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SOIL QUALITY TECHNICAL NOTE NO. 3

August 6, 2001

SUBJECT: SOI – SOIL QUALITY INFORMATION SHEETS FOR RANGELAND

Purpose. To distribute Rangeland Soil Quality Information Sheet Numbers 1-10.

Effective Date. Effective upon receipt.

Explanation. The attached Soil Quality Information Sheets for rangeland describe soil properties that change in response to management. The sheets provide information that is related to a number of the indicators used in rangeland health assessments. They support rangeland inventories and monitoring and provide management strategies for planning purposes. These sheets illustrate the practical materials developed collaboratively by the Soil Quality Institute, the Grazing Lands Technology Institute, the National Soil Survey Center, the USDA Agricultural Research Service and the USDI Bureau of Land Management. The information is primarily intended for use in the planning process, but can also be used as an educational resource for teaching about soil quality on rangeland. The sheets are intended for as wide an audience as possible.

Filing Instructions. File in the Soil Quality Binder (distributed June 1999) behind the tab marked "Inventory/Assessment" (190-22-11).

Distribution. Additional bulk supplies of these sheets can be requested from the National Soil Survey Center by phone at (402)-437-5499. Copies may also be downloaded from the Soil Quality Institute website at: http://www.statlab.iastate.edu/survey/SQI/range.html or from the Grazing Lands Technology Institute at http://www.ftw.nrcs.usda.gov/glti/projects.html.

Contact. Comments and suggestions regarding this publication should be sent to the Soil Quality Institute by facsimile at (505) 646-5889, or by phone at (505) 646-2660.

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Attachment

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Soil Quality Information Sheet

Rangeland Soil Quality—**Introduction**

USDA, Natural Resources Conservation Service May 2001

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.

What is soil quality?

Soil quality is the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries, sustain plant and animal productivity, maintain or enhance the quality of water and air, and support human health and habitation. Changes in the capacity of soil to function are reflected in soil properties that change in response to management or climate.

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;

- the conditions needed for germination, seedling establishment, vegetative reproduction, and root growth; and
- the ability of the soil to act as a filter and protect water and air quality.

How are soil quality indicators integrated into rangeland assessments and monitoring?

Ecological processes on rangeland are evaluated with soil and vegetation indicators. Evaluations made through assessment and monitoring provide information about the functional status of soil and rangeland. Soil quality indicators are properties that change in response to management, climate, or both and reflect the current functional status. Functions include maintaining soil and site stability; distributing, storing, and supplying water and plant nutrients; and maintaining a healthy plant community.

How are soil quality indicators used on rangeland?

Assessment.—Soil quality indicators are used to increase the value and accuracy of rangeland assessments and trend analysis. Assessments help to identify areas where problems occur and areas of special interest. Land managers can use this information and other inventory and monitoring data to make management decisions, which, in turn, affect soil quality. When assessments or comparisons are made, the rangeland ecological site description is used as the standard. For the soils associated with a given ecological site, the properties that change in response to management or climate are used as indicators of change.

Monitoring.—Tracking trends in the functional status of the soil and the plant community helps to determine the success of the management practices or the need for additional management changes or adjustments. Regular measurement of soil quality indictors at the same location can detect changes over seasons or years and provide early warning of future vegetation changes.

How do I get more information?

For additional information, refer to rangeland information sheet 2, "Indicators for Assessment and Monitoring." For soil quality information related to rangeland health indicators, refer to the rangeland soil quality information sheets listed in the following table. Download the sheets from:

http://www.statlab.iastate.edu/survey/SQI

Rangeland health indicator [1]	Related rangeland soil quality information sheets
1. Rills	Water Erosion
2. Waterflow patterns	Infiltration
3. Pedestals and/or terracettes	Water Erosion, Wind Erosion
4. Bare ground	Water Erosion, Wind Erosion
5. Gullies	Water Erosion
6. Wind-scoured areas	Wind Erosion
7. Litter movement	Water Erosion, Wind Erosion
8. Soil surface resistance to erosion	Physical and Biological Soil Crusts, Aggregate Stability
9. Soil surface loss or degradation	Water Erosion, Wind Erosion
10. Plant community composition and distribution relative to infiltration and runoff	Infiltration
11. Compaction layer	Compaction
12. Functional/structural groups	Soil Biota
13. Plant mortality/ decadence	
14. Litter amount	Organic Matter
15. Annual production	
16. Invasive plants	
17. Reproductive capability of perennial plants	

[1] These qualitative assessment indicators are from *Interpreting Indicators of Rangeland Health,* Version 3, 2000, TR 1734-6, BLM (http://www.ftw.nrcs.usda.gov/glti).

(Prepared by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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Soil Quality Information Sheet

Rangeland Soil Quality— Indicators for Assessment and Monitoring

USDA, Natural Resources Conservation Service May 2001

What are indicators?

Indicators are key soil or plant community characteristics that are sensitive to change in the environment. They reflect complex ecosystem processes that are too difficult or expensive to be measured directly. They provide information about the current status of rangeland ecosystems. Trends from indicators measured regularly provide clues about the response of the system to management. Soil quality indicators complement vegetation indicators and may be qualitative or quantitative.

What soil quality indicators are used on rangeland?

Soil properties.—Physical, biological, and chemical soil properties are included. Some properties, such as bulk density, reflect limitations to root growth, seedling emergence, and water infiltration. Other properties, such as the diversity and activity of soil biota, reflect the availability of both water and nutrients to plants. Soil organic matter and soil aggregate stability reflect a combination of physical, biological, and chemical processes.

Soil surface features.—Pedestals, exposed plant roots, rills, gullies, wind scours, and soil deposition reflect such processes as runoff and erosion. These indicators are commonly assessed qualitatively.

Spatial patterns and variability.—The distribution and cycling of water and nutrients in rangeland soils are affected over both short and long distances by such processes as erosion and deposition. The kinds, amounts, and spatial distribution of living plants and decaying residue on the soil also affect nutrients and water. Accordingly, as the distribution of soil organic matter becomes less uniform, resource availability declines in some patches and increases in others.

The following qualitative assessment indicators and the attributes they reflect are from *Interpreting Indicators of Rangeland Health,* Version 3, 2000, TR 1734-6, BLM (http://www.ftw.nrcs.usda.gov/glti):

Rangeland health indicator	Soil/site stability	Hydro-logic function	Biotic integrity
1. Rills	X	X	
2. Waterflow patterns	X	X	
3. Pedestals and/or terracettes	X	X	
4. Bare ground	X	X	
5. Gullies	X	X	
6. Wind-scoured areas	X		
7. Litter movement		X	
8. Soil surface resistance to erosion	X	X	X
9. Soil surface loss or degradation	X	X	X
10. Plant community composition and distribution relative to infiltration and runoff		X	
11. Compaction layer	X	X	X
12. Functional/structural groups			X
13. Plant mortality/ decadence			X
14. Litter amount		X	X
15. Annual production			X
16. Invasive plants			X
17. Reproductive capability of perennial plants			X

How are indicators selected?

The indicators chosen depend on the functions to be assessed or monitored and the scale (e.g., management unit, ranch, watershed, or region) at which the information is needed. Rangeland ecosystem functions include maintaining soil and site stability; distributing, storing, and supplying water and plant nutrients; and supporting a healthy plant community. Good indicators are:

- strongly related to the function and scale of interest,
- sensitive to change,
- compatible with time and resource availability and technical expertise, and
- relatively easy to observe or measure in a reliable manner.

Assessment

Assessment estimates or measures the functional status of ecological processes. The assessment must start with an understanding of the standard to be used for comparison. For assessments of rangeland, the ecological site description is used as a standard at the site scale. Information from the ecological site description should be supplemented, if possible, with data from local reference sites.

The optimum time and location for making assessments depend on the objectives. Potential objectives include:

- selection of sites for monitoring,
- gathering of inventory data used in making decisions,
- identification of areas at risk of degradation, and
- targeting of management inputs.

The timing of assessments also depends on seasonal cycles. Some soil properties are highly variable on a daily, seasonal, or yearly basis in response to changes in both temperature and moisture. For example, the total amount of organic matter in a soil is relatively insensitive to seasonal changes, whereas rills can become less apparent, depending on the length of time and conditions since the most recent major storm.

Careful site selection helps to ensure that the assessment sites are truly representative of the area of interest. The sites should be on the same soil and in the same landscape position as the area they represent. Offsite features, such as roads, homesteads, and other areas of recent or historic disturbances, can have significant impacts and should either be avoided or noted. The management history of the site can aid in interpretation.

Monitoring

Monitoring identifies changes in the resource through the orderly collection, analysis, and interpretation of quantitative data. It must be conducted over time at permanently marked locations and include baseline data if it is to ascertain the trend of the change in the functional status of the resource. Monitoring is often designed so that measurements can be made consistently by more than one observer. Reference data or standards may be used to establish management goals and aid in interpretation of the monitoring results.

Site selection for monitoring depends primarily on the objectives, which 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.

If the objective is to determine progress or trend, the sites that are representative of the management unit should be selected. If the objective is to provide an opportunity to modify management before degradation occurs, the sites that are most vulnerable should be selected. The detected changes must be real and must occur rapidly enough for land managers to correct problems before undesired and perhaps irreversible loss of soil quality occurs. The monitoring plan should include the proper measurement frequency, which either limits or captures seasonal variability, as dictated by the objectives.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

(Prepared by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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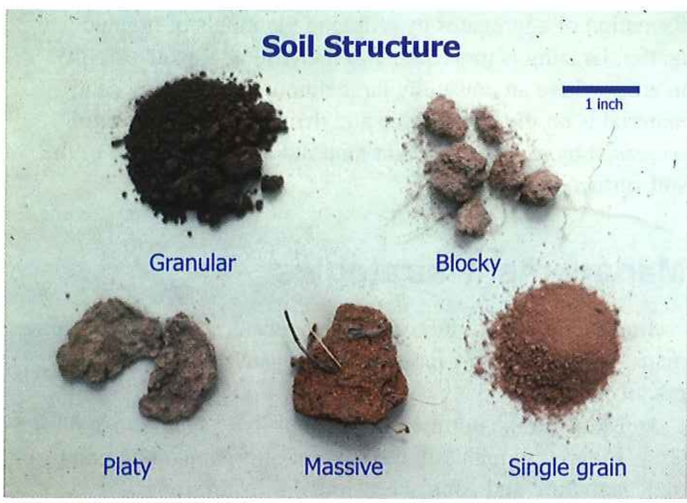
Soil Quality Information Sheet

Rangeland Soil Quality—**Aggregate Stability**

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

What are soil aggregates?

Soil aggregates are groups of soil particles that are bound to each other more strongly than to adjacent particles. Organic matter "glues" produced when soil biota break down dead roots and litter hold the particles together. Threadlike strands of fungi also bind particles into aggregates. Microscopic aggregates are the building blocks of larger aggregates. The larger aggregates and the arrangement of them, along with chemical attraction between particles, determine soil structure. The structure of the surface layer commonly is granular or blocky, but a degraded surface layer can be crusted, platy, or structureless. Pores important for the movement of air, water, and plant nutrients occur within and between aggregates. Pores also provide thoroughfares for soil organisms.



What is aggregate stability?

Aggregate stability refers to the ability of aggregates to resist degradation. Additions of organic matter to the soil enhance the stability of aggregates. Raindrops, flowing water, and windblown sand grains can break apart soil aggregates, exposing organic matter to decomposition and loss. Physical disturbances, such as vehicle traffic and trampling, can break down soil structure. Soils can resist degradation differently when wet or dry. For example, dense, cloddy soils can be very stable when dry but unstable when wet.

Why is aggregate stability important?

Stable aggregates are critical to erosion resistance, water availability, and root growth. Soils with stable aggregates at the surface are more resistant to water erosion than other soils, both because soil particles are less likely to be detached and because the rate of water infiltration tends to be higher on well aggregated soils. Unstable aggregates disperse during rainstorms, then form a hard physical crust when the soil dries. Physical crusts restrict seedling emergence because they have few pores for air and water entry into the soil. The crusts result in more runoff, more erosion, and less available water. Aggregated soils hold more water than other soils and provide pores for root growth. Large, stable aggregates can resist degradation and removal by wind better than small, weak ones.

Aggregate stability is a good indicator of the content of organic matter, biological activity, and nutrient cycling in the soil. The amount of organic matter increases after the decomposition of litter and dead roots begins. Stable aggregates result from this process because soil biota produce material that binds particles together. "New" organic matter stabilizes the larger aggregates, while the smaller aggregates are more likely to be bound by "old" organic matter. New organic matter holds and can release more nutrients.

Changes in aggregate stability may serve as early indicators of recovery or degradation of soils and, more generally, of ecosystems. Perennial plants can often persist long after the soil and plant community have become too degraded to support plant regeneration, while recovery is often occurring long before desirable plants become reestablished.

How is aggregate stability measured?

Where to sample.—Aggregate stability in areas of rangeland is commonly measured on soil samples removed from the top one-fourth to one-half inch of the soil. This part of the soil is most likely to be removed by wind or water erosion. Deeper samples can also be analyzed. Samples should be collected both from beneath plants and from spaces between plants. Several samples should be collected from each area.

Simple field method (no drying or weighing required).—This method can be applied in the field with relatively simple tools. Remove at least nine soil fragments from the soil surface. These fragments should be one-fourth to one-third inch in diameter. Place each in a separate sieve constructed from 3/4-inch PVC and window screen. Place each air-dry fragment in distilled water 1 inch deep. After 5 minutes, gently sieve each fragment five times, pulling the sieve completely out of the water with each cycle. Soils with low stability will appear to "melt" as soon as they are placed in the water, while soils with high stability will remain intact even after sieving.

What affects aggregate stability?

The stability of aggregates is affected by soil properties that change relatively little and by properties that change in response to changes in vegetation and management. As a result, measurements of the aggregate stability of a given soil should be compared only with measurements for the same or similar soils with similar textures.

Soil properties.—Soil properties that change relatively little include texture and type of clay. Expansion and contraction of clay particles as they become moist and then dry can shift and crack the soil mass and create or break apart aggregates. Calcium in the soil generally promotes aggregation, whereas sodium promotes dispersion. The quantity of calcium and sodium is specific to each type of soil.

Vegetation.—Management affects the plant community. Changes in the composition, distribution, and productivity of plant species affect aggregation-related soil properties, including aggregate stability, the amount and type of organic matter in the soil, and the composition and size of the soil biotic community. The amount of plant cover and the size of bare patches also are important. The centers of large bare spaces receive few inputs of organic matter and are susceptible to degradation.

Grazing.—Disturbance of the soil surface by grazing animals has both beneficial and detrimental effects on aggregate stability. It breaks the soil apart, exposing the organic matter "glues" to degradation and loss by erosion; however, it also can incorporate litter and standing dead vegetation into the soil, increasing the content of organic matter in the soil. Heavy grazing that significantly reduces plant production disrupts the formation of aggregates by reducing the inputs of organic matter. Grazing is more likely to increase aggregate stability in areas where an unusually large amount of standing dead material is on the soil surface and the risk of erosion is not increased by removal of plant material and disturbance of the soil surface.

Management strategies

Improving the productivity of rangeland through good range management normally increases aggregate stability. Include practices that:

- Maintain the optimum amount of live vegetation and litter in order to maintain the content of organic matter and soil structure and control erosion.
- Decrease the number and size of bare areas.
- Minimize soil surface disturbances, especially in arid areas.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

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Soil Quality Information Sheet

Rangeland Soil Quality—**Compaction**

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

What is compaction?

Soil compaction occurs when moist or wet soil aggregates are pressed together and the pore space between them is reduced. Compaction changes soil structure, reduces the size and continuity of pores, and increases soil density (bulk density). Wheel traffic or pressure (weight per unit area) exerted on the soil surface by large animals, vehicles, and people can cause soil compaction. In areas of rangeland, compacted soil layers are generally at the soil surface or less than 6 inches below the surface, although they can be as deep as 2 feet under heavily used tracks and roads. Increases in density can be small to large.

When is compaction a problem?

Compaction changes several structural characteristics and functions of the soil. It is a problem when the increased soil density and the decreased pore space limit water infiltration, percolation, and storage; plant growth; or nutrient cycling.

Water movement and storage.—Compaction reduces the capacity of the soil to hold water and the rate of water movement through soil. It limits water infiltration and causes increased runoff and, in some areas, increased erosion. Compacted wheel tracks or trails can concentrate runoff that can create rills or gullies, especially on steep slopes. When the amount of water that enters the soil is reduced, less water is available for plant growth and percolation to deep root zones. Water entering the soil can perch on a subsurface compacted layer, saturating the soil to or near the surface or ponding on the surface. This water readily evaporates. Compaction can increase the water-holding capacity of sandy soils. An increase in the amount of water stored near the soil surface and a decrease in the amount of water deeper in the soil may favor the shallower rooted annuals over the deeper rooted plant species, such as shrubs.

Plant growth.—Where soil density increases significantly, it limits plant growth by physically restricting root growth. Severe compaction can limit roots to the upper soil layers, effectively cutting off access to the water and nutrients stored deeper in the soil. Anaerobic conditions (lack of oxygen) can develop in or above the compacted layer during wet periods, further limiting root growth. Even in arid climates, anaerobic conditions can occur where water accumulates.

Nutrient cycling.—Compaction alters soil moisture and temperature, which control microbial activity in the soil and the release of nutrients to plants. Anaerobic conditions increase the loss of soil nitrogen through microbial activity. Compaction changes the depth and pattern of root growth. This change affects the contributions of roots to soil organic matter and nutrients. Compaction compresses the soil, reducing the number of large pores. This reduction can restrict the habitat for the larger soil organisms that play a role in nutrient cycling and thus can reduce the number of these organisms.

How can compacted soil layers be identified?

The following features may indicate a compacted soil layer:

- platy, blocky, dense, or massive appearance;
- significant resistance to penetration with a metal rod;
- high bulk density; and
- restricted, flattened, turned, horizontal, or stubby plant roots.

Because some soils that are not compacted exhibit these features, refer to a soil survey report for information about the inherent characteristics of the soil. Each soil texture has a minimum bulk density (weight of soil divided by its volume) at which root-restricting conditions may occur, although the restriction also depends on the plant species.

Texture	Root-restricting bulk density (g/cm^3)*
Coarse, medium, and fine sand and loamy sand other than loamy very fine sand	1.80
Very fine sand, loamy very fine sand	1.77
Sandy loam	1.75
Loam, sandy clay loam	1.70
Clay loam	1.65
Sandy clay	1.60
Silt, silt loam	1.55
Silty clay loam	1.50
Silty clay	1.45
Clay	1.40

* Grams per cubic centimeter.

What affects the ability of soil to resist compaction?

Moisture.—Dry soils are much more resistant to compaction than moist or wet soils. Soils that are wet for long periods, such as those on north-facing slopes and those on the lower parts of the landscape, where they receive runoff, are susceptible to compaction for longer periods than other soils. Saturated soils lose the strength to resist the deformation caused by trampling and wheeled traffic. They become fluid and turn into "mud" when compressed.

Texture.—Sandy loams, loams, and sandy clay loams are more easily compacted than other soils. Gravelly soils are less susceptible to compaction than nongravelly soils.

Soil structure.—Soils with well developed structure and high aggregate stability have greater strength to resist compression than other soils.

Plants and soil organic matter.—Near-surface roots, plant litter, and above-ground plant parts reduce the susceptibility to compaction by helping to cushion impacts. Vegetation also adds soil organic matter, which strengthens the soil, making it more resistant to compaction.

What breaks up a compacted layer?

Natural recovery is often slow, taking years to decades or more. Cycles of wetting and drying and of shrinking and swelling can break down compacted layers, especially in clays and clay loams. Deep compaction occurs in smaller areas than shallow compaction, but it persists longer because it is less affected by the soil expansion caused by freezing. Shallow compaction may be very persistent, however, in areas that are not subject to freezing and thawing.

Roots help to break up compacted layers by forcing their way between soil particles. Plants with large taproots are more effective at penetrating and loosening deep compacted layers, while shallow, fibrous root systems can break up compacted layers near the surface. Roots also reduce compaction by providing food that increases the activity of soil organisms. Large soil organisms, such as earthworms, ants, and termites, move soil particles as they burrow through the soil. Small mammals that tunnel through and mix the soil also are important in some plant communities.

Management strategies that minimize compaction

- Minimize grazing, recreational use, and vehicular traffic when the soils are wet.
- Use only designated trails or roads; reduce the number of trips.
- Do not harvest hay when the soils are wet.
- Maintain or increase the content of organic matter in the soil by improving the plant cover and plant production.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

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Soil Quality Information Sheet

Rangeland Soil Quality—**Infiltration**

USDA, Natural Resources Conservation Service May 2001

What is infiltration?

The process of water soaking into the soil is infiltration. "Infiltration rate" is simply how fast water enters the soil and is usually measured in inches or millimeters per hour. This rate depends on soil texture (amount of sand, silt, and clay) and on soil structure. Soils in good condition have well developed structure and continuous pores to the surface. As a result, water from rainfall or snowmelt readily enters these soils.

Why is infiltration important?

Soil is a reservoir that stores water for plant growth. The water in soil is replenished by infiltration. The infiltration rate can be restricted by poor management. Under these conditions, the water does not readily enter the soil and it moves downslope as runoff or ponds on the surface, where it evaporates. Thus, less water is stored in the soil for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure that can further decrease the infiltration rate.

Runoff can cause soil erosion and the formation of gullies. It also carries nutrients and organic matter, which, together with sediment, reduce water quality in streams, rivers, and lakes. The sediment reduces the capacity of reservoirs to store water. Excessive runoff can cause flooding, erode streambanks, and damage roads. Runoff from adjacent slopes can saturate soils in low areas or can create ponded areas, thus killing upland plants. Evaporation in the ponded areas reduces the amount of water available to plants.

What factors affect infiltration?

The proportion of water from rainfall or snowmelt that enters the soil depends on "residence time" (how long the water remains on the surface before running off) and the infiltration rate. These are affected by vegetation and many soil properties.

Residence time

The length of time that water remains on the surface depends on the slope, the roughness of the soil surface, and obstructions to overland flow, such as plant bases and litter. Consequently, plant communities with large amounts of basal area cover, such as grasslands, tend to slow runoff more than communities with small amounts of basal cover, such as shrub lands.

Infiltration rate

The infiltration rate is generally highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils.

Vegetation

A high percentage of plant cover and large amounts of root biomass generally increase the infiltration rate. Different plant species have different effects on infiltration. The species that form a dense root mat can reduce the infiltration rate. In areas of arid and semiarid rangeland, the infiltration-limiting layer commonly is confined to the top few millimeters of the soil, particularly in the open spaces between plant canopies. These areas receive few inputs of organic matter, which build soil structure. Also, the impact of raindrops in these areas can degrade soil structure and form physical crusts.

Soil properties

The properties that affect infiltration and cannot be readily changed by management include:

Texture.—Water moves more quickly through the large pores and spaces in a sandy soil than it does through the small pores in a clayey soil. Where the content of organic matter is low, texture plays a significant role in the susceptibility of the soil to physical crusting.

Clay mineralogy.—Some types of clay develop cracks as they dry. These cracks rapidly conduct water to the subsurface and seal shut once the soil is wet.

Minerals in the soil.—High concentrations of sodium tend to inhibit the development of good structure and promote the formation of surface crusts, which reduce the infiltration rate. Calcium improves soil structure.

Soil layers.—Subsurface soil, including a subsoil of dense clay, cemented layers, and highly contrasting layers, such as coarse sand over loam, can slow water movement through soil and thus limit infiltration.

Depth.—Soil depth controls how much water the soil can hold. When soil above an impermeable layer, such as bedrock, becomes saturated, infiltration ceases and runoff increases.

The properties that affect infiltration and can be readily changed by management or a shift in vegetation are:

Organic matter and soil biota.—Increased plant material, dead or alive, generally improves infiltration. As organic matter is broken down by soil organisms, it binds soil particles into stable aggregates that enhance pore space and infiltration.

Aggregation and structure.—Good soil structure improves infiltration. Soils with good structure have more pores for the movement of water than soils with poor structure. If aggregates are stable, the structure remains intact throughout a rainstorm.

Physical crusts.—Physical crusts form when poorly aggregated soils are subject to the impact of raindrops and/or to ponding. Particles broken from weak aggregates can clog pores and seal the surface, thus limiting water infiltration.

Biological crusts.—Biological crusts can either increase or reduce the infiltration rate. Their effect on the infiltration rate depends on many other factors, including soil texture.

Pores and channels.—Continuous pores connected to the surface convey water. Such organisms as earthworms, ants, and termites increase the number of pores. Termites, however, can decrease the infiltration rate by reducing the amount of litter cover, and some ant species seal the surface around their nests.

Soil density.—A compacted zone close to the surface restricts the entry of water into the soil and often results in surface ponding. Increased bulk density reduces pore space and thus the amount of water available for plant growth.

Water-repellent layer.—As shrubs and an underlying thick layer of litter burn in a hot fire, very high temperatures can occur directly beneath the shrubs. The heat forces a gas from the burning plant material into the soil. When it cools, the gas forms a water-repellent layer that limits infiltration. This feature is temporary, although it may persist for a number of years. Some soils can be slightly water repellent when dry.

Management strategies

The soil and vegetation properties that currently limit infiltration and the potential for increasing the infiltration rate must be considered in any management plan. Where waterflow patterns have been altered by a shift in vegetation, such as a shift from grassland to open-canopy shrub land, restoration of higher infiltration rates may be difficult or take a long period, especially if depletion of organic matter and/or soil loss have occurred. Excessive grazing of forage can impair infiltration. Management strategies include:

- Increase the amount of plant cover, especially of plants that have positive effects on infiltration.
- Decrease the extent of compaction by avoiding intensive grazing and the use of machinery when the soils are wet.
- Decrease the formation of physical crusts by maintaining or improving the cover of plants or litter and thus reducing the impact of raindrops.
- Increase aggregate stability by increasing the amount of organic matter added to the soil through residue decomposition and vigorous root growth.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

(Prepared by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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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.

Table 1.—Soil organic matter

Component	Rate of decay	Primary function
Light fraction	Weeks to months	• Serves as food for soil organisms • Stores and provides plant nutrients
Physically protected	Decades	• Enhances soil structure, porosity, and the water-holding capacity
Chemically stable	Hundreds to thousands of years	• Holds nutrients • Stabilizes microaggregates

Why is organic matter important?

Soil organic matter enhances soil functions and environmental quality because it:

- binds soil particles together into stable aggregates, thus improving porosity, infiltration, and root penetration and reducing runoff and erosion;

Organic mattter darkens and stabilizes the surface layer in soils.

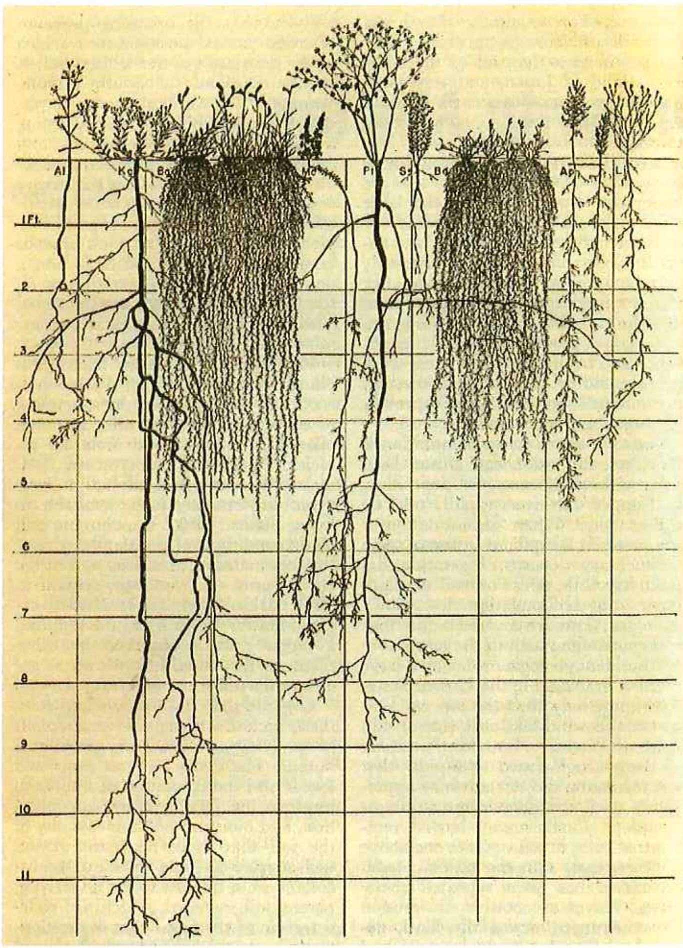
- enhances soil fertility and plant productivity by improving the ability of the soil to store and supply nutrients, water, and air;
- provides habitat and food for soil organisms;
- sequesters carbon from the atmosphere;
- reduces mineral crust formation and runoff; and
- reduces the negative water 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



root production is very important. Every year, about 25 percent of the total root biomass in areas of tall prairie grasses dies and becomes available for incorporation into the soil as organic matter. In the drier areas, such as areas of short prairie grasses, about 50 percent of the root biomass becomes available, but the total amount is less than that in the areas of tall grasses.

Plant composition and distribution control the distribution of organic matter. The horizontal and depth distribution of roots, the distribution of plants across the landscape, and the susceptibility of roots to decay vary among species. The roots of forbs and shrubs generally contribute less organic matter to the surface layer of the soil than the roots of grasses. Changes in the composition of plant species, especially from grasses to shrubs, affect the contribution of roots to soil organic matter. The organic matter is enhanced by litter beneath shrubs in areas of arid and semiarid rangeland. Fire initially reduces the amount of plant residue added to the soil. If the fire results in a shift from shrubs to grasses, however, the long-term effect can be an increase in soil stability and organic matter.

Soil organisms break down litter, dead roots, and organic matter into smaller fragments and compounds. As they decompose organic matter, they convert nutrients into plant-available forms and release carbon dioxide into the atmosphere. Warm, moist soil supports higher decomposition rates than waterlogged, dry, or cool soil.

Wind erosion and water erosion increase losses of organic matter. Erosion breaks down soil aggregates, exposing physically protected organic matter to decomposition and loss. Organic-rich soil from the surface layer is carried away by runoff or wind. Litter redistribution by wind or water from or to surrounding rangeland also affects the content of organic matter.

Grazing can change plant composition and distribution and increase or decrease the amount of organic matter in the soil. Grazing can increase the rate of root turnover, but overgrazing reduces the amount of plant energy available for the growth of new roots. Trampling by livestock can help to incorporate the plant material above the ground into the soil. In arid ecosystems, however, little plant material is available for incorporation. Trampling also breaks up soil aggregates, exposing organic matter to decomposition and loss through erosion.

Management strategies

The following strategies can help to maintain the optimum content of organic matter in rangeland soils:

- Increase or maintain plant production.
- Promote the growth of species with high root production and promote a mix of species with different rooting depths and patterns.
- Promote the incorporation of above-ground plant material in moist plant communities with large amounts of standing plant material (e.g., areas of tall prairie grasses).
- Protect the soil from erosion by maintaining or increasing the plant cover and reducing the amount of bare soil.
- Properly manage grazing, fire, and vehicle use and thus promote the desired plant community and protect the soil from erosion.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

(Prepared by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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Soil Quality Information Sheet

Rangeland Soil Quality—
Physical and Biological Soil Crusts

USDA, Natural Resources Conservation Service May 2001

What are soil crusts?

A **physical crust** is a thin layer with reduced porosity and increased density at the surface of the soil. A **biological crust** is a living community of lichen, cyanobacteria, algae, and moss growing on the soil surface and binding it together. A **chemical crust** or precipitate is white or pale colored and forms in soils with a high content of salts. Both chemical and biological crusts can form on and extend into a physical crust. This information sheet deals only with physical and biological crusts.

Why are soil crusts important?

Physical crusts generally indicate that the amount of organic matter in the soil has decreased and/or erosion has occurred. They have low aggregate stability, disperse readily when wet, and are easily reformed by raindrop impact or flowing water. They seal the soil surface, reduce the rate of water infiltration, and can increase runoff. Physical crusts generally have a very low content of organic matter and support little soil biological activity. The dense nature of the crusts can impede seedling emergence. Water that ponds in flat, crusted areas is likely to evaporate, reducing the amount of water available to plants. Physical crusts generally help to control wind erosion, but they do not protect the soil from water erosion.

Biological crusts stabilize the soil surface, protecting it from erosion. Depending on soil characteristics, biological crusts may increase or reduce the rate of water infiltration. By increasing surface roughness, they reduce runoff, thus increasing infiltration and the amount of water stored for plant use. Some organisms in biological crusts can increase the amount of nitrogen and other nutrients in the soil. In semiarid ecosystems biological crusts can provide a significant amount of nitrogen for plant growth. The germination of plants may be enhanced or inhibited, depending on the nature of the biological crust and the plant species. In general, the relative importance of biological crusts increases as annual precipitation and the potential plant cover decrease.

What determines crust formation?

Physical crusts form when organic matter is depleted from the surface layer, soil aggregates become weak, and raindrops disperse the soil into individual particles that clog soil pores, seal the surface, and form a layer that is dense when dry. A physical crust consisting of numerous thin bands can form when sediment from erosion is carried downslope and buries the soil surface. Physical crusts are more common on silty, clayey, and loamy soils and are relatively thin or weakly expressed, if present at all, on sandy soils. Soils with a high content of sodium disperse readily in water and are more susceptible to crust formation than other soils.

A physical crust.

A biological crust, primarily moss and cyanobacteria.

To examine a crust, lift the soil surface with a knife tip and look for cohesive layers or thin bands parallel to the soil surface. These layers have no apparent binding by visible strands of organic material, such as cyanobacteria. Fragments of physical crusts disperse or "melt" when placed in water. A vesicular crust is a type of physical crust with many small, unconnected air pockets or spaces similar to those in a sponge.

A biological crust occupies a large amount of the surface of calcareous and gypsiferous soils. Soil texture, moisture, temperature, season of precipitation, and history of disturbance largely determine the dominant organisms in the crust. For example, moss tends to be dominant in the Columbia Basin, whereas cyanobacteria and lichen are dominant in the Mojave, Sonoran, and Chihuahuan Deserts.

What affects crusts?

Organic matter and plants.—Organic matter in the soil inhibits physical crust formation by promoting the development of stable aggregates that resist rupture, dispersion, and water erosion. Plant cover, litter, and biological crusts inhibit the development of physical crusts by intercepting raindrops before they strike bare soil. Litter cushions biological crusts from trampling. Litter and plant cover moderate temperature and moisture extremes on the soil surface and thus aid in the development and diversity of biological crusts.

Soil features and erosion.—Soil features, such as fine texture, compaction, loss of organic matter, and soil structure, and an increase in the amount of bare ground decrease the rate of water infiltration and increase runoff. Increased runoff can erode the soil surface, removing biological crusts and leaving behind a layer that has a lower content of organic matter and is more susceptible to dispersion and physical crust formation. Burial by wind erosion and water erosion or a large amount of litter can damage biological crusts and kill some organisms. Burial of an unbroken physical crust does not overcome its water-restrictive features.

Fire.—Hot, frequent fires can damage some biological crusts. Increased runoff and erosion following hot catastrophic fires can promote the development of physical crusts and the loss of biological crusts.

Disturbances.—Both physical and biological crusts can be affected by physical disturbances caused by wheeled or tracked vehicles, livestock hooves, and hiking and cycling. The impact is determined by the severity, frequency, and timing of the disturbance and by the size of the disturbed area. Physical crusts tend to reform during the first rainstorm after a disturbance.

Management strategies

The development of objectives relative to soil crusts is an important part of rangeland management. Biological crusts protect the soil from water erosion and wind erosion. Physical crusts can protect soils from wind erosion as effectively as biological crusts, except on very coarse textured soils. In the more humid areas, it generally is desirable to break up physical crusts and thus improve seedling emergence and plant establishment; however, desirable biological crusts can be destroyed when the physical crusts are broken. Adequate organic matter, seeds of desirable species, and a period of rest are needed for successful establishment of plants after crusts are broken.

Recovery of biological crusts may take decades to hundreds of years. Therefore, preventing degradation by minimizing disturbance is important. Biological crusts that are in areas of low rainfall, are on coarse textured soils with low stability, and are in areas with a large amount of bare ground are most susceptible to frequent disturbances and have the longest recovery times. Biological crusts of all types are least susceptible to disturbance when the soil is frozen or is covered with snow. Biological crusts on sandy soils are less susceptible to disturbance when the soils are wet or moist, and the ones on clayey soils are less susceptible when the soils are dry. Trampling or grazing when the soil surface is very wet or ponded should be avoided because it can displace and bury the biological crust.

The following management strategies apply to land used for grazing, wildlife habitat, or recreation:

- Maintain the optimum amount of live vegetation, litter, and biological crust relative to the site potential in order to maintain the content of organic matter and soil structure and control erosion.
- In humid areas improve soil structure and plant establishment by incorporating organic matter into the soil while breaking up a physical crust.
- Defer grazing and recreational use during periods when biological crusts are most susceptible to physical disturbances.
- Use prescribed burning according to the needs of each site to prevent fuel buildup that can produce hot fires followed by severe erosion.
- Control the establishment and spread of invasive annual plants that can carry fire.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

(Prepared by the Soil Quality Institute, Grazing Lands Technology Institute, and National Soil Survey Center, Natural Resources Conservation Service, USDA; the Jornada Experimental Range, Agricultural Research Service, USDA; and Bureau of Land Management, USDI)

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Soil Quality Information Sheet

Rangeland Soil Quality—**Soil Biota**

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

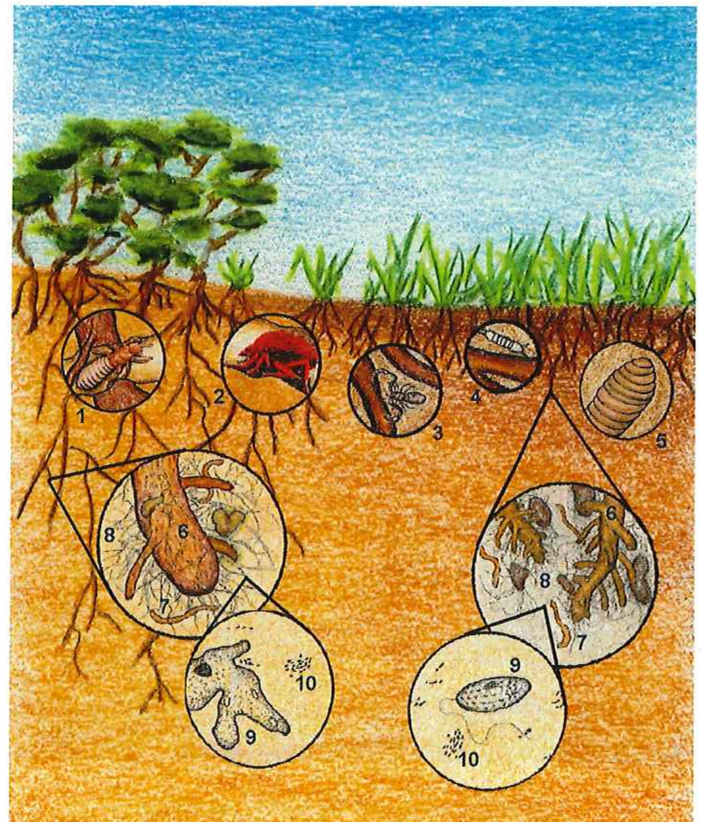
What are soil biota?

Soil biota, the biologically active powerhouse of soil, include an incredible diversity of organisms. Tons of soil biota, including micro-organisms (bacteria, fungi, and algae) and soil "animals" (protozoa, nematodes, mites, springtails, spiders, insects, and earthworms), can live in an acre of soil and are more diverse than the community of plants and animals above ground. Soil biota are concentrated in plant litter, the upper few inches of soil, and along roots. Soil organisms interact with one another, with plant roots, and with their environment, forming the soil food web.

What do soil biota do?

As soil organisms consume organic matter and each other, nutrients and energy are exchanged through the food web and are made available to plants. Each soil organism plays a role in the decomposition of plant residue, dead roots, and animal remains. The larger soil organisms, such as millipedes and earthworms, shred dead leaves and residue, mix them with the soil, and make organic material more accessible to immobile bacteria. Earthworms can completely mix the top 6 inches of a humid grassland soil in 10 to 20 years. Ants and termites mix and tunnel through soils in areas of arid and semiarid rangeland.

Predators in the soil food web include scorpions, centipedes, spiders, mites, some ants, insects, and beetles. They control the population of soil biota. The smaller organisms, including mites, springtails, nematodes, and one-celled protozoa, graze on bacteria and fungi. Other organisms feed on dead roots, shredded residue, and the fecal by-products of the larger organisms. The smallest soil organisms, microscopic bacteria and fungi, make up the bulk of the biota in the soil. They finish the process of decomposition by breaking down the remaining material and storing its energy and nutrients in their cells. Algae and fungi are the first organisms to colonize rock and form "new soil" by releasing substances that disintegrate rock.



1. Termite 2. Red velvet mite 3. Pseudoscorpion 4. Springtail 5. Earthworm 6. Root tip 7. Nematode 8. Fungi 9. Protozoa 10. Bacteria

Why are soil biota important?

Through their interactions in the soil food web, the activities of soil biota link soil with the plants and animals above ground. Soil organisms perform essential functions that allow soil to resist degradation and provide benefits to all living things.

Residue decomposition.—Without the soil food web, the remains of dead plants and animals would accumulate on the earth's surface, making nutrients unavailable to plants. Soil biota decompose these organic residues and some forms of organic matter in the soil. They convert these materials into new forms of organic matter and release carbon dioxide into the air. Many of the biota can break down pesticides and pollutants.

Nutrient storage and release.—Most of the annual nutrient needs of rangeland plants are supplied through decomposition of organic matter in the soil. As soil organisms consume organic materials, they retain (immobilize) nutrients in their cells. This process prevents the loss of nutrients, such as nitrogen, from the root zone. When fungi and bacteria die or are eaten by other organisms, nutrients are mineralized, that is, slowly released to the soil in plant-available forms. Nutrient immobilization and mineralization occur continuously throughout the year.

Some bacteria and fungi provide nutrients to plants in exchange for carbon. Special types of bacteria, called nitrogen fixers, infect the roots of clover and other legumes, forming visible nodules. The bacteria convert nitrogen from the air in the soil into a form that the plant host can use. When the leaves and roots die and decompose, nitrogen levels increase in the surrounding soil, improving the growth of other plants. Fungi produce hyphae that frequently look like fine white entangled threads in the soil. Some fungal hyphae (mycorrhizal fungi) attach to plant roots and act like an extended root system, providing nutrients and water to the plant.

Water storage, infiltration, and resistance to erosion.—Soil biota form water-stable aggregates that store water and are more resistant to water erosion and wind erosion than individual soil particles. Threads of fungal hyphae bind soil particles together. Bacteria and algae excrete material that "glues" soil into aggregates. As they tunnel through the soil, the larger soil biota form channels and large pores between aggregates, increasing the water infiltration rate and reducing the runoff rate.

Left: Active ant mound. Right: Old ant mound.

What affects soil biota?

Soil biota multiply rapidly when organic material, roots, and plant litter, their food source, are available and the soil is moist and warm. Seasonal patterns of biological activity coincide with plant growth stages, litter fall, and root die-off. To be active, bacteria require films of water in soil pores, whereas fungi can function in drier conditions. When the soil is too dry, bacteria and fungi become less active or temporarily shut down, protozoa form dormant cysts, and the number of most other organisms declines. When the soil is saturated and anaerobic, the number of denitrifying bacteria increases. Organisms affect each other through predation and competition for food and space. Small soil pores can restrict the movement of large soil organisms.

Different types of vegetation produce different types of litter and plant residue and thus provide different food sources for soil biota. Changes in the vegetation or the pattern of plant distribution affect the soil organisms.

Management considerations

Grazing.—Proper management of the plant community is the best strategy for maintaining the benefits of the soil food web. Plant production and the supply of organic matter can be maintained or enhanced by timely grazing, the proper frequency of grazing, and control of the amount of vegetation removed. If the plant community is overgrazed, a reduction in the amount of surface plant material and roots will result in less food for soil organisms. As biological activity decreases, a downward spiral of the important functions of soil organisms results in a lower content of organic matter and impedes nutrient cycling, water infiltration, and water storage. Heavy grazing also can reduce the abundance of nitrogen-fixing plants, causing a decrease in the supply of nitrogen for the entire plant community.

Erosion.—Erosion removes or redistributes the surface layer of the soil, the layer with the greatest concentration of soil organisms, organic matter, and plant nutrients. Runoff and wind erosion redistribute litter from one area of rangeland to a surrounding area. The loss of organic matter reduces the activity of soil biota in the areas from which the litter has been removed.

Compaction by grazing animals and vehicles.—Soil compaction reduces the larger pores and pathways, thus reducing the amount of habitat for nematodes and the larger soil organisms. Compaction can also cause the soil to become anaerobic, increasing losses of nitrogen to the atmosphere.

Fire and pest control.—Fire can kill some soil organisms and reduce their food source while also increasing the availability of some nutrients. Pesticides that kill above-ground insects can also kill beneficial soil insects. Herbicides and foliar insecticides applied at recommended rates have a smaller impact on soil organisms. Fungicides and fumigants have a much greater impact on the soil organisms.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

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Soil Quality Information Sheet

Rangeland Soil Quality—Water Erosion

USDA, Natural Resources Conservation Service May 2001

What is water erosion?

Water erosion is the detachment and removal of soil material by water. The process may be natural or accelerated by human activity. The rate of erosion may be very slow to very rapid, depending on the soil, the local landscape, and weather conditions.

Water erosion wears away the earth's surface. Sheet erosion is the more-or-less uniform removal of soil from the surface. Rill and gully erosion occurs when concentrated runoff cuts conspicuous channels into the soil. Deposition of the sediment removed by erosion is likely in any area where the velocity of running water is reduced—behind plants, litter, and rocks; in places where slope is reduced; or in streams, lakes, and reservoirs.

Why is erosion a concern?

Loss of topsoil changes the capacity of the soil to function and restricts its ability to sustain future uses.

Erosion removes or redistributes topsoil, the layer of soil with the greatest amount of organic matter, biological activity, and nutrients. The ability of a plant community to recover after topsoil is lost is restricted.

Erosion breaks down soil structure, exposing organic matter within soil aggregates to decomposition and loss. Degraded soil structure reduces the rate of water infiltration.

Erosion of nutrient-rich topsoil can cause a shift to less desirable plants, such as from grass to shrub species. In this process, soil organic matter and nutrients eroded from one area contribute to resource accumulation in another, such as the area around shrubs.

Erosion of shallow soils can decrease the thickness of the root zone and the amount of air, water, and nutrients available to plants.

The sediment removed by erosion can bury plants and roads; accumulate in streams, rivers, and reservoirs; and degrade water quality.

What causes water erosion?

Erosion is caused by the impact of raindrops on bare soil and by the power of running water on the soil surface. Natural erosion rates depend on inherent soil properties, slope, and climate, which together determine the ability of the site to support vegetation. Accelerated erosion occurs when the plant cover is depleted, the spaces between plants becomes larger, and soil structure is degraded by excessive disturbance or reduced inputs of organic matter. Compaction increases runoff and the risk of accelerated erosion. Runoff concentrated by poorly designed or maintained roads or trails can cause accelerated erosion on the adjacent slopes and in roadbeds.

Many vegetation and soil properties affect the risk of erosion. Each specific soil has its own natural erosion rate. A sandy or clayey texture generally is less erodible than loam or silt loam. Sandy soils that formed in material weathered from decomposed granitic rock, however, are highly erodible. Soils with rock fragments or biological crusts on the surface are protected from the impact of raindrops. Stable soil aggregates bound together by organic matter resist erosion, enhance infiltration, and result in less runoff. The amount of runoff and the power of water to erode and transport soil are greater on long, steep slopes. Bare soil between plants is most susceptible to erosion.

What are some indicators of erosion?

Erosion and the risk of erosion are difficult to measure directly. Other soil properties that affect erosion and can change with management, including soil surface stability, aggregate stability, infiltration, compaction, and content of organic matter, can be measured. Measuring these properties can shed light on the susceptibility of a site to erosion. Comparing visual observations along with quantitative measurements to the conditions indicated in the ecological site description or a reference area helps to provide information about soil surface stability, sedimentation, and soil loss.

The visual indicators used to identify past erosion include:

- bare soil;
- pedestaled plants or rocks;
- exposed roots;
- terracettes (benches of soil deposited behind obstacles);
- an increase in the number and connectivity of waterflow patterns between plants;
- soil deposition at slope changes;
- changes in thickness of topsoil;
- exposure of subsoil at the surface;
- rills, headcutting, and/or downcutting in gullies;
- sediment in streams, lakes, and reservoirs; and
- reduced plant growth.

When measured every few years, the following indicators can be used to predict where accelerated erosion is likely to occur in the future:

- an increase in the amount of bare ground or in the size or connectivity of bare patches,
- reduced soil aggregate and soil surface stability, and
- reduced water infiltration.

Management strategies that minimize water erosion

The risk of erosion and the potential for recovery after erosion must be considered in any management plan. The risk of erosion is increased by a fire frequency or intensity that is either greater or less than is expected for the site; by disturbances, such as heavy grazing; and by the establishment of weeds. Areas with fertile topsoil are most likely to recover after a disturbance. In areas where much of the topsoil is lost, the site may no longer be able to support the historic vegetation. Management strategies include:

- Maintain or increase the cover of plants or litter on the soil through the application of good rangeland management practices.
- Reduce soil surface disturbances, especially in arid areas.
- Increase the rate of water infiltration and improve soil aggregate stability by improving or maintaining the quality of the plant community.
- Minimize grazing and traffic when the soil is wet and thus prevent the reduced infiltration caused by compaction and physical crusting.
- Build water bars and direct waterflow from roads, trails, or vehicle tracks across the slope or into existing drainageways.
- Maintain road surfaces and drainageways.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

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Soil Quality Information Sheet

Rangeland Soil Quality—Wind Erosion

USDA, Natural Resources Conservation Service May 2001

What is wind erosion?

Wind erosion is the physical wearing of the earth's surface by wind. Wind erosion removes and redistributes soil. Small blowout areas may be associated with adjacent areas of deposition at the base of plants or behind obstacles, such as rocks, shrubs, fence rows, and roadbanks. In many cases the fine soil particles and organic matter are blown offsite or into the atmosphere as dust. Reducing the amount of bare ground by increasing the extent of vegetation, litter, and biological crusts reduces the risk of wind erosion.

Why is erosion a concern?

Loss of topsoil changes the capacity of the soil to function and restricts its ability to sustain future uses.

Erosion removes topsoil, the layer of soil with the greatest amount of organic matter, biological activity, and nutrients, creating a less favorable environment for plant growth.

Erosion breaks down soil structure, exposing organic matter within soil aggregates to decomposition and loss. Degraded soil structure reduces the rate of water infiltration.

Erosion of nutrient-rich topsoil can cause or accelerate a shift to less desirable plants, such as from grass to shrub species. In this process, soil organic matter and nutrients eroded from one area contribute to resource accumulation in another, such as the area around shrubs.

Erosion decreases soil depth and therefore the amount of air, water, and nutrients available for plant growth. This decrease can have a greater impact on shallow soils than on other soils.

Windblown dust affects animal and human health, creates public safety hazards, and degrades air quality.

Deposits of windblown soil can bury plants and fences and obstruct roadways.

What causes wind erosion?

Wind erosion can occur only when windspeed at the soil surface is sufficient to lift and transport soil particles. Moist soils and soils with stable aggregates or rock fragments are less likely to be eroded than other soils. Thick lichen crusts provide greater resistance to erosion than thin crusts. Sand moving across the soil surface wears away soil aggregates and thin crusts, causing more soil particles to become detached and to be blown away. A cover of plants disrupts the force of the wind.

Soils are more susceptible to wind erosion where disturbance exposes individual particles and soil aggregates to the wind. When physical or biological crusts are crushed or broken apart by such disturbances as heavy grazing, vehicle or foot traffic, and water erosion, particle movement begins at the lower windspeeds. The following conditions increase the susceptibility of the soil to wind erosion:

- crushed or broken soil surface crusts during windy periods;
- a reduction in the plant cover, biological crusts, and litter, resulting in bare soil;
- a decrease in the amount of organic matter in the soil, causing decreased aggregate stability; and
- long, unsheltered, smooth soil surfaces.

What are some indicators of wind erosion?

Erosion and the risk of erosion are difficult to measure directly. Other soil properties that affect erosion and can change with management, including soil surface stability, aggregate stability, and content of organic matter, can be measured. Measuring these properties can shed light on the susceptibility of a site to erosion. Comparing visual observations along with quantitative measurements to the conditions in the ecological site description or a reference area helps to provide information about soil surface stability and wind erosion.

The visual indicators used to identify past erosion include:

- bare soil,
- wind-scoured areas between plants,
- a drifted or rippled soil surface,
- loose sand on physical crusts,
- biological crusts buried by soil,
- pedestaled plants or rocks,
- exposed roots,
- soil deposition on the leeward side of plants and obstacles,
- litter movement to the leeward side of plants and obstacles,
- exposure of subsoil at the surface,
- reduced plant growth, and
- dust clouds.

When measured over time, the following indicators can be used to predict where accelerated erosion is likely to occur in the future:

- an increase in the amount of bare ground or in the size of bare patches,
- reduced soil surface stability, and
- a reduction in the amount of organic matter.

Management strategies that minimize wind erosion

The risk of erosion and the potential for recovery after erosion must be considered in any management plan. Disturbances, such as heavy grazing, fire that removes too much plant cover and litter, or vehicle and foot traffic, can increase the risk of wind erosion. Physical crusts protect the soil from wind erosion but can retard plant establishment. Areas with fertile topsoil are most likely to recover after a disturbance. Where much of the topsoil is lost, the site may no longer be able to support the historic vegetation. Management strategies include:

- Maintain or increase the protective cover of plants and litter on the soil through the application of good rangeland management practices.
- Reduce disturbances of physical and biological crusts, especially in arid areas.
- Maintain soil aggregate stability by improving or maintaining the quality of the plant community.

Lichen and cyanobacteria stabilize soil.

A physical crust protects soil.

For more information, check the following: http://www.statlab.iastate.edu/survey/SQI **and** http://www.ftw.nrcs.usda.gov/glti

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