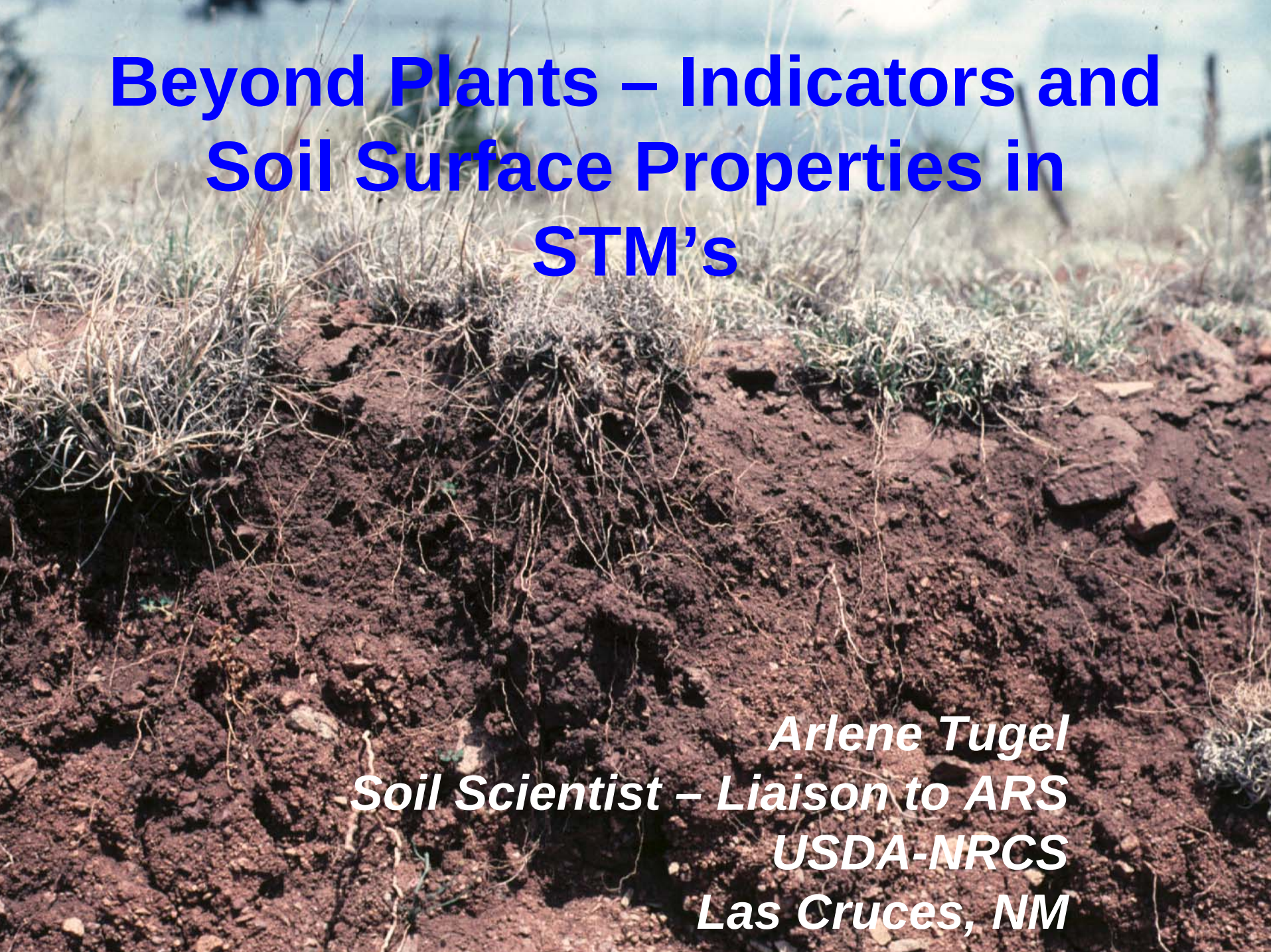
Beyond Plants – Indicators and Soil Surface Properties in STM's



Arlene Tugel
Soil Scientist – Liaison to ARS
USDA-NRCS
Las Cruces, NM

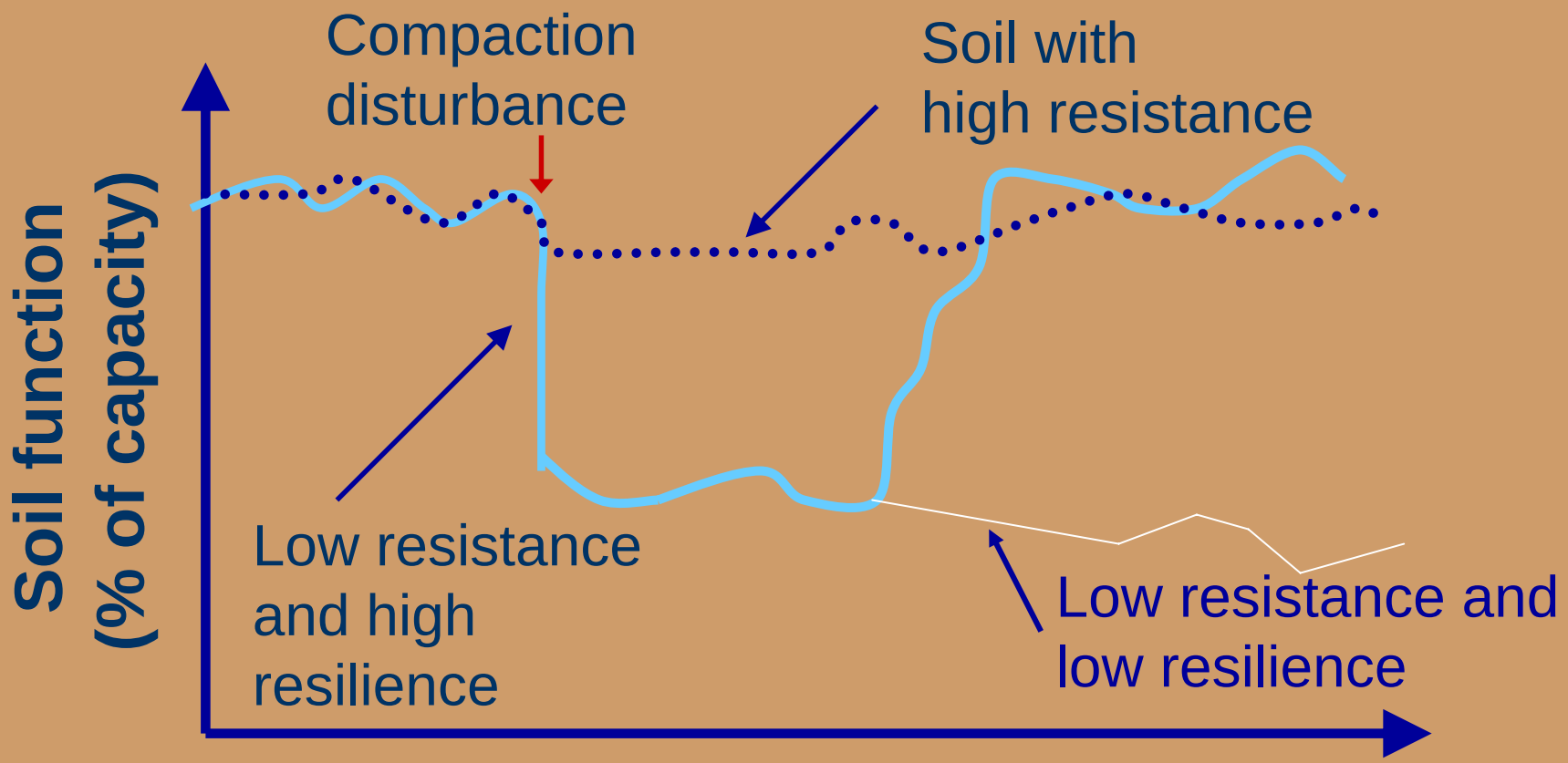
Soil degradation can affect:

- **Plant production, reproduction and mortality**
- **Erosion**
- **Vegetation changes**
- **Establishment and growth of invasive plants**
- **Water yields and water quality**
- **Air quality**
- **Wildlife habitat**
- **Carbon sequestration**

Transitions

Cause of transition	Accelerating practice
Directional climate change	?? Redefine potential
Soil degradation	Increase root biomass
Altered hydrology	Gully plugs, create meanders
Competitor establishment	Selective herbicide application
Depletion of seed pool	Seeding
Catastrophic fire	Seeding, selective herbicides

Disturbances, function, soil resistance and resilience



(Seybold, et al., 1999)

Transitions: Soil degradation processes after disturbance

- **Organic matter loss**
  - **Reduced biological activity**
  - **Nutrient depletion**
  - **Structural degradation**
  - **Crusting, sealing**
  - **Decreased porosity**
- **Compaction**
- **Increased bare spaces**
- **Increased soil temperature**
- **Salinization**
- **Water-logging/artificially drained**
- **Fire-induced water repellency**
- **Erosion**
  - **Nutrient depletion**

Using indicators to detect soil degradation

- Indicator: “A soil or plant property that is sensitive to change.”

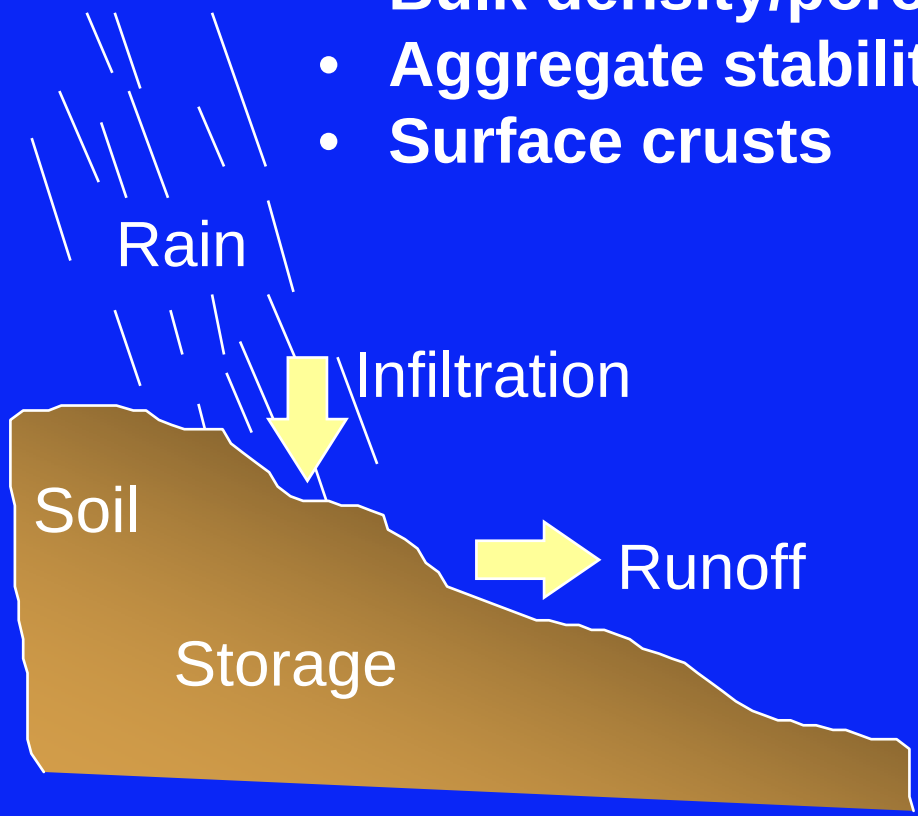
- Reflects complex processes that are too difficult or costly to measure.
  - Primary ecological processes (nutrient cycling, energy flows, water cycle)
  - Degradation processes

- Gives a snapshot in time.

Processes and indicators

- **Soil organic matter**
- **Bulk density/porosity**
- **Aggregate stability**
- **Surface crusts**

Affect infiltration



Hydrologic function

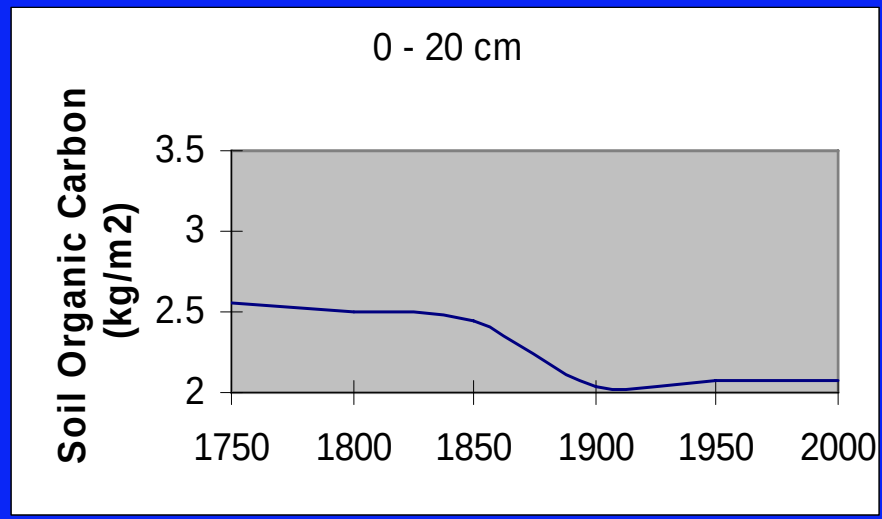
Dynamic soil properties

= soil properties that change over the human time scale.

Soil quality indicators are dynamic soil properties

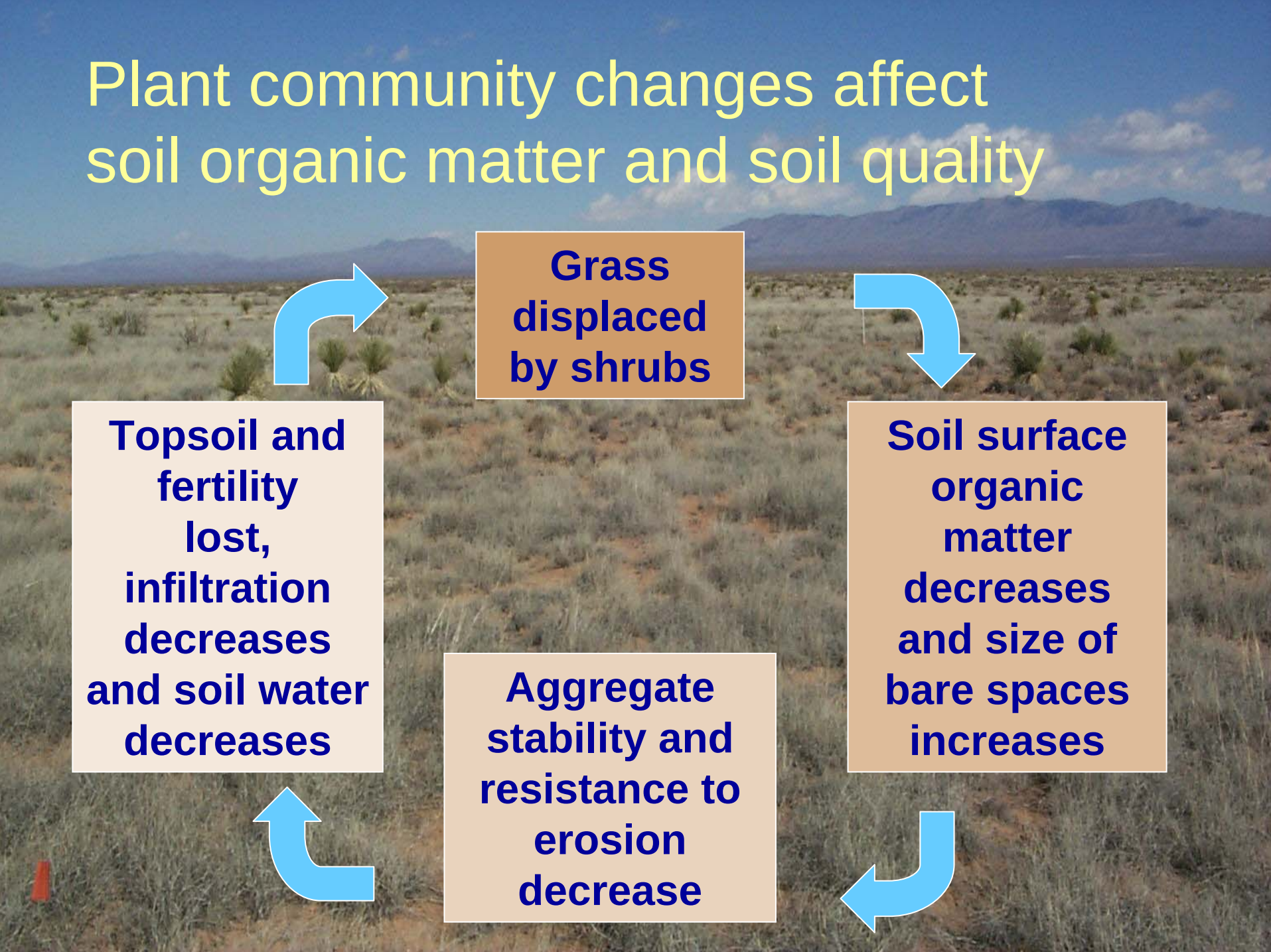
Decades = management time scale

Decades to centuries = recovery time scale

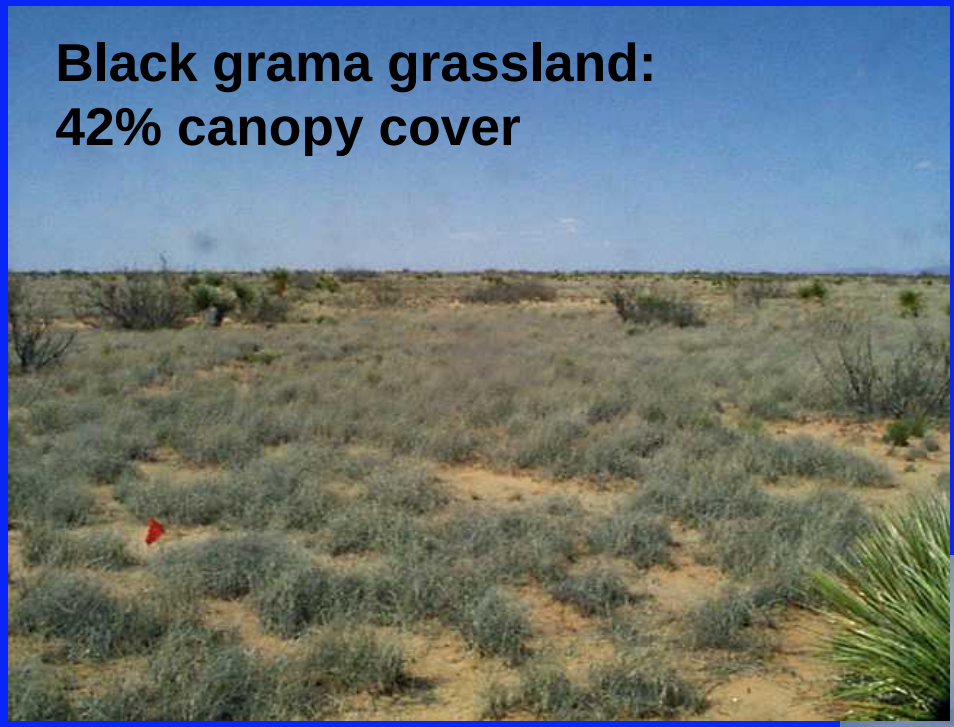


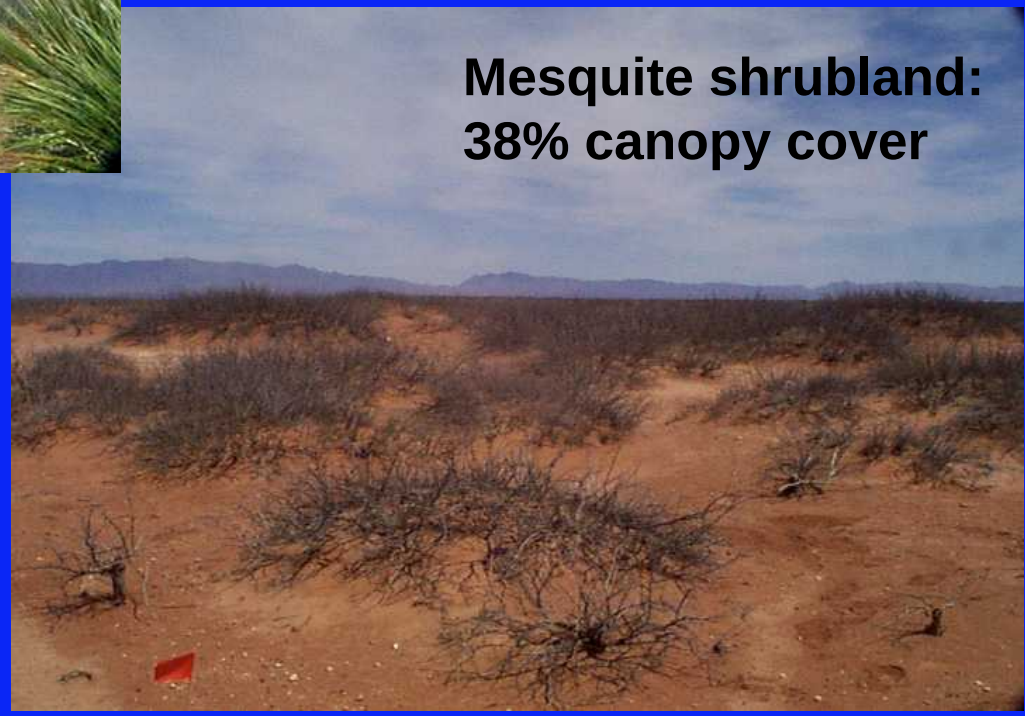
Redrawn from Hibbard, 1995

Plant community changes affect soil organic matter and soil quality



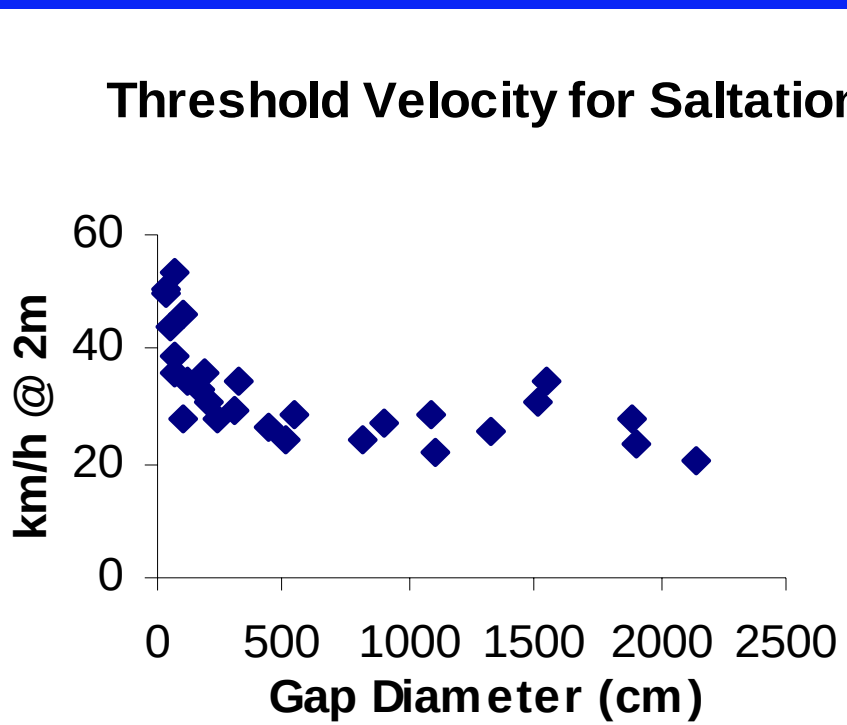
Process indicator: proportion of soil surface covered by large gaps

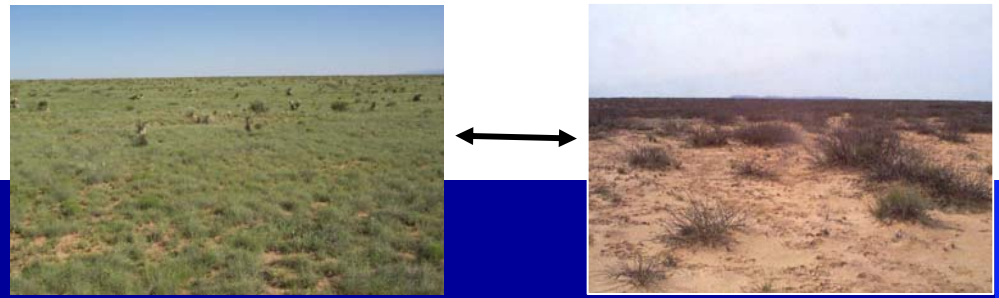




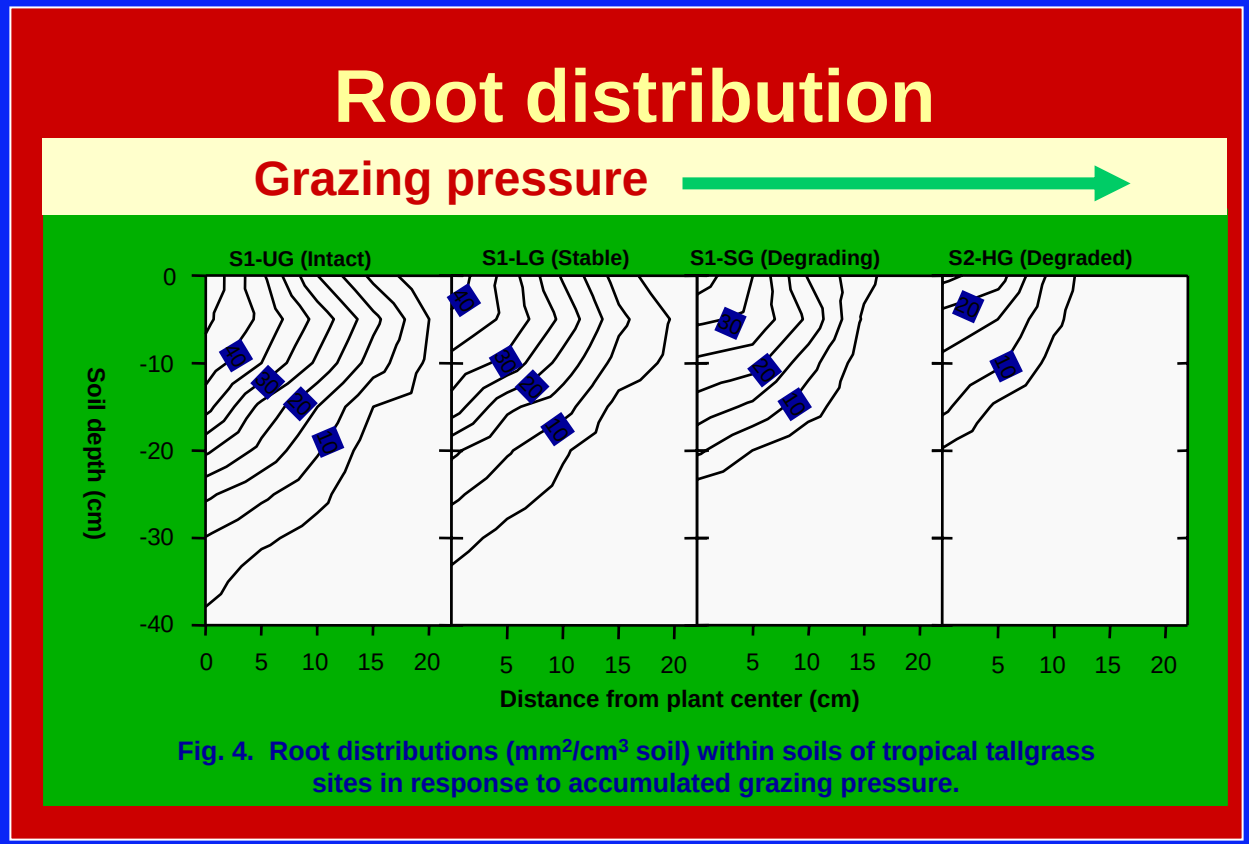
Calibration example (gap intercept method)

Wind erosion thresholds are often crossed during shrub invasion as gap sizes increase





Management-plant-soil interactions drive transitions



Norfolk, et. al. 2001

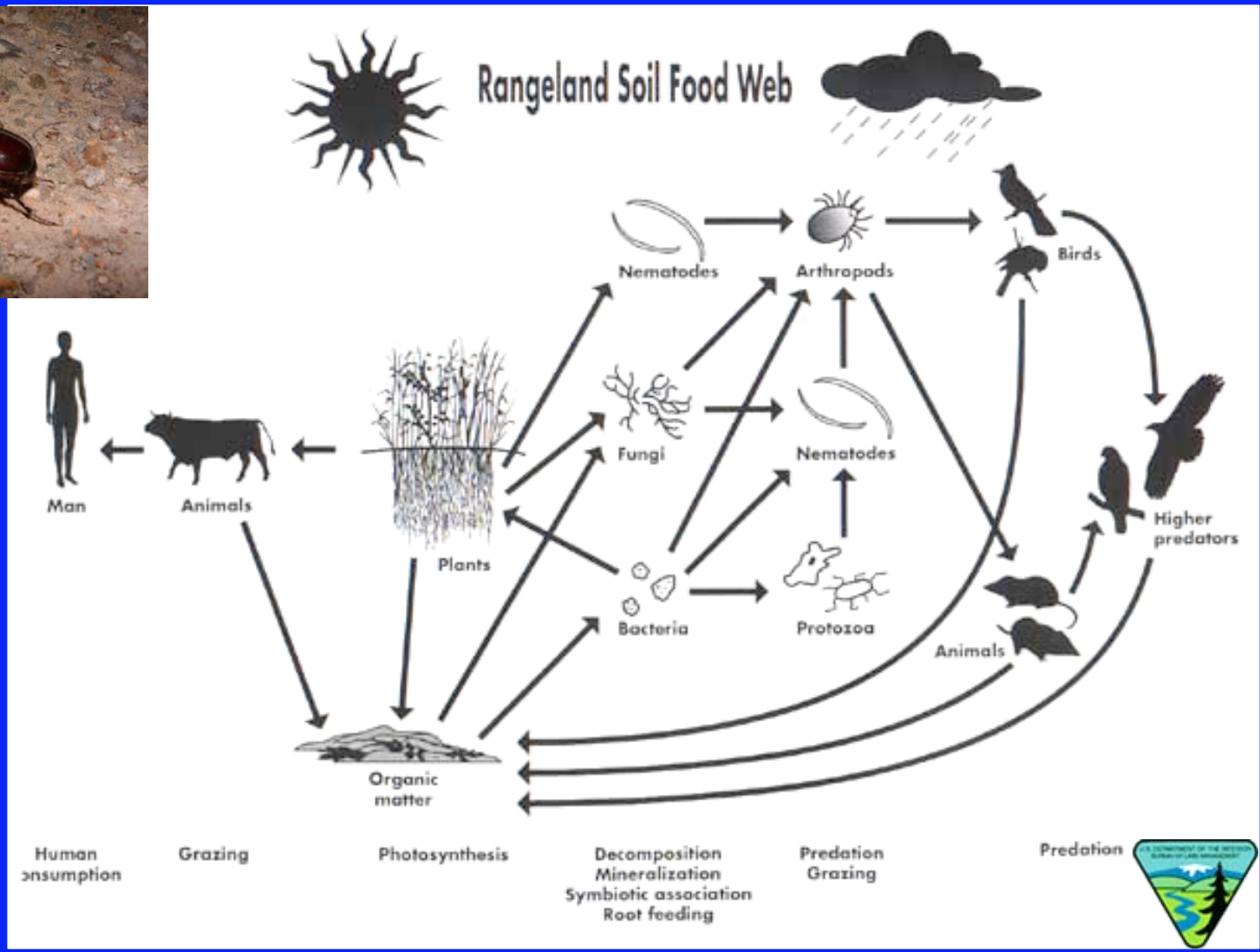
Soil organic matter

Short term

Long term

Soil Organic Matter		
TYPE	**RATE OF DECAY**	**FUNCTION**
Light fraction	Weeks to months	• Serves as food for soil organisms • Stores and provides plant nutrients
Physically protected	Decades	• Enhances soil structure and porosity and water holding capacity
Chemically stable	Hundreds to thousands of years	• Hold nutrients • Stabilizes micro-aggregates • Gives soil its dark color

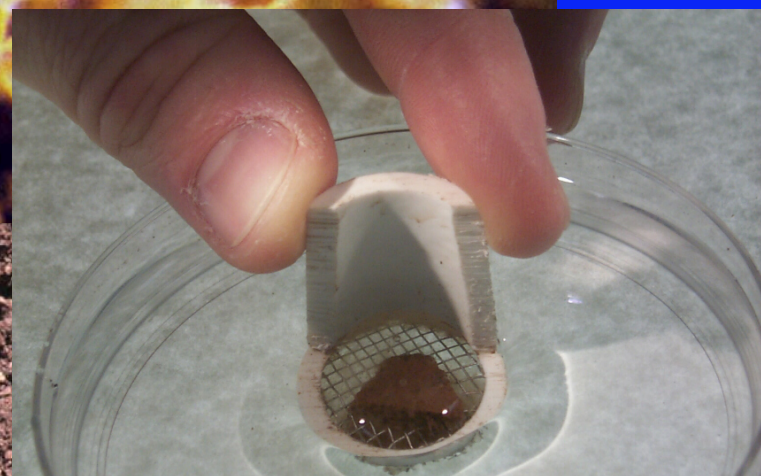
Biotic Integrity
Organic matter and nutrient cycling



Soil and Site Stability

Organic matter and soil aggregates:

bound together by fungi, root exudates and "glues" (polysaccharides) secreted by bacteria



Hydrologic function
Organic matter, physical characteristics and water

Physical crusting

Infiltration and runoff

Biological crusts may be important for:

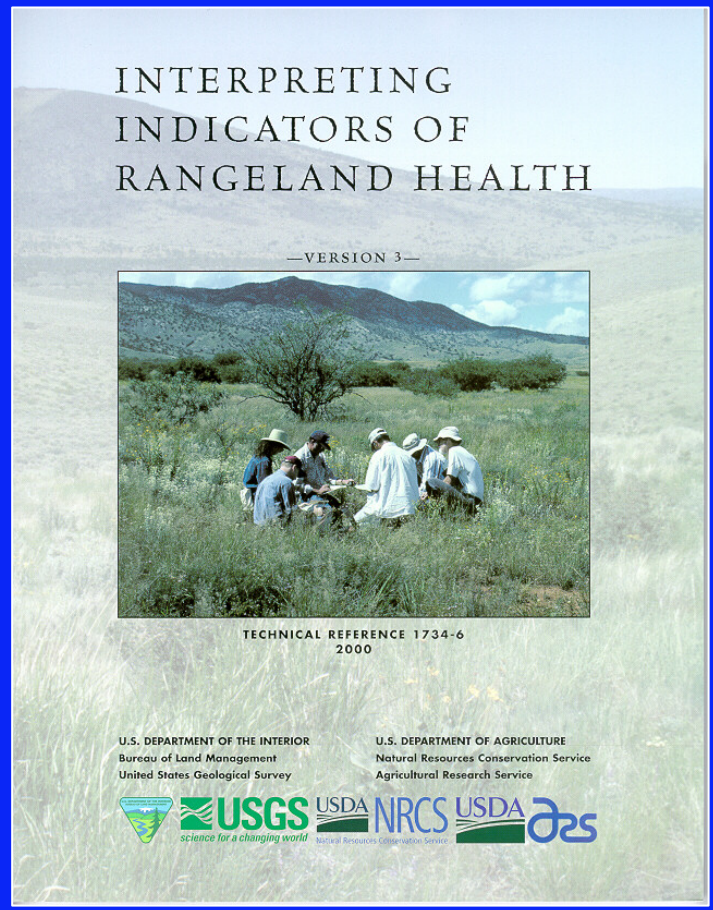
surface roughness/infiltration, soil stability, and nutrient cycling.

Excessive traffic compacts soil.

- Soil compaction and physical crusting reduce water infiltration.
- This can increase erosion and reduce water available for plants.
- Subsoil compaction can reduce rooting depth.

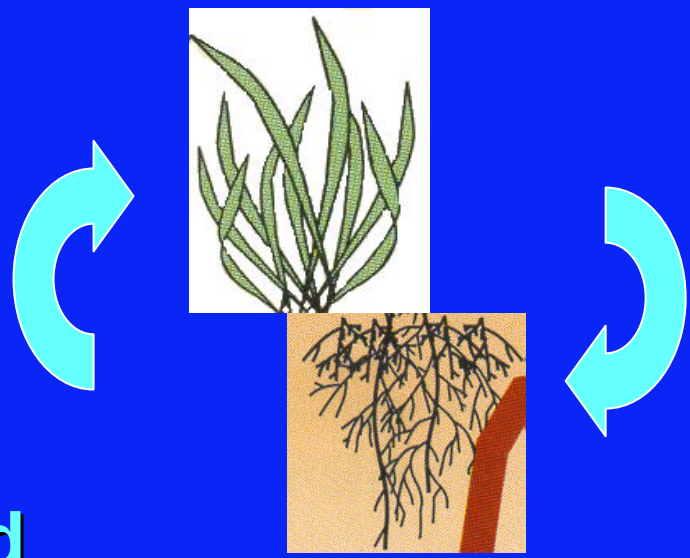
Erosion patterns

- Rills
- Gullies
- Water flow patterns
- Wind scour
- Pedestals
- Terracettes



State and Transition Models and Narratives

- **STATE - a complex of two ecosystem components, the soil base and vegetation structure.**
  - **Soil formation determines the site's capability.**
  - **Interaction between soil and vegetation determines functional status of the site.**

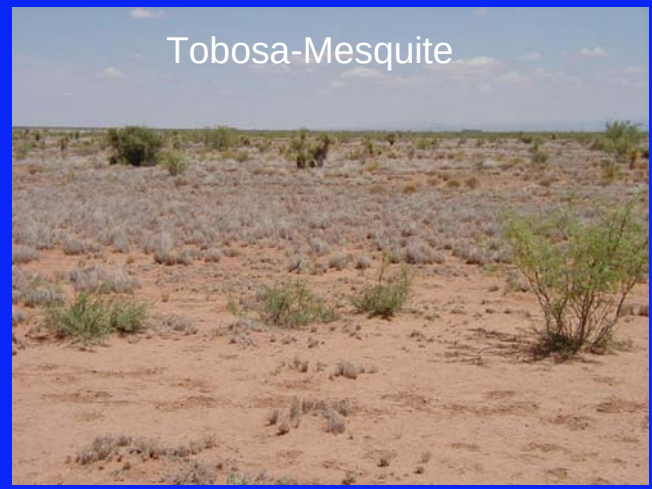


Stringham, et al., 2001, 2003

Rates of degradation may vary among soil series correlated to one Ecological Site (even though they have similar HCPC and dynamics)

Typic Calciargid, Dona Ana
% carbonates 0-30 cm =7.7
% clay 0-30 cm = 18.4

Loamy SD-2



Typic Calciargid, Berino
% carbonates 0-30 cm =0.2
% clay 0-30 cm = 25.7

Degraded states are more frequent on Dona Ana soils than on Berino soils

Transitions may not involve dramatic changes in vegetation

Nickel series, MLRA 42, typic aridic Gravelly

Recent grassland loss, potential
for recovery

Crossed a biotic threshold, soils not yet degraded

Dark A Light A

Grassland absent for decades, recovery unlikely

Already crossed a soil degradation threshold

The dynamic relationship between soil and vegetation is key to defining thresholds

1. Use indicators to help determine transitions and states.

Need to understand cause and affect.

- What are management affects on soil and plants, aka on ecological processes?
- How do plant community shifts affect soil properties (dynamic soil properties)?
- How do shifts in dynamic soil properties affect plant communities?

2. Include specific soil degradation process when choosing and describing mechanisms of change.

Organic matter loss
Reduced biological activity
Structural degradation
Crusting, sealing
Decreased porosity
Compaction
Increased soil temperature
Nutrient depletion
Salinization
Water-logging
Fire-induced water repellency
Erosion

3. Strategies for the Text - Add descriptions of rangeland health/soil quality indicators

How do we distinguish the states and communities?

- **Diagnosis**: Grass cover is fairly uniform with few large bare areas present. Mature piñon and/or juniper are an important component of the site with canopy averaging 25 percent. Evidence of erosion such as pedestalling of grasses, rills and gullies are infrequent.

- From MLRA-36, WP-2: Savannah, David Trujillo, author

- **Why we think this is good:**
- 1) Descriptive
- 2) Refers to data
- 3) Refers to rangeland health indicators

Where do I get more information on soil quality indicators?

Rangeland soil quality

Rangeland Sheet 1

Soil Quality Information Sheet

Rangeland Soil Quality—Introduction

May 2001

USDA, Natural Resources Conservation Service

What is rangeland?

Rangeland is land on which the native vegetation is predominantly grasses, grasslike plants, forbs, or shrubs. This land includes natural grasslands, savannas, shrub lands, most deserts, tundras, areas of alpine communities, coastal marshes, and wet meadows.

What is rangeland health?

Rangeland health is the degree to which the integrity of the soil, the vegetation, the water, and the air as well as the ecological processes of the rangeland ecosystem are balanced and sustained.

What is soil?

Soil is a dynamic resource that supports plants. It consists of mineral particles of different sizes (sand, silt, and clay), organic matter, and numerous species of living organisms. Soil has biological, chemical, and physical properties, some of which change in response to how the soil is managed. The kind of soil is defined by the inherent soil properties that do not readily change in response to management.

What is soil quality?

Soil quality is the capacity of a specific kind of soil to [illegible] within natural or managed ecosystem boundaries, [illegible] productivity, maintain or enhance the quality of water and air, and support human health and habitation.

What does soil quality affect on rangeland?

- Plant production, reproduction, and mortality
- Erosion
- Water yields and water quality
- Wildlife habitat
- Carbon sequestration
- Vegetation changes
- Establishment and growth of invasive plants
- Rangeland health

How are soil quality and rangeland health related?

Rangeland health and soil quality are interdependent. Rangeland health is characterized by the functioning of both the soil and the plant communities. The capacity of the soil to function affects ecological processes, including the capture, storage, and redistribution of water; the growth of plants; and the cycling of plant nutrients. For example, increased physical crusting decreases the infiltration capacity of the soil and thus the amount of water available to plants. As the availability of water decreases, plant production declines, some plant species may disappear, and the less desirable species may increase in abundance. Changes in vegetation may precede or follow changes in soil properties and processes. Significant shifts in vegetation generally are associated with changes in soil properties and processes and/or the redistribution of soil resources across the landscape. In some cases, such as accelerated erosion resulting in a change in the soil profile, this shift may be irreversible, while in others, recovery is possible.

Why is soil quality important?

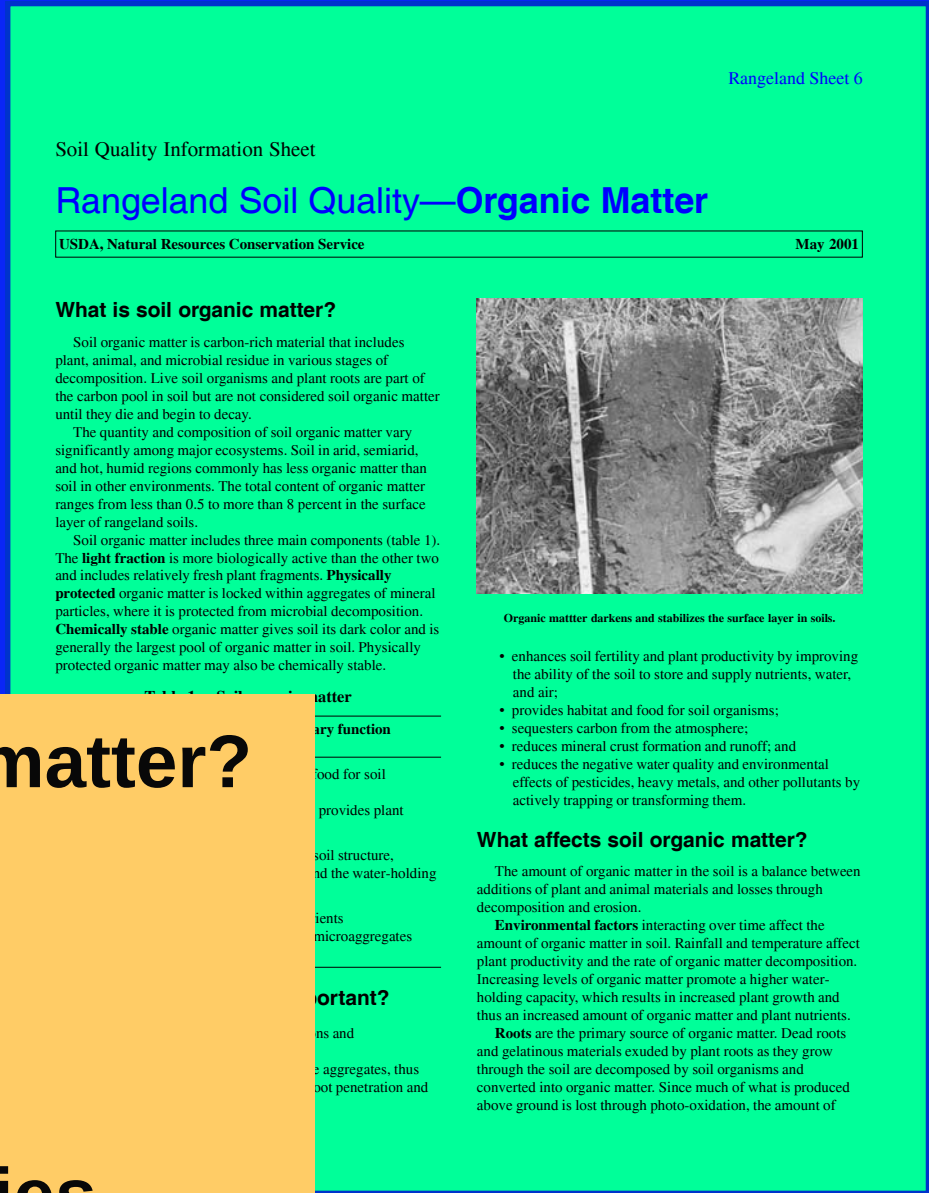
Changes in soil quality that occur as a result of management affect:

- the amount of water from rainfall and snowmelt that is available for plant growth;
- runoff, water infiltration, and the potential for erosion;
- the availability of nutrients for plant growth;

http://soils.usda.gov/sqi/

2. Assessment and monitoring
3. Aggregate stability
4. Compaction
5. Infiltration
6. Organic matter
7. Physical and biological crusts
8. Soil biota
9. Water erosion
10. Wind erosion

Information sheets



Rangeland Sheet 6

Soil Quality Information Sheet

Rangeland Soil Quality—Organic Matter

USDA, Natural Resources Conservation Service **May 2001**

What is soil organic matter?

Soil organic matter is carbon-rich material that includes plant, animal, and microbial residue in various stages of decomposition. Live soil organisms and plant roots are part of the carbon pool in soil but are not considered soil organic matter until they die and begin to decay.

The quantity and composition of soil organic matter vary significantly among major ecosystems. Soil in arid, semiarid, and hot, humid regions commonly has less organic matter than soil in other environments. The total content of organic matter ranges from less than 0.5 to more than 8 percent in the surface layer of rangeland soils.

Soil organic matter includes three main components (table 1). The **light fraction** is more biologically active than the other two and includes relatively fresh plant fragments. **Physically protected** organic matter is locked within aggregates of mineral particles, where it is protected from microbial decomposition. **Chemically stable** organic matter gives soil its dark color and is generally the largest pool of organic matter in soil. Physically protected organic matter may also be chemically stable.

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Organic mattter darkens and stabilizes the surface layer in soils.

- enhances soil fertility and plant productivity by improving the ability of the soil to store and supply nutrients, water, and air;
- provides habitat and food for soil organisms;
- sequesters carbon from the atmosphere;
- reduces mineral crust formation and runoff; and
- reduces the negative water quality and environmental effects of pesticides, heavy metals, and other pollutants by actively trapping or transforming them.

What affects soil organic matter?

The amount of organic matter in the soil is a balance between additions of plant and animal materials and losses through decomposition and erosion.

Environmental factors interacting over time affect the amount of organic matter in soil. Rainfall and temperature affect plant productivity and the rate of organic matter decomposition. Increasing levels of organic matter promote a higher water-holding capacity, which results in increased plant growth and thus an increased amount of organic matter and plant nutrients.

Roots are the primary source of organic matter. Dead roots and gelatinous materials exuded by plant roots as they grow through the soil are decomposed by soil organisms and converted into organic matter. Since much of what is produced above ground is lost through photo-oxidation, the amount of

- **What is soil organic matter?**
- **Why is it important?**
- **How is it measured?**
- **What affects it?**
- **Management strategies**

Chemical indicators may also be important

- Active carbon
- Soil nutrients
- Carbonates
- Electrical conductivity/salinity
- Sodicity
- Cation exchange capacity
- Soil contaminants

Qualitative soil methods

Infiltration

Soil stability kit

Aggregate stability

Penetrometer

Bulk density

pH, EC

Samples for
- Organic carbon
- SAR, etc

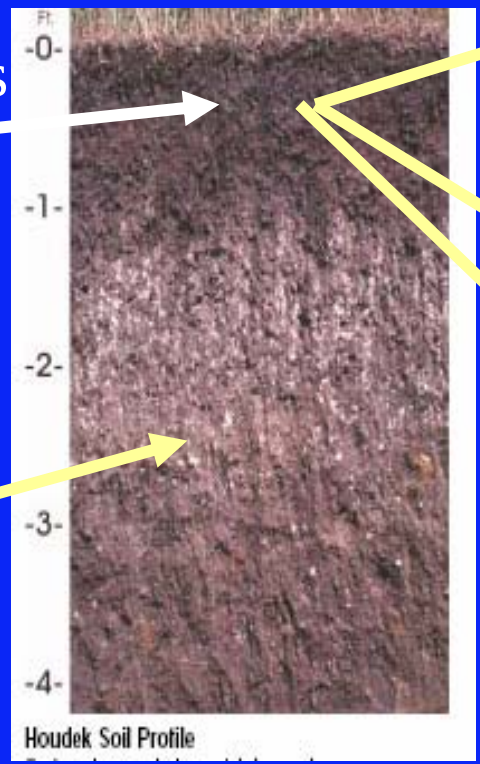
Soil and vegetation change: Dynamic soil properties and STM's

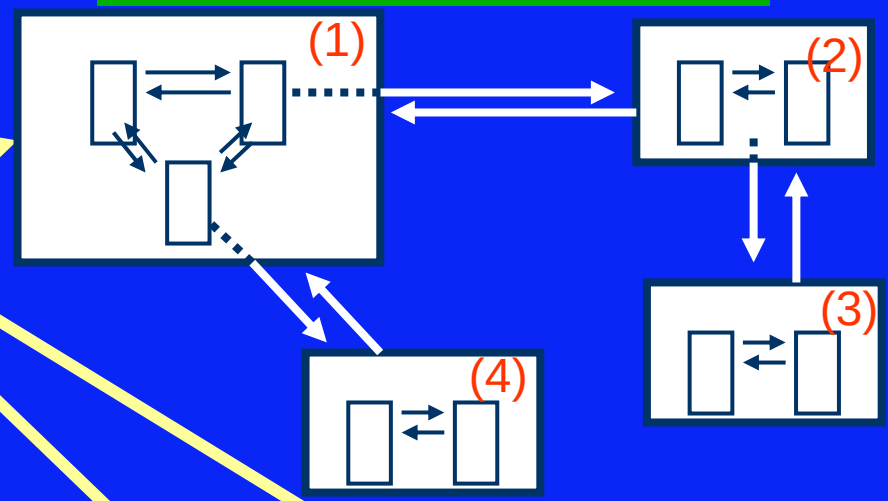
Soil survey today: Only one set of values exists for all land uses

Need multiple values based on management (states)

Dynamic Properties
(Use-dependent)

Static Properties





(5) Tilled Cropland

(6) No-till Cropland

Summary

1. How well a soil (site) functions is related to the effect of soil degradation on primary ecological processes.
2. Consider differences in near-surface soil properties as clues to identification of states.
3. Remember that different soils can respond differently to the same disturbance
4. Include soil dynamics in STM's.
5. Soil scientists have a role in developing and describing STM's

- Rangeland Health: "The degree to which the integrity* of the soil, vegetation, water, & air as well as the **ecological processes** of the rangeland ecosystem are balanced and sustained."

- * "Integrity is the maintenance of the functional attributes characteristic of a locale, including normal variability"