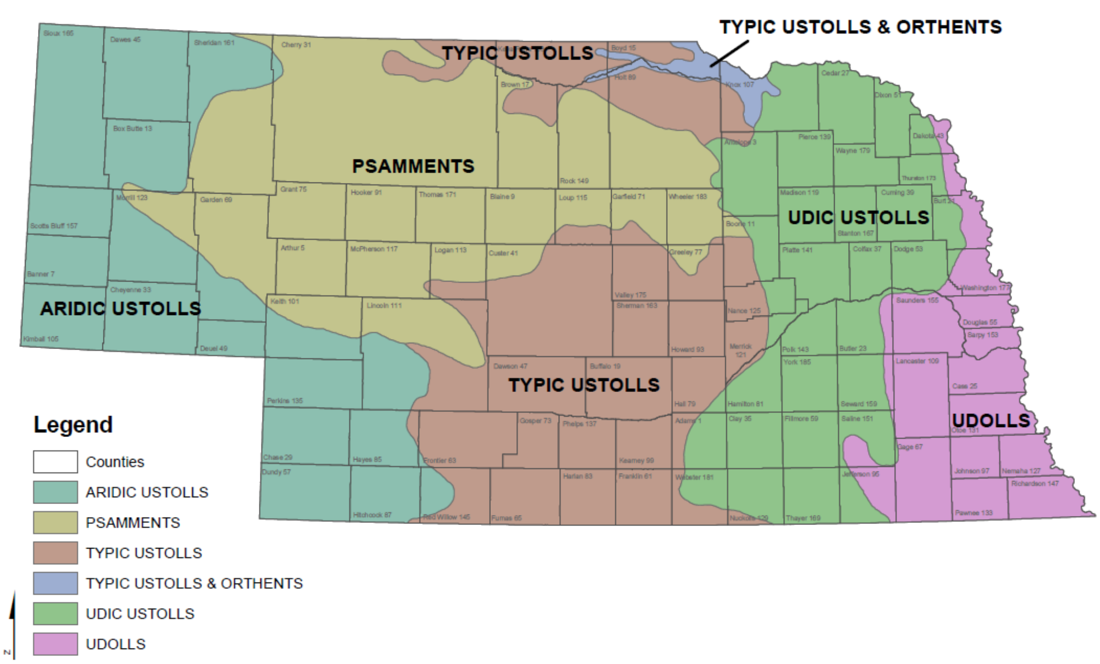


NEBRASKA SOIL ASSOCIATION MAP

1 – Pierre – Samsil
2. – Bridgeport – Keith
3. – Rough broken land
4 – Keith – Rosebud
5. – Anselmo – Keith
6. – Mitchell – Tripp
7 – Valentine – Dunday
8. – McCook – Las
9. – Keith – Colby
10. – Holt – Valentine
11 – Reliance – Boyd
12 – Thurman – Jansen
13 – Loup – Valentine
14 – Thurman – Valentine
15 – Moody – Crofton
16 – Crofton – Nora
17. – Colby – Ulysses
18. – Hall – Wood River
19 – Leshara – Platte
20. – Sharpsburg – Marshall
21 – Marshall – Monona
22. – Luton – Haynie
23 – Holdrege – Colby
24 – Holdrege – Hastings
25. – Kenesaw – Holdrege
26 – Hastings – Crete
27 – Sharpsburg – Shelby
28. – Crete – Fillmore
29. – Crete – Wymore
30 – Wymore – Pawnee
31 – Lancaster – Hedville

RELIEF MAP OF NEBRASKA

Soil Areas of Nebraska



Sources: Nebraska Natural Resources Conservation Service State Office. 2010. Soil Areas of Nebraska. Nebraska Natural Resources Conservation Service, Lincoln, NE.

NRCS Natural Resources Conservation Service

NE - T.G. Notice 614, Section I, NRCS - July 2010

Holdrege
Nebraska State Soil

Soil Science Society of America

Introduction

Many states have a designated state bird, flower, fish, tree, soil, rock, etc. And, many states also have a state soil - one that has significance or is important to the state. The Holdrege is the official state soil of Nebraska. Let's explore how the Holdrege is important to Nebraska.

History

The Holdrege Soil was first described as separate from surrounding soils in 1917 in Phelps County, NE and named for the nearby community of Holdrege. It was selected by the state legislature in 1979 to represent the soil resources of the state as the Official State Soil. Agriculture and soil are very important aspects of Nebraska's economy.

What is Holdrege Soil?

The Holdrege soils are very deep with small and medium (*clay* and *silt*) sized soil particles that result in excellent water storage but may restrict water movement through the soil. Every soil can be separated into three separate size fractions called *sand*, *silt*, and *clay*, which makes up the *soil texture*. They are present in all soils in different proportions and say a lot about the character of the soil.

The soil particles were originally deposited by wind and stabilized by tall- and mixed-grass prairie. Lands that have been cleared for agriculture have great potential for wind *erosion*. The soil is generally found on flat (less than 4%) slopes and has high natural fertility making it excellent for use in agriculture when conservation practices are observed.

Where to dig a Holdrege

Yes, you can dig a soil. It is called a soil pit and it shows you the *soil profile* **(Figure 1)**. The different horizontal layers of the soil are actually called *soil horizons*. Holdrege soils occur on about 1.8 million acres in south-central Nebraska. The Holdrege is most often found in the highlighted region of the below map **(Figure 2)**. This does not mean that other types of soil are not found in that portion of the state, just that Holdrege is very common.

Importance

The south-central region of the state, where Holdrege is common, has the greatest concentration of high yielding irrigated corn production in Nebraska **(Figure 4)**. Nebraska ranks third in the U.S. production of corn grain, and Holdrege is one of the many healthy soils that allow this high yield production because of its high natural fertility and high water storage capacity.

Photo: Chip Clark/Smithsonian Institution

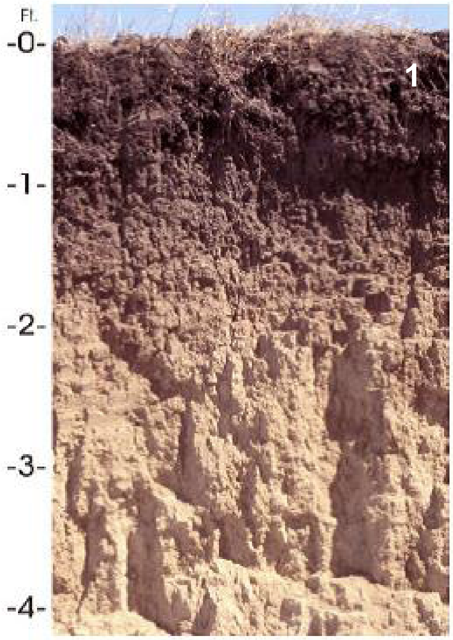
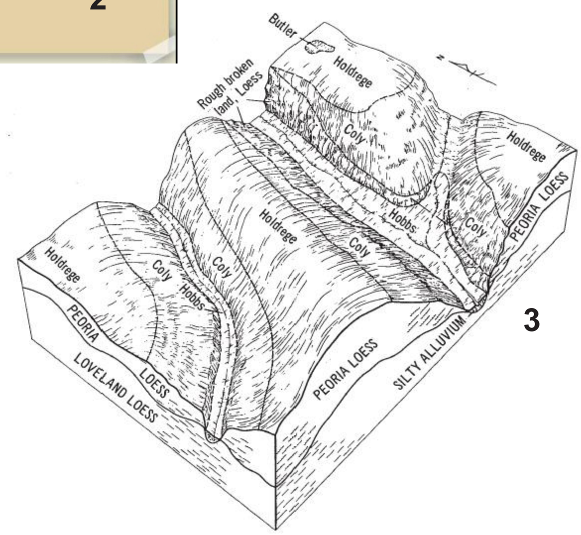


Fig. 1 Holdrege soil profile showing dark top layer due to addition of organic matter from prairie grasses. Source: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=stelprdb1236841

Fig. 2 Holdrege soil series are the most common in the south central part of Nebraska. Source:http://forces.si.edu/soils/interactive/statesoils/index.html

Fig. 3 Holdrege soil is formed on flat upland portion of the landscape which is stable and promotes soil development. Source: NRCS. Soil Survey of Phelps County, Nebraska..



Uses

Soils everywhere are used for agriculture (growing fibers, fuels, and foods for people and animals); support engineering (roads, buildings, tunnels); recreation (ball fields, playgrounds, and camping areas); natural ecosystems (wetlands); and more.

The Holdrege is extensively used for agriculture. Most of this for corn production, but also for other crops including wheat, soybean, sorghum, and alfalfa. Some areas are also used as pasture and rangelands for cattle production.

Some towns are settled on Holdrege soil. How would you feel if your house was built on the State Soil? Special, I think.

Limitations

While soil underlies nearly everything humans do, some soils are not as well suited for one or more of the uses discussed above. This is referred to as a "limitation". Soils with limitations required special management and adaptations in order to be able to carry out the intended use without damaging the soil.

Soil experts, called *Soil Scientists*, have studied the suitability of Holdrege soils for various uses and have determined that there are few limitations to restrict the use of Holdrege soils for construction, recreation, or crop production. The major limitation is that the fine grained particles at the soil surface easily dislodge creating *erosion* hazard and dusty conditions during use.

Holdrege soils have no limitations for support of buildings and homes with and without basements; however, those homes may not be able to use traditional septic systems because the fine textured soil restricts water movement.

The Holdrege soils are generally rated as class II and III for agricultural production. High potential for *erosion* and limited rainfall are the features that keep these flat, fertile soils from attaining the highest rating of class I.

Management

The primary limitation is also the main management concern for use of the Holdrege and other soils in Nebraska. It is critical to minimize *erosion* and preserve soil resources for a sustainable future. The keys to reducing *erosion* are to keep the soil surface covered and to reduce disturbance of the soil surface **(Figure 5)**. Keeping the soil surface covered can be accomplished by leaving more residue in the field after harvest or using mulches in gardens and construction sites. Soil disturbance can be reduced by reducing tillage in crop fields and only disturbing areas necessary during construction.

No-till is a practice for crop production where the field is not plowed between crops. This means the soil is not disturbed. It also leaves residue on the soil surface rather than bury it under ground. No-till has also been proven to allow more water to be stored in the *soil profile*. Since Nebraska is a state with limited natural rain and increasing groundwater use restrictions for *irrigation*, increasing the water storage of the soil profile is beneficial to crop production.

The region where Holdrege commonly experiences a good deal of wind *erosion* **(Figure 6)**. In addition to increasing ground cover and reducing disturbance, management practices that reduce wind access to soil are also beneficial for reducing *erosion*. One example of such a practice would be to plant tree wind breaks at field borders. Trees lift winds and protect the soil surface for a distance 10 times the height of the wind break. Reduced winds will also reduce evaporation and water losses from the soil (leaving more water for plant growth).

Fig. 4. Irrigation is a major source of water for growing corn on the Holdrege soil.Photo credit: Wale Adewunmi

Irrigation water management is an important concern in central Nebraska. Soil scientists recommend using low pressure sprinklers or other systems designed to increase water use efficiency and decrease water *erosion* caused by *irrigation* water.

Holdrege Soil Formation

Before there was soil, there were rocks, and in between, ClORPT. Without ClORPT, there will be no soil. So, what is ClORPT? It is the five major factors that are responsible for forming a soil like the Holdrege. These are **Cl**imate, **O**rganisms, **R**elief, **P**arent material, and **T**ime. The ClORPT is responsible for the development of soil profiles and chemical properties that differentiate soils. So, the characteristics of Holdrege soil (and all other soils) are determined by the influence of ClORPT. Weathering takes place when environmental processes such as rainfall, and freezing and thawing cycles act on rocks causing them to dissolve or break into pieces. After weathering, ClORPT acts on rock pieces, deposited sediments, and vegetative materials to form soils.

Climate – Temperature and precipitation influence the rate at which parent materials weather, and dead plants and animals decompose. They affect the chemical, physical and biological relationships in the soil. Holdrege soils formed in areas with relatively low annual rainfall, resulting in less horizon development than wetter regions, and therefore are considered young soils. There has been enough precipitation for *clays* and *carbonates* to move in the soil creating some horizon development.

Organisms – This refers to plants and animal life. In the soil, plant roots spread out, animals burrow in, and bacteria break down plant and animal tissue. These activities and others speed up the breakdown of large soil particles into smaller ones. Plants and animals also influence the formation and differentiation of *soil horizons*. Plants determine the kinds and amounts of *organic matter* that are added to a soil under normal conditions. Animals breakdown complex compounds into small ones and in so doing add *organic matter* to soil. Holdrege soils formed under prairie grasses, the extensive roots of which led to being high in *organic matter* (which increases its fertility) and excellent for crop production. Darker soil colors indicate greater *organic matter* content **(Figure 1)**.

Relief –Landform position or relief describes the shape of the land (hills and valleys). The steepness of a location and the direction it faces make a difference in how much sunlight the soil gets and how much water it stores. Deeper soils form at the bottom of the hill rather than at the top because gravity and water move soil particles downhill. Holdrege soils formed on relatively flat *upland* landscapes **(Fig.3).** Soils on flat *upland* surfaces are more stable and therefore have more development than those found on slopes, which experience *erosion*, or lowlands, which experience *deposition*.

Fig. 5. Maintaining ground cover by leaving crop residue on the soil is one of the conservation practices to reduce soil loss by wind erosion. Photo credit: Wale Adewunmi

Fig. 6. Holdrege soil is prone to wind erosion of fine soil particles of silt size. Conservation management practices must be used to prevent this type of soil loss.

Parent material (C horizon) – Just like people inherit characteristics from their parents, every soil inherited some traits from the material from which it formed. Some soils form into bedrock but many have parent materials that were transported and deposited by glaciers, wind, water, or gravity. The Holdrege soil formed in *loess* (pronounced luss), which is fine grained (typically *silt* sized) material that has been deposited by blowing wind. Calcium *carbonates* present in these *loess* deposits can still be seen in the deeper, undeveloped part of the *soil profile* known as the C horizon.

Time – All the factors act together over a very long time to produce soils. As a result, soils vary in age. The length of time that soil material has been exposed to the soil-forming processes makes older soils different from younger soils. Generally, older soils have better defined *horizons* than younger soils. Less time is needed for a soil profile to develop in a humid and warm area with dense vegetative cover than in a cold or dry area with sparse plant cover. More time is required for the formation of a well-defined *soil profile* in soils with fine textured material than in soils with coarse-textured soil material.

Ecoregions, Soils, and Land Use in Nebraska

Nebraska is a large state with great soil diversity. It also has much more topography than it generally recieves credit for. The windy nature of the state has created topography from loess hill deposits and sand dunes. However, of the six recognized *ecoregions* of the state, five are considered plains and are made up of soil that is dominantly silty in nature **(Fig.7)**. The portion of the loess hills that are in Nebraska fall into the Western Corn Belt Plains *ecoregion*.

The three main plains areas (Western High Plains, Central Great Plains, Western Corn Belt Plains) can trace their separation to climate. The drier, western area was dominated by short grass prairie; the soils of this region are the least developed and have the shallowest *horizons*. The wetter, eastern plains (part of the Corn Belt) were dominated by tall grass prairie and have the deepest, most developed soils of the state. The central region was stabilized by mixed-grass prairie. These *ecoregions* are all suitable for and dominantly used for agriculture with higher water use crops (corn and soybeans) grown in the eastern portion of the state and lower water use crops (sunflower and dry beans) grown in the western portion of the state.

The sixth *ecoregion*, the Nebraska Sand Hills, is where Nebraska finds its greatest ecosystem diversity. The sand hills are both the largest sand dune complex in the Western Hemisphere and the largest wetland system in the United States with a number of seasonal and alkaline lakes also present to house great wildlife diversity. The Sand Hills are a fragile ecosystem that is laregely unsuitable for crop production or urban infrastucture but has proven very successful as rangeland for cattle production and habitat for wildlife and game.

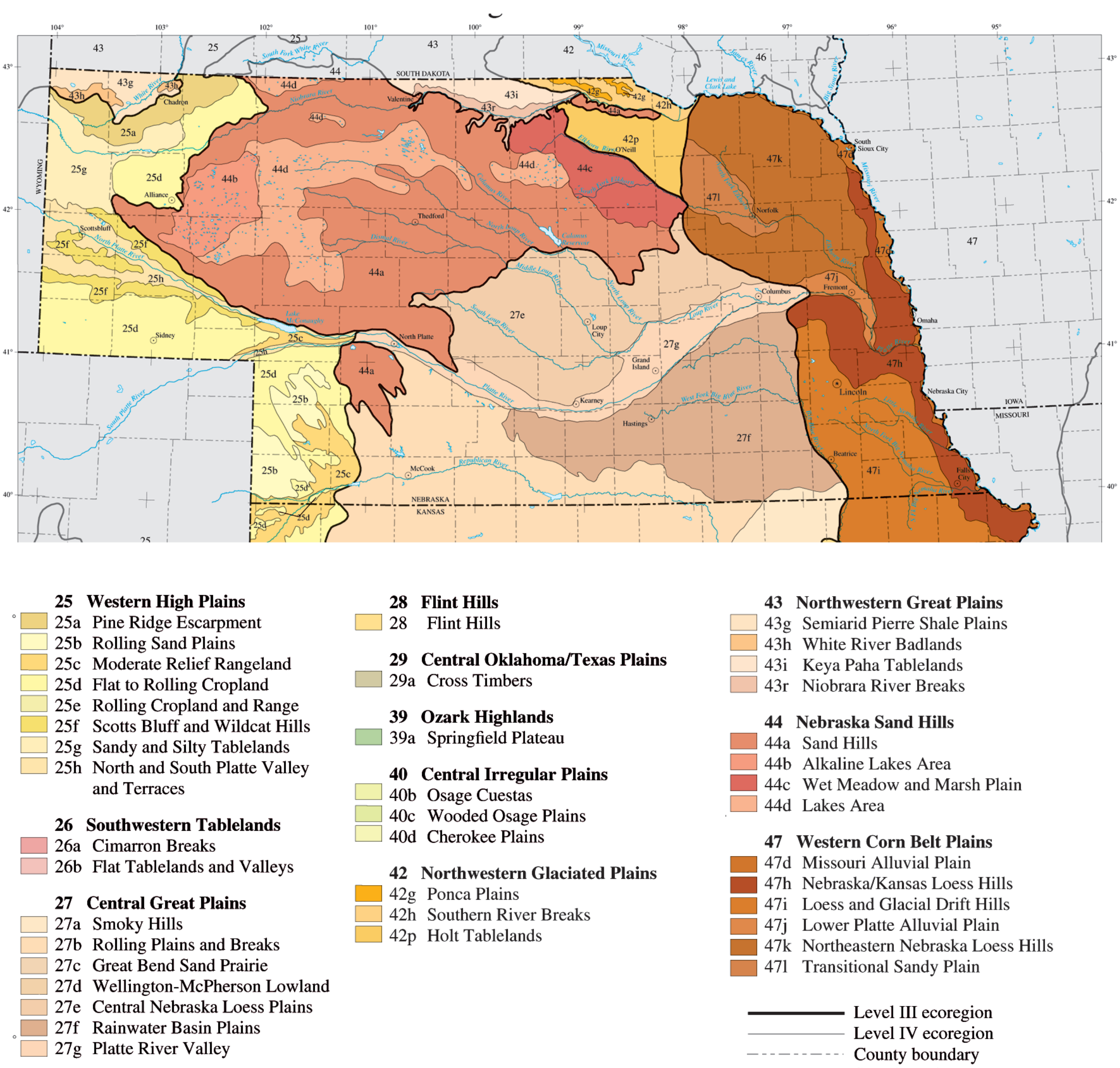


Fig. 7. Soil ecoregions in Nebraska.

Glossary

Carbonate: An accumulation of calcium carbonate ($CaCO3$) in the soil.

Clay: A soil particle that is less than 0.002 mm in diameter. Clay particles are so fine they have more surface area for reaction. They hold a lot of nutrients and water in the soil. A clay soil is a soil that has more than 40% clay, less than 45% sand and more than 60% silt.

Deposition: The process by which sediments, soil, and rocks are added to a landform or land mass. Wind, ice, and water, as well as sediment flowing via gravity, transport previously eroded sediment, which, at the loss of enough kinetic energy in the fluid, is deposited, building up layers of sediment.

Ecoregion: Represents areas with similar biotic and abiotic characteristics which determine the resource potential and likely responses to natural and man-made disturbances. Characteristics such as, climate, topography, geology, soils and natural vegetation define an ecoregion. They determine the type of land cover that can exist and influence the range of land use practices that are possible.

Erosion: The process of eroding or being eroded by wind, water, or other natural agents.

Geology: The study of earth, the materials (rocks) it is made of, and the physical and chemical processes that change it over time.

Geologic formation: Is a body of rock of considerable extent with distinctive characteristics that allow geologists to map, describe, and name it.

Horizon: see Soil horizons

Infiltration: The process by which water on the ground surface enters the soil.

Irrigation: The practice of supplementing natural rainfall with additional water to improve crop production. Irrigation may use groundwater or surface water sources, such as rivers.

Leaching: The removal of soluble material from soil or other material by percolating water.

Loess: A loosely compacted deposit of windblown silt-sized sediment. Also a soil parent material transported to and deposited in current location by wind.

Organic matter: Material derived from the decay of plants and animals. Always contains compounds of carbon and hydrogen.

Permeability: The ease to which gases, liquids or plant roots penetrate or pass through a layer of soil.

Sand: A soil particle between 0.05 and 2.0 mm in diameter. Sand is also used to describe soil texture according to the soil textural triangle, for example, loamy sand.

Soil Series: The lowest category of U.S. system of soil classification. It is commonly used to name the dominant soil units on detailed soil maps.

Silt: A soil particle between 0.002 and 0.05 mm diameter. It is also used to describe a soil textural class.

Soil Forming Factors: The surrounding environment that leads to differences in soil properties. The factors include Parent Material, Climate, Relief (Topography), Biological Activity, Time, and in some cases, Human Activity.

Soil Horizon: A layer of soil with properties that differ from the layers above or below it.

Soil Management: The sum total of how we prepare and nurture soil, select type of crops that suitable for a type of soil, tend the crop and the soil together, type of fertilizer and other materials added to soil so as to maintain productive and preserve soil.

Soil Profile: The sequence of natural layers, or horizons, in a soil. It extends from the surface downward to unconsolidated material. Most soils have three major horizons, called the surface horizon, the subsoil, and the substratum.

Soil Scientist: A soil scientist studies the upper few meters of the Earth's crust in terms of its physical and chemical properties; distribution, genesis and morphology; and biological components. A soil scientist needs a strong background in the physical and biological sciences and mathematics.

Soil Texture: The relative proportion of sand, slit, and clay particles that make up a soil. Sand particles are the largest and clay particles the smallest. Learn more about soil texture at www.soils4teachers.org/physical-properties

Subsoil: (B horizon) The soil horizon rich in minerals that eluviated, or leached down, from the horizons above it. Not present in all soils.

Topography: The shape of the land surface. (Relief: refers to differences in elevation of different points in a region.)

Topsoil: (A horizon) –Mostly weathered minerals from parent material with a little organic matter added. The horizon that formed at the land surface.

Upland: The higher ground of a region or an area of land lying above the level where water flows or where flooding occur.

Well-drained: One of several drainage classes used by soil scientist to indicate the depth to the water table during the growing season. Well drained means the water table is below 122 cm or 4 ft during the growing season.

Additional Resources

Lindbo, D. et al. 2008. *Soil! Get the Inside Scoop*. Soil Science Society of America, Madison, WI.

Lindbo, D. L., D. A. Kozlowski, and C. Robinson (ed.) 2012. *Know Soil, Know Life*. Soil Science Society of America, Madison, WI.

Web links for more information | Soil Links

Resources for Teachers, www.soils4teachers.org

Have Questions? Ask a Soil Scientist,https://www.soils.org/ask

Soil Science Society of America, https://www.soils.org/

Natural Resources Conservation Service, State Soils Homepage http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=stelprdb1236841

NRCS Links

Natural Resources Conservation Service, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/

Natural Resources Conservation Service, Educational Resources, http://soils.usda.gov/education/resources/k_6/

Nebraska NRCS, http://www.nrcs.usda.gov/wps/portal/nrcs/main/ne/soils/

UNL CropWatch Youth Innovation, http://cropwatch.unl.edu/cropwatch-youth

UNL CropWatch Soil Management, http://cropwatch.unl.edu/soils

References

National Cooperative Soil Survey, Official Series Description-Holdrege Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/H/HOLDREGE.html

Natural Resources Conservation Service, USDA. *Holdrege – Nebraska State Soil*. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=stelprdb1236841#list

University of Nebraska at Lincoln, School of Natural Resources, Conservation and Survey Division – http://snr.unl.edu/data/publications/HoldregeSoil.asp

US Environmental Protection Agency, Ecoregions of Kansas and Nebraska. http://www.epa.gov/wed/pages/ecoregions/ksne_eco.htm

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