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Describing Indicators of Rangeland Health

Technical Reference 1734-9

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Natural Resources Conservation Service
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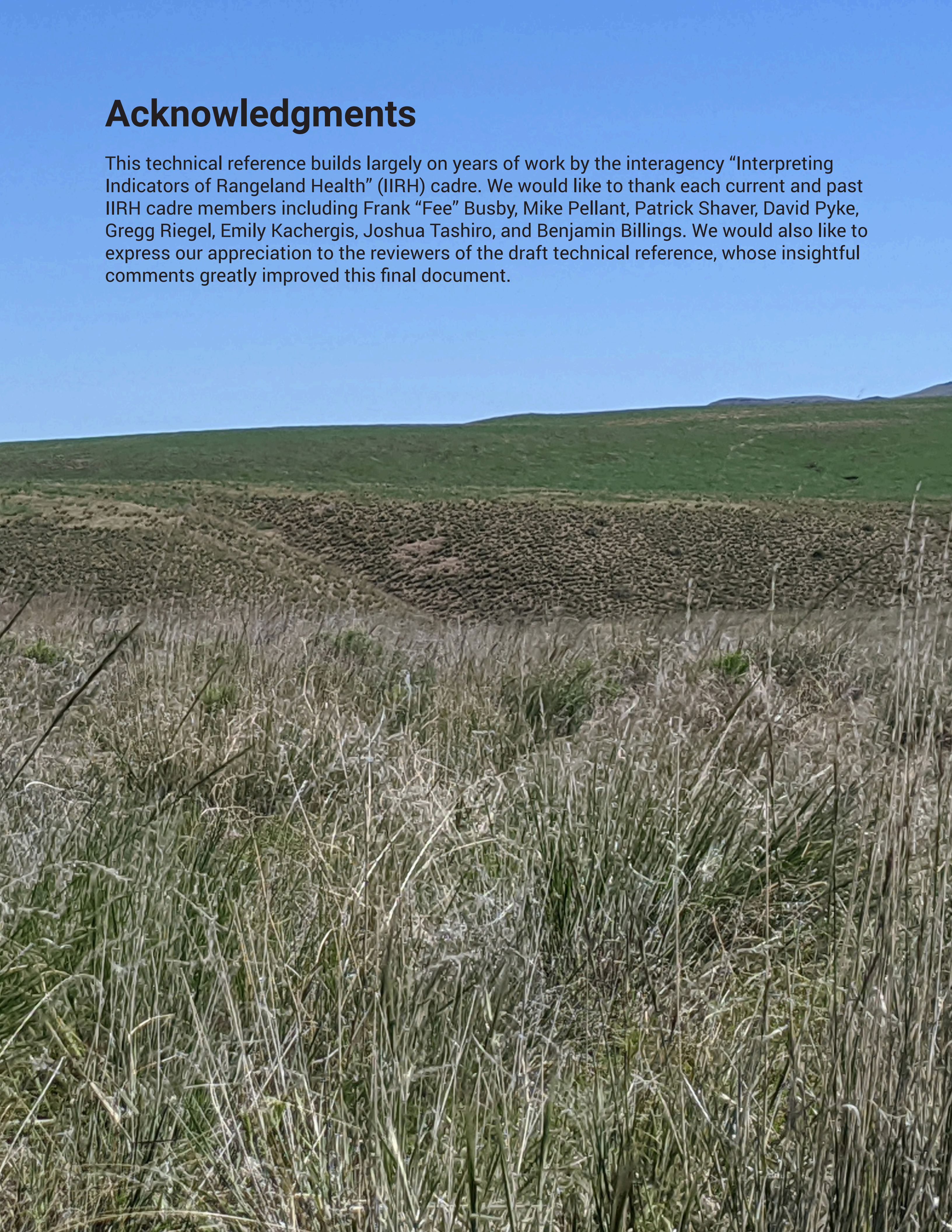

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1. Overview/Summary

This technical reference explains a simple, repeatable protocol to describe and quantify 17 indicators of rangeland health. The protocol uses a combination of quantitative measurements and qualitative observations. Users of the Describing Indicators of Rangeland Health (DIRH) protocol should possess basic rangeland monitoring experience, knowledge of soils and vegetation, and strong observational skills. This protocol does not rate degree of indicator departure from an ecological reference; instead, a standardized system is used to classify and describe each of the 17 indicators independent of a reference.

Describing Indicators of Rangeland Health may be used in several ways, including:

- As a rapid assessment when it is not feasible to conduct an Interpreting Indicators of Rangeland Health (IIRH) assessment.
- Supplementing standardized quantitative monitoring data with structured observations of difficult-to-measure indicators such as soil erosion indicators.
- Facilitating education and communication about rangeland conditions and ecology.
- Informing the development and revision of rangeland health reference sheets and ecological site-specific evaluation matrices, which are used for IIRH assessments.
- Expanding the scientific understanding of the relationships between changes in quantitative indicators and ecosystem processes, including informing erosion models.
- Informing subsequent completion of IIRH assessments using an appropriate reference sheet.

2. Introduction

Rangeland ecosystem processes, including interactions among soil, water, and biological ecosystem components, are complex, making it difficult to observe or measure ecological processes in the field. However, ecological indicators can be measured or observed to derive valuable insights about ecological attributes and processes. A suite of related indicators should be used to assess rangeland health (Karr 1992); however, not all indicators are practical to measure in the field. An approach that combines quantitative measurements and structured qualitative observations can enable a rapid assessment of numerous ecological indicators and enable detection of signs of degradation that may be missed using only standard quantitative field methods (Lepak et al. 2022).

The IIRH protocol (Pellant et al. 2000, 2005, and 2020 and referred to hereafter as TR 1734-6) was developed to assess the health of upland areas and has been used extensively for over 20 years on private and public rangelands in the United States, as well as in other countries (Lepak et al. 2022). IIRH is a primarily qualitative assessment; it uses structured observations of 17 rangeland health indicators, and rates the departure of each indicator from a reference condition. The indicator ratings are then used in combination to assess three attributes of rangeland health: soil and site stability, hydrologic function, and biotic integrity. However, IIRH can only be conducted in locations where (1) a land classification system, such as the ecological site classification system, is available, (2) the ecological potential is understood, and (3) a reference sheet exists that describes the expected characteristics of the 17 indicators under the natural range of variability. Specialized expertise and training are also required to maximize reliability and repeatability of IIRH assessments and minimize bias potentially associated with qualitative assessments.

If any of the requirements for conducting IIRH assessments cannot be met, the DIRH protocol may be used as an alternative framework for collecting structured measurements and observations of the 17 indicators of rangeland health (Figure 1). Although some of the 17 indicators can be fully or partially assessed quantitatively using common rangeland monitoring methods, other indicators are difficult or impractical to measure in the field and are instead described qualitatively. Unlike with the IIRH protocol, the DIRH protocol describes and classifies all indicators using universal classification categories and criteria, rather than judging the degree of departure relative to their expected condition under the natural range of variability.

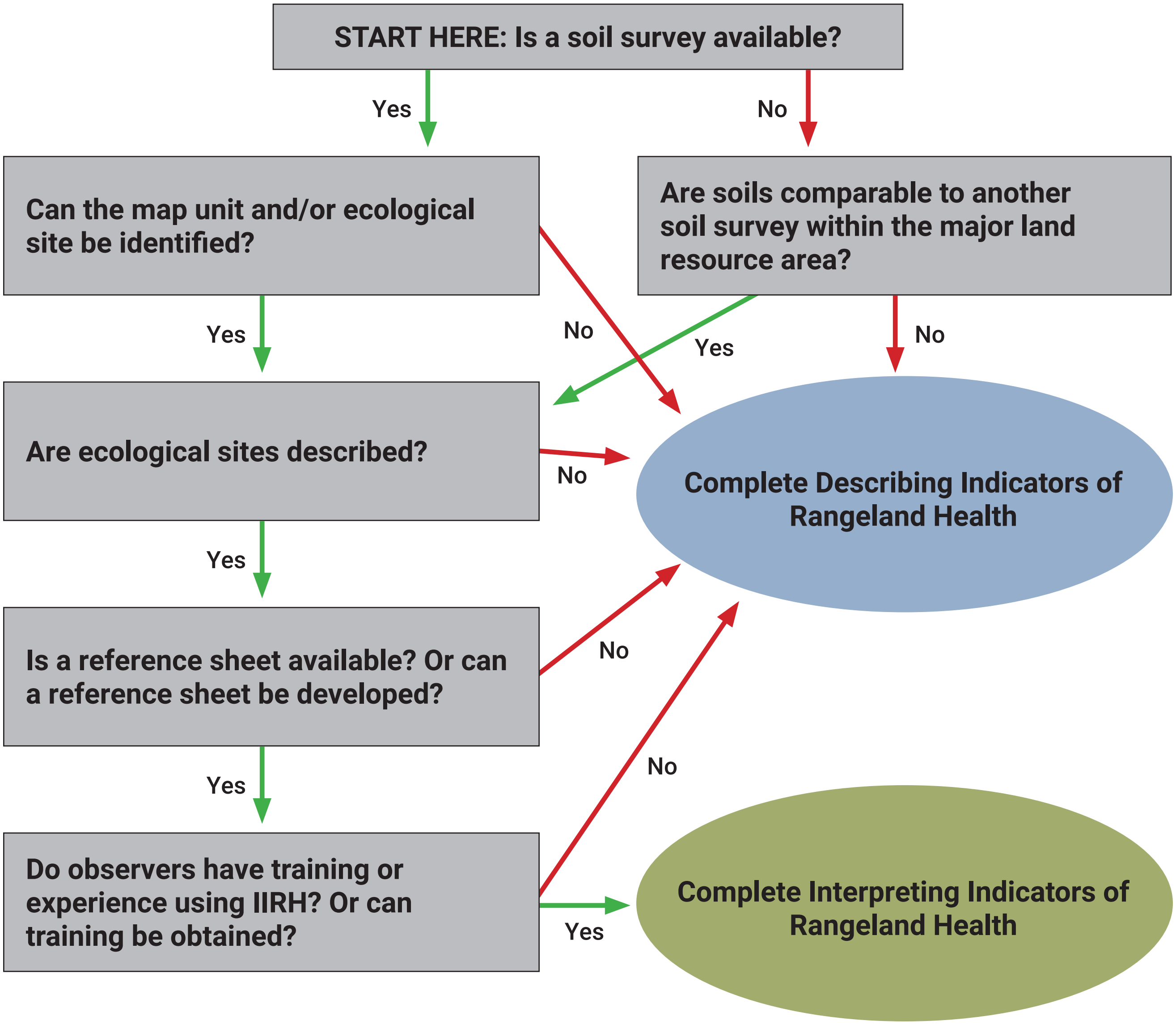


Figure 1. Decision tree for determining when to use Interpreting Indicators of Rangeland Health or Describing Indicators of Rangeland Health.

This technical reference provides field staff who have basic soils, vegetation, and monitoring experience with the guidance needed to conduct DIRH assessments, either as standalone assessments or as part of other assessment and monitoring projects. The reader is encouraged to refer to TR 1734-6 for a more in-depth discussion of the indicators, data applications, and ecological concepts underlying both the IIRH and DIRH protocols. In some circumstances information from DIRH assessments may be used to complete IIRH assessments once the reference is defined (see Section 8, After Completing the Assessment for more information).

The DIRH protocol has been outlined by Herrick et al. (2019) and is also included as an appendix to TR 1734-6. However, this DIRH technical reference provides more step-by-step instructions for field practitioners and incorporates changes to the previously described protocol. Implementation of the provided methods and procedures will result in DIRH assessments that leverage standardized quantitative data collection methods, are more consistent with TR 1734-6, and better meet the objectives of the intended applications described below.

3. Intended Applications

The DIRH protocol is described as a way of "linking indicators to characteristics that define land potential, informing our understanding of land potential by defining the historic natural range of variability for specific types of land" (Herrick et al. 2019), and may be used in several other ways. Intended applications, which are discussed in more detail in the After the Assessment section of this technical reference include but are not limited to:

Rapid assessments where IIRH is not feasible. DIRH may be used when a rapid, structured assessment is needed, but ecological sites are not identified, or other requirements of IIRH cannot be met. For example, the protocol may be used to rapidly identify signs of erosion and provide general information about post-fire vegetation recovery. This information can then be used to help identify monitoring priorities and support adaptive management decisions, such as post-fire treatments or grazing resumption.

Supplementing quantitative inventory and monitoring projects. Inventory and monitoring projects or programs may include DIRH as a supplement to quantitative data collection methods. Including structured observations of indicators that are difficult to measure can add value to the resulting datasets and may enable detection of resource issues that would not be captured by quantitative data alone (Jablonski et al. 2021, Lepak et al. 2022). Because DIRH explicitly addresses ecosystem processes, it can be used to help interpret the results of assessment and monitoring systems that are limited to measuring soil properties (e.g., many laboratory-based soil health protocols, or dynamic soil properties) and/or vegetation composition and structure. Several DIRH indicators are the same as or similar to those included in soil health assessment systems, such as the Natural Resources Conservation Service's (NRCS's) "Cropland In-Field Soil Health Assessment" (NRCS 2021), and standardized vegetation monitoring protocols such as the Bureau of Land Management's (BLM) terrestrial Assessment, Inventory and Monitoring (AIM) protocol. See the text box Relationship of DIRH to Monitoring on page 7 for appropriate application of DIRH when monitoring change over time.

Education and communication. DIRH assessments provides an excellent opportunity for illustrating rangeland health concepts and indicators in the field. Using clear descriptions of indicators and their characteristics, DIRH can be used to demonstrate how changes (e.g., soil erosion) can be detected on the landscape. Using an evaluation area where indicators are relatively prominent, participants can learn to recognize each indicator, conduct group exercises to collect quantitative measurements, and integrate qualitative and quantitative observations to describe each indicator.

Developing rangeland health reference sheets. DIRH is an ideal method for documenting indicator conditions at ecological reference areas when developing or revising reference sheets, which describe site potential under the natural range of variability and are required when conducting IIRH assessments. The DIRH protocol facilitates collection of quantitative data and description of indicator characteristics recommended for inclusion in reference sheets, as described in Appendix 1a of TR 1734-6, Version 5. DIRH assessments conducted in areas on the same ecological site that are at potential may be used for reference sheet development.

Developing rangeland health evaluation matrices. DIRH assessments help inform development of ecological site-specific evaluation matrices, which are recommended for IIRH assessments. DIRH assessments conducted in areas on the same ecological site that both are and are not at potential should be used to develop ecological site-specific evaluation matrices.

Supplementing erosion models. Soil erosional indicators assessed in the DIRH protocol may provide additional insight when paired with wind and water erosion models when evaluating the historic, ongoing, and future risk of soil erosion. DIRH may be used in conjunction with erosion models such as the Aeolian Erosion (AERO) model (Edwards et al. 2022), the Rangeland Hydrology and Erosion Model (RHEM) (Nearing et al. 2011; Webb et al. 2020), and the Erosion Risk Management Tool (ERMiT) (Robichaud, 2008).

DIRH is **not** intended to be used to:

- Monitor trend without repeatable, quantitative data collection. Qualitative descriptions used in DIRH are a moment-in-time snapshot of indicator conditions. A valid monitoring approach incorporating DIRH must incorporate robust, repeatable quantitative measurements, which provide the basis for detecting changes in conditions over time.
- Rate the attributes of rangeland health. Unlike IIRH, the DIRH protocol does not compare site observations to an ecological reference, therefore departures from the expected conditions and the attributes of rangeland health cannot be rated. Thorough, detailed DIRH assessments supported by consistent quantitative data and supplemental information may be used to complete the IIRH protocol using an appropriate reference sheet to rate the indicators, and the attributes of rangeland health (soil/site stability, hydrologic function, and biotic integrity).
- Identify the cause of degradation or make management decisions alone, without the benefit of other lines of evidence. When a DIRH assessment suggests that land health concerns may exist, further supporting information should be collected.

The DIRH protocol is intended for use on the following types of land:

- **Rangelands,** which are “lands on which the indigenous vegetation (climax or natural potential) is predominantly grasses, grass-like plants, forbs, or shrubs and is managed as a natural ecosystem” (SRM 1998). Rangeland vegetation types appropriate for DIRH assessments include grasslands, savannas, shrublands, desert, tundra, and alpine communities.
- **Woodlands,** which are areas with a low density of trees forming open plant communities that support an understory of shrubs and herbaceous plants. The DIRH protocol can be applied in open and dry forest systems and woodlands (e.g., oak, pinyon-juniper).
- **Ephemeral systems,** which are drainage areas in rangelands and woodlands that receive more water than typical upland ecological sites. Ephemeral drainages do not support hydric vegetation because the water remains for short periods of time (generally less than 1 month at a time in most years). The DIRH protocol can be applied in ephemeral systems if they are of sufficient size. See Section 5.3 of TR 1734-6, Version 5 for additional discussion of ephemeral systems.

Although the DIRH protocol is not specifically designed for croplands, wetlands, riparian areas, or closed-canopy forests, most of the indicators can also be applied in these systems to provide insight into ecosystem processes. When applying DIRH to these other types of land, consider whether additional indicators should be used (see Section 6, Optional Indicators). A related protocol, “Describing Indicators of Pasture Health,” is also available for use in grazed pasture lands and can be found in the “National Range and Pasture Handbook” (NRCS 2022).

Relationship of DIRH to Monitoring

While DIRH is a moment-in-time assessment rather than a monitoring protocol intended to identify changes over time, it can be a useful supplement to quantitative rangeland monitoring protocols. Many of the indicators are also relevant to woodlands, forests, pasture lands, and croplands.

Conducting DIRH assessments at established monitoring locations may provide advantages such as availability of well-documented supplemental information (e.g., site photos and soils data). However, it is important to consider whether the existing monitoring location meets the objectives for completing the DIRH assessment.

Useful monitoring applications of DIRH include (1) detecting early warning of resource problems, (2) prioritizing and designing monitoring plans and management actions, and (3) supplementing quantitative monitoring protocols.

(1) DIRH provides a structured basis for rapid visual detection of resource problems, which can help prioritize where management interventions or additional monitoring may be needed. Many DIRH indicators are easily recognized by trained individuals while they are in the field, whether completing a formal DIRH assessment, or simply observing indicators while completing other field work. For example, a rancher who has participated in DIRH assessments or training may be more likely to take note of DIRH indicators such as signs of reduced plant vigor, or active wind erosion while tending to livestock in a grazing allotment or pasture.

(2) When resource issues are identified through a DIRH assessment, the results can be also be used to prioritize monitoring locations and select monitoring methods. For example, if invasive plant species are a concern, cover and density methods may be used to monitor changes in invasive species abundance over time.

(3) Several DIRH indicators are difficult to measure but can assist with understanding how ecosystem processes are changing, as well as help detect signs of degradation that may be missed by quantitative methods. Together, the DIRH assessment and quantitative monitoring can inform management decisions. For example, measured changes in plant cover and bare ground can be considered along with soil stability values, and qualitative descriptions of erosional indicators such as water flow patterns and pedestals and terracettes to better understand how cover changes are affecting ecological processes.

4. Considerations When Preparing to Conduct DIRH Assessments

4.1 Timing of Assessments

Timing should be taken into account when planning assessments. Consideration for local phenology patterns ensures that assessments are conducted at a time of the year when plant species can be identified, and their reproductive capability can be assessed. Although DIRH is a point-in-time assessment, it should be conducted when the most important indicators for the area or ecological site are accessible and readily observed. During, or soon after the growing season, is generally the optimal time to observe the biotic indicators. However, some of the hydrology and erosion indicators are more apparent early in the growing season immediately following rain, or during the dry season when wind erosion is most likely to occur.

4.2 DIRH Assessment Teams

Multi-disciplinary teams are strongly recommended for completing DIRH assessments. First, multiple observers help to ensure thorough observation of all indicators in the field and can provide efficiencies by sharing the tasks of digging soil pits and collecting quantitative data. Each observer is likely to focus on specific indicators based on their background and training. For example, an analysis of over 500 IIRH assessments in Utah found that assessments of soils-related indicators were more reliable when the team included a member with soils expertise (Miller 2008).

4.3 Training and Calibration

As with other assessment and monitoring techniques, investing in observer training and calibration prior to conducting DIRH assessments is critical to ensure consistent, reliable results. It is recommended that observers participate in training for the quantitative methods that will be used to support the DIRH assessment. Regular calibration between observers is also recommended for both quantitative and qualitative indicator descriptions. Calibration on quantitative methods can be accomplished by having observers independently collect data in the same location using the same methods, and then calculating indicator values and comparing results and collaboratively identifying the sources of variability between observers. This process should be repeated until observers are reliably obtaining similar results for each method. Calibration on qualitative indicator observations can be achieved following a similar process; within a defined evaluation area, each observer uses the DIRH evaluation and Functional/Structural Groups worksheets to classify and describe each indicator. The results can then be compared, and reasons for differences discussed. These calibration exercises should be repeated periodically during the field season, or when transitioning between ecosystem types with substantially different kinds of vegetation and/or soils.

4.4 Equipment and Supplies

Equipment and supplies required for each DIRH assessment may vary depending upon the purpose of the assessment and the supporting quantitative data that is collected. At a minimum, a camera, shovel, soil color reference, and soil stability test kit should be available, as well as the appropriate data forms. A checklist of equipment and references is provided in Appendix 1.

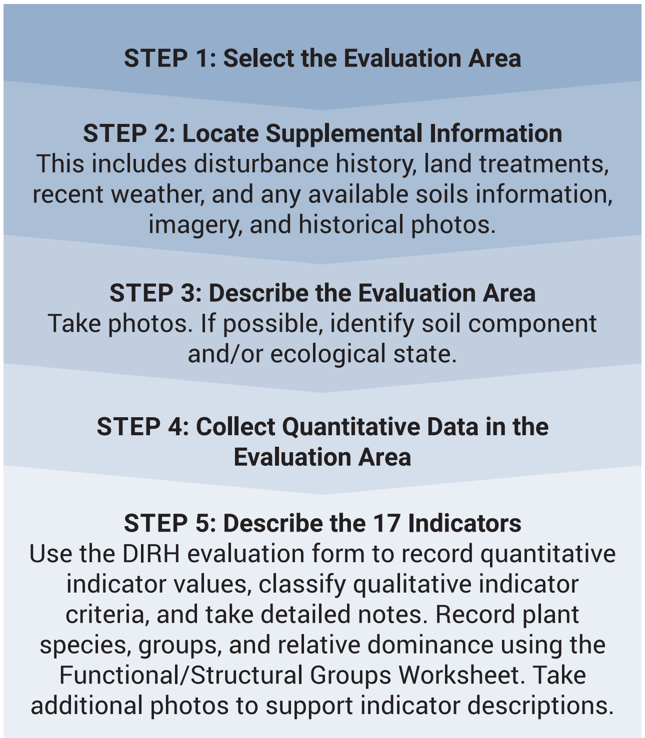
5. Describing Indicators of Rangeland Health: A Five-Step Process

The DIRH protocol consists of a five-step workflow, which is summarized in Figure 2, and is based on a previously described two-step process (Herrick et al. 2019, Pellant et al. 2020).

5.1 Step 1. Select the Evaluation Area

Approaches to selecting evaluation area locations vary depending on project objectives and should follow accepted organizational protocols. The DIRH protocol can be incorporated as a component of a structured data collection process (e.g., the BLM's terrestrial Assessment, Inventory and Monitoring (AIM) protocols), conducted at existing monitoring locations or targeted locations such as key areas, which are selected due to specific resource concerns or management objectives (SRM 1998, BLM 1999, Herrick et al. 2009). Evaluation areas may also be selected using other approaches based on the objectives of the project or individual assessment. For example, it may be appropriate to select targeted, non-random DIRH evaluation areas, such as an area that may be at risk of erosion due to localized disturbances or an ecological reference area that may be used to develop a rangeland health reference sheet. It is important to acknowledge that targeted approaches may incorporate bias and present limitations for aggregating assessment results and making statistical inferences to larger areas. Randomized site selection may be preferred when the intent is to analyze conditions across a larger area of interest, such as an entire pasture or large vegetation treatment. There are many resources available for further discussion of sampling considerations including but not limited to: "Measuring and Monitoring Plant Populations" (Elzinga et al. 1998), "Sampling Vegetation Attributes" (BLM 1999), and the "Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems Volume II: Design, Supplementary Methods and Interpretation" (Herrick et al. 2009), all of which can be used to inform DIRH evaluation area selection.

Each DIRH evaluation area should be approximately 0.5–1 acres (0.2–0.4 hectares) in size. When completing DIRH as part of a structured, plot-based monitoring project, the DIRH evaluation area should coincide with the footprint of the monitoring plot (Figure 4). When possible, the evaluation area should be relatively homogeneous in terms of slope, landform, soil features (e.g., surface texture and color, proportion of rock), management, disturbance, and vegetation. This increases the likelihood that the evaluation area represents a single soil type and/or ecological site. The boundaries of the evaluation area should be temporarily marked to ensure that all measurements and indicator observations are made across the same area.



STEP 1: Select the Evaluation Area

STEP 2: Locate Supplemental Information
This includes disturbance history, land treatments, recent weather, and any available soils information, imagery, and historical photos.

STEP 3: Describe the Evaluation Area
Take photos. If possible, identify soil component and/or ecological state.

STEP 4: Collect Quantitative Data in the Evaluation Area

STEP 5: Describe the 17 Indicators
Use the DIRH evaluation form to record quantitative indicator values, classify qualitative indicator criteria, and take detailed notes. Record plant species, groups, and relative dominance using the Functional/Structural Groups Worksheet. Take additional photos to support indicator descriptions.

Figure 2. Summary of the five-step process of conducting a DIRH assessment.

5.2 Step 2. Locate Supplemental Information

Supplemental information provides valuable context for the DIRH assessment and may include, but is not limited to:

- Recent weather
- Disturbance history (e.g., wildfire)
- Land treatment records
- Offsite influences
- Wildlife, livestock, recreation, or other land use information
- Imagery

DIRH assessments intended to support the interpretation of quantitative data, (e.g., reference sheet development or consideration in management decisions) or completion of IIRH assessments, should include as much supplemental information as possible. This will maximize the usefulness of the DIRH data and help users avoid misinterpretations that may result from the lack of appropriate contextual information. The following is a summary of the types of information that may be relevant, but other types of supplemental information may be needed depending on local circumstances and the interpretations being made from the DIRH assessment. Note that these categories are often overlapping (e.g. land treatments can be considered part of disturbance history).

Recent weather: Recent weather can affect several indicators. Therefore, weather information for at least the two years prior to the assessment provides important context for indicator descriptions. For example, plant vigor and litter amount may decrease during and following drought periods or increase in response to favorable growing conditions. Water flow patterns may be more prominent shortly after an intense rainstorm. Weather station records, spatial web services (e.g., Climate Engine (www.climateengine.org), and local knowledge are potential weather information sources. Recent weather data should be compared to long-term climatic averages to gain an understanding of whether recent conditions are similar, or if recent weather has been generally warmer or colder and whether precipitation has been higher or lower than usual.

Disturbance history: Information about disturbance provides valuable context when interpreting DIRH assessments. Wildfire is an example of a natural disturbance that can be expected to drive plant community changes at an evaluation area. Other natural disturbances that may be documented include but are not limited to insect or rodent population increases or decreases, native herbivore use, droughts, and wet periods. Note that land treatments and other human activities are also considered disturbances.

Land treatments: Information on land treatments may be helpful, including a wide range of vegetation and soil manipulations, such as use the of mechanical equipment, herbicides, prescribed fire, or seeding. Dates, types of treatments (including seed mixtures if applicable), results from monitoring studies (if available), and treatment polygons all provide context for conducting an assessment. Local knowledge and agency or landowner records may provide this information. For example, the U.S. Geological Survey (USGS) maintains the Land Treatment Digital Library (https://ltdl.wr.usgs.gov), which contains information on land treatments implemented on public lands managed by the Bureau of Land Management. Treatments on Forest Service land may be found in the FSGeodata Clearinghouse (https://data.fs.usda.gov/geodata/edw/datasets.php).

Offsite influences: It is important to consider how evaluation areas may be affected by natural or anthropogenic offsite influences, which should be noted when documenting supplemental information. For example, an evaluation area at the bottom of a steep slope may receive additional runoff during storm events, making it more susceptible to erosion. Offsite influences can include but are not limited to the topographic position; roads; trails; gullies; water sources; mining; or any developments nearby that may modify runoff, serve as vectors for spreading weeds, or otherwise alter ecological processes within the evaluation area.

Wildlife, livestock, recreation, or other land use information: Land use information should also be used when interpreting DIRH assessments and is often available from local land managers. For example, vegetation cover or plant reproductive capability may be reduced if a DIRH assessment is completed during or after livestock grazing.

Imagery: Aerial photos, historical photographs, and remotely sensed imagery may be useful supporting information to help understand site history and spatial context. For example, aerial photos, such as those available from Google Earth, the National Agriculture Imagery Program (NAIP), or USGS Earth Explorer can help to determine exact boundaries of disturbances like wildfire or land treatment extents. Historical photographs, particularly of the general landscape and vegetation, can also provide context for site potential to help inform indicators such as functional/structural groups, invasive plants, and plant community composition. Similarly, satellite imagery and derived remote sensing models such as LANDFIRE Biophysical Settings (https://landfire.gov) or the Rangeland Analysis Platform (RAP; https://rangelands.app/) can give contextual information regarding ecological potential, disturbance history, and vegetation cover going back to 1986.

5.3 Step 3. Describe the Evaluation Area

When DIRH assessments will be used to make interpretations about land health, ecological site potential, or other management applications, it is important to thoroughly describe the physical features of the evaluation area. Slope, aspect, soil texture and depth, and other variables greatly influence ecological function and the occurrence of the 17 indicators. For example, water erosion indicators are often more evident on steeper slopes, and plant cover and composition may be different on hotter, drier south-facing slopes as compared to cooler, wetter north-facing slopes.

The DIRH Evaluation Area Description Form (Appendix 2) is used to describe the physical characteristics of the evaluation area and to summarize relevant supplemental information. Other plot characterization forms may be used in place of the DIRH form if specified by a data collection protocol or to better meet the objectives of the assessment. For example, when DIRH assessments are conducted alongside terrestrial AIM methods, the Plot Characterization and Plot Observation forms in the "Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems" (Herrick et al. 2017) should be used instead of the DIRH Evaluation Area Description Form. Applications, such as Land-Potential Knowledge System (LandPKS; www.landpotential.org), may also be used to record evaluation area characteristics.

The required level of documentation of the soil and plot characteristics depends upon the intended uses of the associated DIRH assessment. Thorough documentation of the evaluation area's physical characteristics may enable future determination of the soil component and/or ecological site. Collecting all the recommended information may not be feasible in some situations, but efforts should be made to collect as much information as practical. For example, even if a full soil pit characterization is not completed, observations of color and structure are required to assess Indicator #9, Soil Surface Loss and Degradation; surface texture should also be recorded while making these observations. Some sites may have challenging soils that limit the ability to dig soil pits, but characteristics such as slope, aspect, and surface texture should still be documented.

Photographs: Photos of the evaluation area are strongly recommended. Include at least two general views in different directions (include some skyline for future point of reference), a photo of each soil pit, and photos showing important indicator observations or anomalies. The time, date, orientation, and location of each photo should be recorded using a photo ID card (Figure 3; Herrick et al. 2017) or electronic application. If quantitative data are collected along transect tapes, taking photos from the beginning of each transect is recommended.

General view photos should be taken prior to collecting data and making detailed plot observations because visible disturbance to soils and vegetation may occur as observers traverse the evaluation area. When completing the DIRH protocol as part of a standardized data collection effort, take photos according to established project procedures.

SITE: R012XY004ID
PLOT: 2018_12XY04_BS3
DATE: 6/16/2018
TRANSECT: 3
AZIMUTH: 240°

Figure 3. An example of a landscape photo with a photo ID card and transect tape.

5.4 Step 4. Collect Quantitative Data

Collecting quantitative data in the evaluation area is strongly recommended to support qualitative observations. It is particularly important to collect quantitative data when DIRH assessments will be used in support of management applications (see Section 7, After Completing the Assessment), or when developing or revising reference sheets. The DIRH Evaluation Form includes fields to enter the required quantitative indicator values (measured or estimated) for each applicable indicator. These are summarized in Table 1, along with the recommended data collection methods for obtaining the indicator values.

The DIRH Functional/Structural Groups Worksheet provides fields to record cover and annual production values for each plant group. Methods, sample sizes, and other data collection decisions should be selected for compatibility with accepted organizational and project-level protocols, and consideration for project objectives and the types of soils and vegetation being sampled. For example, more points may be needed to obtain accurate cover estimates in sparse vegetation (Drezner and Drezner 2021).

Table 1. Summary of the quantitative indicators and soil characteristics recorded as part of DIRH assessments, recommended measurement methods and sample sizes, and selected alternative measurement methods. Required quantitative indicator values and soil characteristics are in **bold**. For each indicator type, additional quantitative indicators that may be calculated and used to support associated rangeland health indicators are also listed. References to methods manuals are in superscript and included in the table footnotes. Additional measurements are also discussed in the "How they are described" section of each indicator description.

<table>
<tr><th>Indicator Type</th><th>Rangeland Health Indicator</th><th colspan="2">Quantitative Indicator Value</th></tr>
<tr><td rowspan="8">Cover</td><td>7. Litter Movement</td><td colspan="2">Litter cover under or between plant canopies</td></tr>
<tr><td>4. Bare Ground</td><td colspan="2">Percent bare ground cover</td></tr>
<tr><td>10. Effects of Plant Community Composition and Distribution on Infiltration</td><td colspan="2">Foliar cover by functional/structural group or species
Basal cover by functional/structural group or species</td></tr>
<tr><td>12. Functional/Structural Groups</td><td colspan="2">Foliar cover by functional/structural group or species</td></tr>
<tr><td>13. Dead or Dying Plants and Plant Parts</td><td colspan="2">Proportion (%) of plants or plant parts that are dead or dying</td></tr>
<tr><td>14. Litter Cover and Depth</td><td colspan="2">Percent litter cover</td></tr>
<tr><td>16. Invasive Plants</td><td colspan="2">Foliar cover of invasive plant species</td></tr>
<tr><td>17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants</td><td colspan="2">Bunchgrass basal cover</td></tr>
<tr><td colspan="4">Recommended method: Line-point intercept[1].
Sample size: Minimum 100 pin drops or point observations recommended, regardless of method used.
Other methods: Step-point intercept[2] or cover stick[3] quadrat-based ocular (visual) cover estimates[4].</td></tr>
<tr><td>Soil Stability</td><td>8. Soil Surface Resistance to Erosion</td><td colspan="2">Soil aggregate stability</td></tr>
<tr><td colspan="4">Recommended method: Soil stability test[1].
Sample size: Eighteen soil surface samples.
Other method: Bottle cap test[5].</td></tr>
<tr><td rowspan="7">Soil surface depth, color, and structure</td><td rowspan="7">9. Soil Surface Loss and Degradation</td><td colspan="2">Soil pit photo from the surface to a depth of at least 35 cm</td></tr>
<tr><td colspan="2">Color of surface (A) horizon (moist)</td></tr>
<tr><td rowspan="3">Soil surface structure</td><td>Type</td></tr>
<tr><td>Size</td></tr>
<tr><td>Grade</td></tr>
<tr><td colspan="2">Subsurface soil color (moist)</td></tr>
<tr><td colspan="2">Depth of subsurface color</td></tr>
<tr><td colspan="4">Method: For each soil pit, record observations for Indicator 9 in the DIRH Evaluation Form. Subsurface soil color is recorded at 10 cm below the bottom of the surface (A) horizon, or 35 cm below the soil surface if the bottom of the surface horizon cannot be identified. Use guidance in Appendix 3 or the NRCS "Field Book for Describing and Sampling Soils"[6] to describe soil surface structure type, size, and grade.
Sample size: At least 2 soil pits–one under a common perennial plant (shrub, if common) or plant patch, and one in interspace.</td></tr>
</table>

<table>
<tr><th>Indicator Type</th><th>Rangeland Health Indicator</th><th>Quantitative Indicator Value</th></tr>
<tr><td rowspan="2">**Annual production**</td><td>12. Functional/Structural Groups</td><td>Annual production by species or functional/structural group</td></tr>
<tr><td>**15. Annual Production**</td><td>**Total pounds per acre or kilograms per hectare of above ground annual production**</td></tr>
<tr><td colspan="3">**Recommended methods**: Total harvest and/or weight units[5] to estimate production based on functional/structural groups.
Sample size: Five plots recommended.
Other methods: Ocular estimates of annual production may be used when observers are experienced in measuring annual production and have calibrated their ocular estimates for the vegetation type(s) being evaluated.
Depending upon project objectives and vegetation type, other annual production estimation methods found in the NRCS “National Range and Pasture Handbook” may be used[7].</td></tr>
<tr><td>**Vegetation Gap**
(recommended)</td><td>4. Bare Ground</td><td>Proportion of soil surface in vegetation canopy gaps
Proportion of soil surface in vegetation basal gaps</td></tr>
<tr><td colspan="3">**Recommended method**: Gap intercept[1] recording canopy and/or basal vegetation gaps > 20 cm.
Sample size: Record gaps along a minimum of 75 m of transect (e.g. three 25-meter transects).
Other method: Stick gap method[3].</td></tr>
</table>

[1]Herrick et al. 2017; [2]BLM 1999; [3]Riginos and Herrick 2010; [4]Elzinga et al. 1998.; [5]Pellant et al. 2020; [6]NRCS 2012; [7]NRCS 2022.

Sampling within the evaluation area: When conducting a DIRH assessment as part of a structured monitoring protocol, implement the protocol's specified plot layout procedures and monitoring methods to derive the applicable quantitative indicators for the DIRH protocol. Most protocols utilize transect tapes; and collect observations and samples at specified intervals along the tapes. This approach is preferred for most DIRH data collection efforts. However, step-point transects (BLM 1999; Figure 4) or other approaches can be used to collect the required data and samples if necessary due to time or equipment constraints. The transect(s) should adequately represent the entire evaluation area spatially. See the checklists in Appendix 1 for recommended sampling equipment and forms.

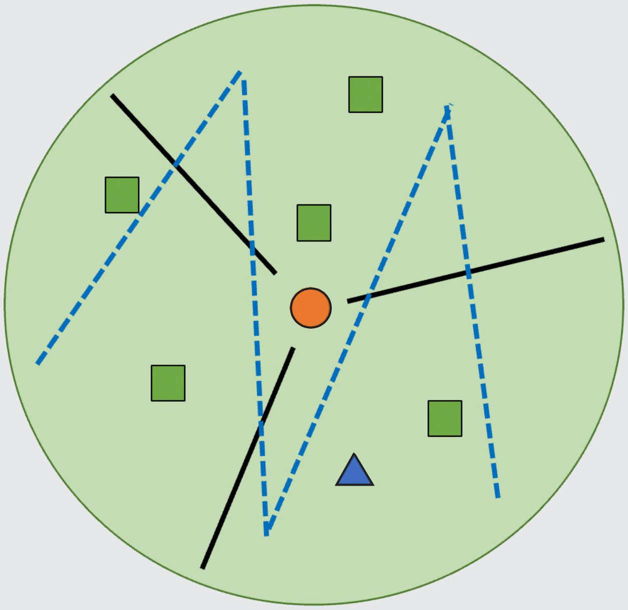


Figure 4. Example of potential sampling approaches within an evaluation area (green circle):

- The solid black lines represent 3, 25-m transects established at set distance and bearing from the plot center.
- The blue dashed lines represent a step-point transect path used to collect point intercept data and soil aggregate samples when transect tapes are not used.
- The primary soil pit (orange dot) is in the plot center.
- At least one additional pit (blue triangle) should be dug in another part of the evaluation area to record soil surface loss and degradation observations.
- The green squares represent 4–5 randomly placed plots used to estimate annual production, avoiding areas that have been disturbed while setting up transect tapes or digging soil pits.

5.5 Step 5. Describe the 17 Indicators of Rangeland Health

Use the DIRH Evaluation Form and the Functional/Structural Groups Worksheet in Appendix 2 to record the presence and condition of the 17 indicators within the evaluation area. DIRH assessments provide the most value when they include detailed notes, required quantitative indicator values, and comprehensive supporting information (e.g., photos, raw quantitative data). Use the abovementioned data forms and documentation techniques, and follow the instructions for each indicator as described in Sections 6.1 through 6.18, to collect data on each indicator.

6. Indicators of Rangeland Health

The DIRH protocol combines standardized measurements, categorical criteria, and written observations to describe the 17 indicators of rangeland health. This section includes brief descriptions of the 17 indicators of rangeland health, focusing on how the indicators are identified and described for the DIRH protocol. For each indicator, an explanation of **what** the indicator is, **why** it is included in the DIRH protocol, and instructions for **how it is described** and/or measured in the field are provided, as well as one or more example photos. Lastly, a completed example of the section of the evaluation form used for each indicator is included. Additional information about identification, measurement, ecological significance, and interpretation of the indicators in the context of IIRH and the attributes of rangeland health can be found in Section 7 of TR 1734-6.

6.1 Rills (Indicator 1)

What: Rills are small, intermittent watercourses with steep sides, usually only several centimeters deep (SSSA 1997). They are linear erosion features that typically run straight down slopes (Figure 5). The potential for rill formation usually increases as the degree of disturbance (loss of cover) and slope increases. Rills usually end at a concentrated water flow pattern, a terracette, or an area where the slope flattens and deposition occurs. Rills may connect into a drainage and erosion network on some sites. See the text box on the next page for guidance on distinguishing rills from water flow patterns and gullies.

Why: Rills are natural features of some soils and ecological sites, such as "badlands" with low vegetation cover. However, in most other areas, rills are an indicator of accelerated runoff and water erosion. Rills may also be the precursors to gully formation.

How they are described: Rills may be assessed by directly measuring or visually estimating their average length and density within the evaluation area. Rills are described using three criteria: (1) the number of rills within a 0.4-hectare (1-acre) plot, (2) the length, width, and depth of the rills, and (3) whether they occur in exposed (unvegetated) areas or in both exposed and vegetated areas. It is also useful to note the estimated length, width, and depth of rills, the degree of slopes they occur on, and whether their formation appears to be associated with disturbances and/or recent weather events such as intense rainstorms.

Completed section of DIRH Evaluation Form for Indicator 1.

1. Rills					
Number	Numerous (> 20/0.4 ha plot)	Moderate (11–20/0.4 ha plot)	Few (5–10/0.4 ha plot)	[✓ Very few (< 5/0.4 ha plot)]	No rills
Length, width, and depth	Very long (> 5 m); may be wide and deep	Long (2–5 m); may be wide and deep	[✓ Moderate length (0.5–2m); may be moderately wide and deep]	Minimal length (0.25–0.5 m), width, and depth	
Distribution	In both exposed and vegetated areas	Mostly in exposed and occasionally vegetated areas	Mostly in exposed and rarely in vegetated areas	[✓ Only in exposed areas]	
Notes (average length, width, and depth; association with slope, bare areas, recent weather and disturbance):					Photos taken ☐

Some small rills have formed in the steeper portion of the evaluation area. These are associated with bare ground around animal burrows and dissipate as the slope becomes more gradual.

Figure 5. Rills on an unvegetated hillslope.

DISTINGUISHING RILLS FROM WATER FLOW PATTERNS AND GULLIES

Rills and water flow patterns are sometimes difficult to distinguish from each other. Generally, rills are small erosional channels where water and soil movement are concentrated in a linear pattern, while water flow patterns are typically much wider than they are deep, yielding a more diffuse and irregular pattern due to plant, litter, or rock obstructions (i.e., they follow the microtopography). Short, linear sections of water flow patterns may be present and are usually distinguished from rills by the lack of downcutting on both sides of the erosion path. In this situation, describe the feature as a water flow pattern. Water flow patterns can transition to rills where slopes increase or if water becomes concentrated causing downcutting on both sides of the linear erosion feature. The photo to the right is an example of erosional features that may be classified as either rills or water flow patterns. If unsure whether an erosional feature is a water flow pattern or a rill, describe it as one or the other, but never as both.

Distinguishing between rills and gullies can also be difficult. Using the definition provided by Selby (1993), rills are less than 1 ft (30 cm) wide and 2 ft (61 cm) deep, whereas gullies exceed these limits.It is important to describe an observed erosional feature as either a gully or a rill, but never as both.

6.2 Water Flow Patterns (Indicator 2)

What: Water flow patterns are the paths that water takes as it moves across the soil surface during periods when surface water from rain or snowmelt exceeds soil infiltration capacity. This pattern of water runoff may also be referred to as sheetflow or overland flow. Water flow patterns follow the microtopography of the landscape; they are often associated with redistributed litter, soil, or gravel (Figure 6). They may be continuous or appear and disappear as the slope and ground cover change. Generally, as slope increases and ground cover decreases, water flow patterns increase (Morgan 1986). Water flow patterns may become less evident with time following large rainfall events or due to the type and distribution of vegetation (e.g., sod grasses or dense annual grasses may make water flow patterns difficult to see).

Why: Like rills, water flow patterns are evidence of water moving across the ground surface and potentially being lost from the site. Excessive water flow patterns are also associated with accelerated erosion. However, water flow patterns can occur within the natural range of variability more than rills.

How they are described: Water flow patterns are described using four criteria: (1) the extent or proportion of the area affected, (2) length and width (3) the occurrence of erosional and depositional areas, and (4) how frequently the water flow patterns are connected. Noting the estimated length and width of flow patterns and number per unit area, degree of slopes they occur on, and association with bare areas, disturbances and/or recent weather events such as intense rainstorms is also helpful.

Completed section of DIRH Evaluation Form for Indicator 2.

2. Water Flow Patterns					
Extent	Extensive (> 50% of area)	[✓ Widespread (25–50% of area)]	Common (10–25% of area)	Infrequent (< 10% of area)	No water flow patterns
Size	Very Long (> 15 m) and wide	Long (6–15 m) and wide	[✓ Moderate long (1.5–6 m)]	Short (< 1.5 m)	
Erosional/ Depositional areas	Widespread	Common	[✓ Minor]	Few	
Connectivity	Frequent	[✓ Occasional]	Infrequent	Rare	
Notes (number per unit area; lenght and width; association with slope, bare areas, recent weather, and disturbance):					Photos taken ☐
Waterflow patterns are found throughout the evaluation area and are moderately long. However, the flow patterns are somewhat faint in appearance, with only isolated areas of erosion or deposition. They are connected to the rills in the steeper portion of the evaluation area, continuing through the flatter areas.					

Figure 6. Examples of water flow patterns in a loamy soil (left) and a sandy soil (right). The lines show the flow paths within the water flow patterns.

6.3 Pedestals and Terracettes (Indicator 3)

What: Pedestals are formed when soil is removed by water or wind from the base of plants or from around rocks or persistent litter, giving them the appearance of being elevated (Figure 7). In some cases, plant roots may be exposed due to this accelerated erosional process. Non-erosional processes, such as frost heaving and soil or litter deposition on and around plants (Hudson 1993), can create features that are similar in appearance but are not erosional pedestals.

Terracettes are “benches” of soil deposition that form behind or between obstacles, such as rocks, plant bases, or large litter, when soil and other materials are redistributed by water movement (Figure 8). As the degree of soil movement by water increases, terracettes may become more numerous and the area of soil deposition becomes larger. The relatively higher elevation of the soil on the upslope side of a terracette is an indication of soil deposition by moving water or of soil erosion below the terracette. Terracettes formed by livestock or wildlife trails on hillsides are not considered erosional terracettes.

Why: Pedestals are an indicator of soil surface erosion from wind and/or water. Terracettes are an indicator of soil movement and deposition by water.

How they are described: Three criteria are used to describe this indicator: (1) the extent

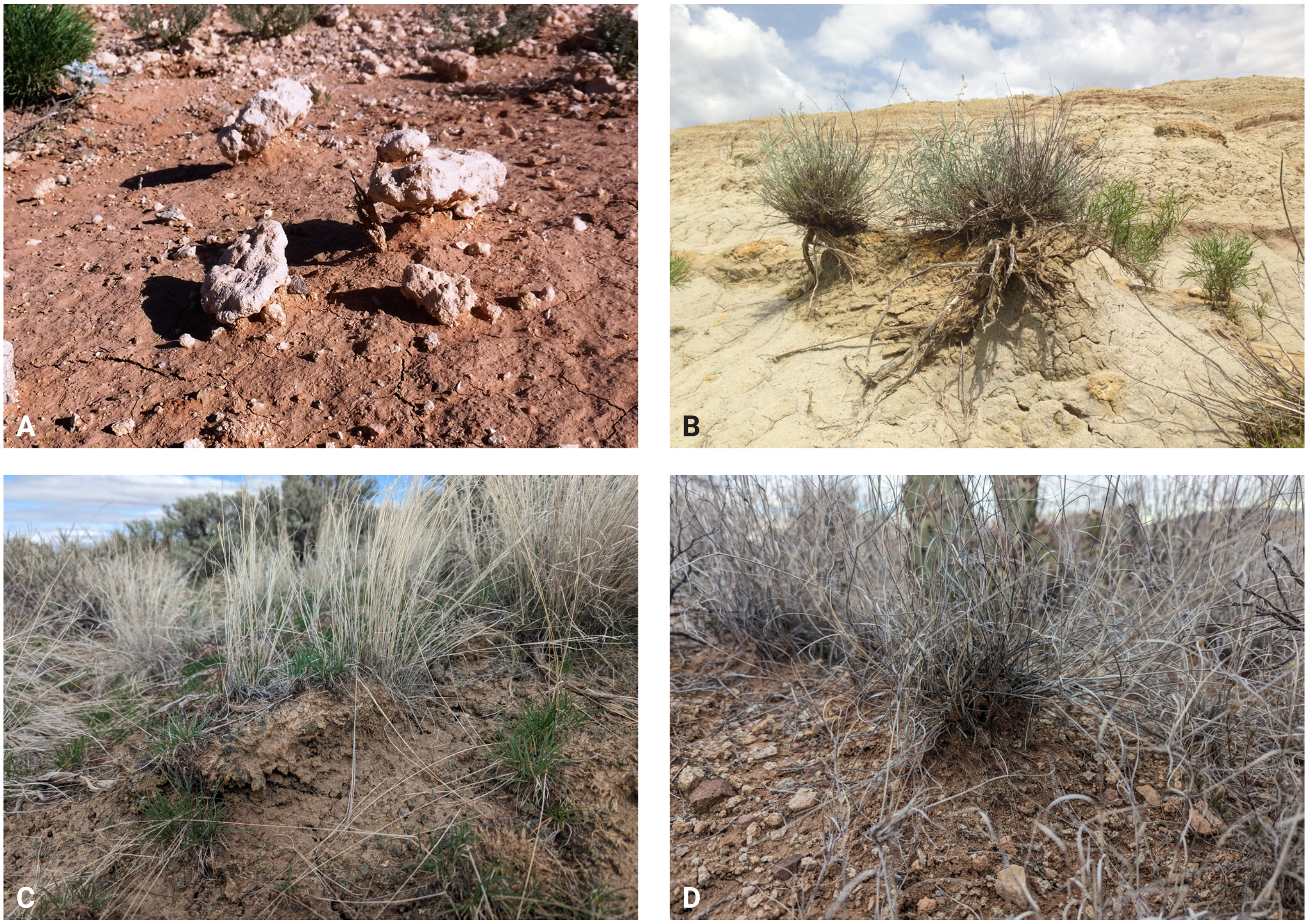


Figure 7. Examples of pedestal formations.
A. Rocks on pedestals formed by wind erosion.
B. An example of shrubs on pedestals with exposed roots.
C. A large pedestal around a group of bunchgrasses.
D. A smaller pedestal around an individual bunchgrass formed by water erosion.

Figure 8. A terracette is formed by soil deposited behind an obstruction, highlighted by the white bracket.

of pedestals, (2) the frequency of exposed roots on plant pedestals, and (3) the extent of terracettes. It is also helpful to estimate the number of pedestals and/or terracettes per unit area, as well as their association with bare areas, slopes, and recent weather and disturbance.

Only features formed by soil erosion processes should be included when describing frequency and severity of pedestals. However, if non-erosional features are present, it is useful to describe them in the notes, particularly if the DIRH assessment may be used for developing or revising reference sheets. Similarly, terracettes formed by animal trails should not be included when classifying the extent of terracette occurrence but should be recorded in the notes.

Completed section of DIRH Evaluation Form for Indicator 3.

3. Pedestals and/or Terracettes					
Extent of pedestals	Extensive	Widespread	[✓ Common]	Uncommon	No pedestals
Root exposure	Frequent	Common	Occasional	[✓ Rare]	
Extent of terracettes	Widespread	Common	Uncommon	Scares	[✓ No terracettes]
Notes (number per unit; association with slope, bare areas, recent weather, and disturbance):					Photos taken ☐
Pedestalled perennial grasses are found in most shrub interspaces associated with water flow patterns, but they are somewhat muted, and rarely have exposed roots. No terracettes were observed.					

6.4 Bare Ground (Indicator 4)

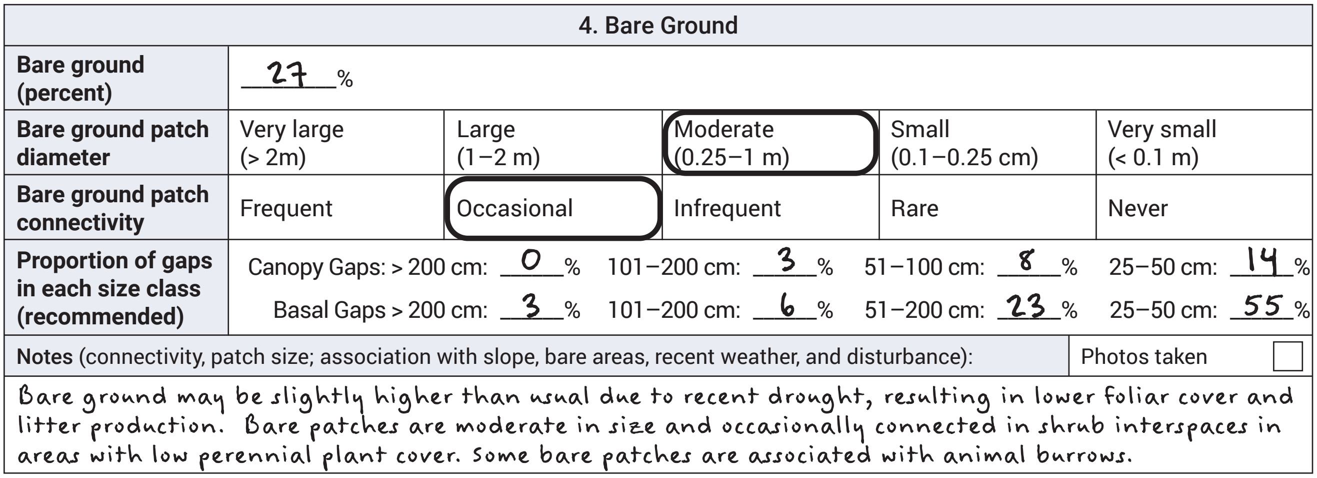
What: Bare ground is exposed mineral soil not covered by vegetation (i.e., live or dead basal and/or canopy cover), gravel or rock ≥ 5 mm in diameter, visible biological soil crusts (see text box, page 24), or litter. A bare ground patch is an area where bare ground is concentrated (Figure 9). Bare ground patches may include some ground cover within their perimeter, but there is proportionally much more bare soil than ground surface cover.

Why: Ground surface cover materials intercept raindrops, reduce soil particle detachment (raindrop splash erosion), and reduce soil movement by water and wind (Weltz et al. 1998). The amount and distribution of bare ground is a direct indication of site susceptibility to accelerated wind or water erosion (González-Botello and Bullock, 2012). In general, a site with bare ground concentrated in a few large patches will be less stable than a site with the same ground cover percentage in which the bare soil is distributed in many small patches, especially if these patches are not connected (Spaeth et al. 1994).

How it is described: Three criteria are used to describe bare ground: (1) the percent of bare ground, calculated from cover data, (2) the average size of bare ground patches, and (3) how frequently bare ground patches are connected. A fourth criterion, vegetation canopy gaps, is recommended and can be useful to understand vegetation structure and a site's vulnerability to wind and water erosion.

Figure 9. A photo showing a concentrated patch of bare ground, outlined by the dashed line.

Completed section of DIRH Evaluation Form for Indicator 4.



4. Bare Ground					
Bare ground (percent)	27 %				
Bare ground patch diameter	Very large (> 2m)	Large (1–2 m)	[✓ Moderate (0.25–1 m)]	Small (0.1–0.25 cm)	Very small (< 0.1 m)
Bare ground patch connectivity	Frequent	[✓ Occasional]	Infrequent	Rare	Never
Proportion of gaps in each size class (recommended)	Canopy Gaps: > 200 cm: 0 % Basal Gaps > 200 cm: 3 %	101–200 cm: 3 % 101–200 cm: 6 %	51–100 cm: 8 % 51–200 cm: 23 %	25–50 cm: 14 % 25–50 cm: 55 %	
Notes (connectivity, patch size; association with slope, bare areas, recent weather, and disturbance):				Photos taken ☐	
Bare ground may be slightly higher than usual due to recent drought, resulting in lower foliar cover and litter production. Bare patches are moderate in size and occasionally connected in shrub interspaces in areas with low perennial plant cover. Some bare patches are associated with animal burrows.					

The amount of bare ground can be measured directly using a point-intercept method. The percent of bare ground is the proportion remaining after accounting for ground surface covered by vegetation (basal and foliar cover), litter, standing dead vegetation, gravel (> 5mm in diameter)/rock, and visible biological soil crust. To calculate percent bare ground from point intercept data, divide the number of bare ground hits by the total number of pin drops (Herrick et al. 2017). Measuring canopy gaps using the gap intercept method is also recommended; the proportion of the total line length in gaps greater than a minimum threshold length can be calculated. Both canopy and basal gap measurements can provide additional information about vulnerability to water erosion. Bare ground patches are usually described based on ocular estimates but may also be measured directly using a tape measure. It is also helpful to note how recent weather or disturbances appear to have affected bare ground amount and/or bare ground patch size.

BIOLOGICAL SOIL CRUSTS ARE NOT BARE GROUND

Visible biological soil crusts include microorganisms (e.g., algae and cyanobacteria) and nonvascular plants (e.g., mosses and lichens) that grow on or just below the soil surface. Biological soil crusts on the soil surface protect the underlying mineral soil from the impact of rain and wind. Therefore, they are not considered bare ground and visible biological soil crusts should be recorded separately when collecting cover data.

Detecting algae and cyanobacteria is often difficult, while mosses and lichens are more visible in most ecosystems. Because of this, algae and cyanobacteria may not be accounted for when collecting cover data. It is important to document data collection rules and methods to ensure that indicator values for biological soil crusts are interpreted consistently.

Two other types of crusts, chemical and physical crusts, may develop in rangeland soils but are not considered as cover because they do not protect the soil surface from wind or water impact in the same way as biological soil crusts. Chemical crusts are identified by salts (usually white) on the soil surface, while physical crusts are thin, dense layers that are usually produced by water sealing soils either through raindrop impact or by saturation, settling, and drying of disturbed soils.

For additional discussion of the different types of soil crusts, refer to Section 5.10 of TR 1734-6.

Examples of biological soils crusts found on rangelands in North America.

6.5 Gullies (Indicator 5)

What: Gullies are well-defined channels cut into the soil by ephemeral water flow that normally follows natural drainage channels (Figure 10). Concentrated water flow may initiate the formation of a gully where runoff accumulates (1) due to rills or water flow patterns having formed a drainage network, (2) at the base of a slope, or (3) on the downslope side of exposed bedrock. Once water has been captured by a gully, the energy associated with the moving water may extend the gully upslope and downslope, cut the channel deeper, and erode the channel sides thereby widening the gully. Upslope erosion can result in headcuts when water undercuts the upslope walls, creating a drop in the gully bottom, which often results in plunge pools (Poesen et al. 2002).

Why: Gullies are rarely expected to occur under the natural range of variability; they are almost always an indicator of accelerated runoff and erosion. A single gully in or near an evaluation area can have a significant effect on hydrologic function and susceptibility of erosion. Once formed, gullies tend to be self-perpetuating (Thwaites et al. 2021); they can increase in length and size rapidly during storm events, presenting the potential for damage to roads, stream channels, floodplains, and other natural and manmade features.

How they are described: Any gully or part of a gully within the evaluation area should be included when describing this indicator. Gullies are described using the following criteria: (1) the overall width and depth, (2) amount of perennial vegetation on the gully banks and bottom, (3) the amount of annual vegetation on the gully banks and bottoms, (4) the occurrence of nickpoints (i.e., cuts or notches in the gully bank; Figure 10), (5) the amount of erosion and/or downcutting, (6) the number of gullies, and (7) the number of active headcuts (Figure 10) in the evaluation area. Observers should also note any gullies or headcuts adjacent to the evaluation area, and their association with slope, bare areas, recent weather, and disturbance.

Figure 10. Three examples of gullies. Top and center: Two examples of relatively shallow gullies found on rangelands. The top photo identifies the **A)** gully bank, **B)** headcut, and **C)** a nickpoint, which are features that should be described for this indicator. Bottom: a very large gully formed in a deep soil.

Completed section of DIRH Evaluation Form for Indicator 5.

5. Gullies					
Depth and/or width	Substantial	Moderate	[✓ Slight]	Minimal	No gullies
Perennial vegetation on banks and bottom	Sporadic or none	Intermittent	[✓ Occasional]	Mostly vegetated	
Annual vegetation on banks and bottom	Sporadic or none	[✓ Intermittent]	Occasional	Mostly vegetated	
Nickpoints	Numerous	Common	Occasional	[✓ Few]	
Bank and bottom erosion and/or downcutting	Substantial	Moderate	[✓ Slight]	Minimal	
Number of gullies in evaluation area: 1			**Number of headcuts in evaluation area:** 0		
Notes (headcuts outside of evaluation area; association with slope, bare areas, recent weather, and disturbance):					Photos taken ☒
A portion of a gully is within the evaluation area, ending in the flatter area; there is an active headcut about 100m upslope from the evaluation area. Part of the gully within the evaluation area is about 0.5m deep and 1m wide, and stabalized by perennial herbaceous vegetation.					

6.6 Wind-Scoured and Depositional Areas (Indicator 6)

What: Wind-scoured areas are formed as fine particles of topsoil are blown away. Wind-scoured areas appear to be swept or scoured smooth by wind action; subsurface soil horizons may be exposed. In areas where the wind has removed litter and soil particles, gravel or rock may be left on the soil surface, or plant roots may be exposed. Some wind-scoured areas, known as blowouts, may appear as "a hollow or depression of the land surface, which is generally saucer or trough-shaped…" (SSSA 1997).

Depositional areas are locations where windblown soil accumulates (Figure 11). Taller vegetation slows the wind and captures airborne soil particles (Pye 1987); thus, depositional areas are usually found under and on the downwind side of shrubs and trees or other obstructions (Gibbens et al. 1983). Depositional areas can become large enough to form a hummock-like landscape (e.g., mesquite dunes).

Figure 11. Examples of wind scour and deposition. Mesquite dunes are formed by wind scouring interspaces and depositing soil under shrubs (left); a bunchgrass crown is buried by soil deposition (right).

Completed section of DIRH Evaluation Form for Indicator 6.

6. Wind-Scoured and Depositional Areas					
Extent of wind-scoured areas	Extensive (> 50% of area)	Common (26–50% of area)	Occasional (10–25% of area)	[✓ Infrequent & few (< 10% of area)]	No wind-scoured areas
Connectivity of wind-scoured areas	Frequent	Occasional	Infrequent	[✓ Rare or never]	
Size of depositional areas	Substantial	Moderate	[✓ Minor]	Minimal or trace	No deposition
Notes (proportion of site affected; deposition source; association with bare areas, depth or size of depositional areas, recent weather, and disturbance:):					Photos taken ☐
Depositional areas were noted around large rocks and shrubs. The depositied soils are probably from an upwind area that is recovering from a severe wildfire. Some small areas appear to be wind-scoured where there are larger bare ground patches and lower-stature shrubs.					

Why: Wind-scoured areas are evidence of soil surface loss and an unstable soil surface. Depositional areas can degrade the soil surface and bury plant crowns. Windblown soil particles can also damage fragile plants and deposit dust layers that impede photosynthesis and plant growth (Sharifi et al. 1997).

How they are described: Wind-scoured and depositional areas are described using three criteria: (1) the extent or proportion of the evaluation area affected by wind scours, (2) how frequently the wind-scoured areas are connected, and (3) the average size of depositional areas. In some cases, the source of deposited soils, such as a large disturbed or bare area upwind from the evaluation area, can be identified and should be included in the notes. Also note the proportion of the site affected by wind-scoured and/or depositional areas, and association with bare areas, recent weather, and disturbance.

6.7 Litter Movement (Indicator 7)

What: Litter is dead plant material on the soil surface, including leaves, stems, and branches, that are detached from the plant. Litter movement refers to the change in the location of litter due to water or wind. Litter often concentrates in areas where wind or water slows or in areas with obstructions (Figure 12). Looking for such accumulations is a good approach for detecting litter movement in an evaluation area. Excess litter accumulations under shrubs may be related to litter movement due to wind, while litter concentrated around obstructions in interspaces may be associated with water movement.

Why: The distance, amount, and size of litter being moved are signs of the amount of energy in overland flow of water, and in wind energy near the soil surface. The greater distances of litter movement, and the size classes of litter being displaced, the greater the potential that soil erosion from water or wind is also occurring.

How it is described: Litter movement is described based on three criteria: (1) the distance of fine litter movement, (2) the distance of large litter movement, and (3) the size of any litter accumulations, which are usually found in depressions or around obstructions such as shrubs. For the purposes of DIRH, fine litter includes herbaceous litter like leaves and grass stems; large litter includes woody litter like shrub branches with a diameter of 5 mm or greater. Litter movement resulting from wildlife, insects, and anthropogenic activities, such as effects of livestock or recreational vehicles, is not included when describing this indicator. Duff (dead plant material that is decomposed so that leaves, stems, and branches are difficult to recognize) is not considered litter and is not included in this indicator.

Completed section of DIRH Evaluation Form for Indicator 7.

7. Litter Movement					
Distance of fine litter movement	Very long (> 6 m)	Long (3–6 m)	[✓ Moderate (1.5–3m)]	Short (0.6–1.5m)	None or very short (< 0.6 m)
Distance of large litter movement	Long (> 3 m)	Moderate (1.5–3 m)	Short (0.6–1.5 m)	Very short (< 0.6 m)	[✓ None]
Size of litter accumulations	Substantial	Moderate	[✓ Small]	Minimal	None
Notes (proportion of litter moved; association with slope, bare areas, recent weather, and disturbance):					Photos taken ☐
Some herbaceous/fine litter movement is occuring, particularly on steeper slopes and in bare areas. Large/woody litter did not appear to be moving from the litter source. Some small accumulations of fine litter were noted around obstructions and in ponding areas of water flow patterns.					

Figure 12. Examples of litter accumulation. On the left, fine litter accumulated at the edge of a water flow pattern. On the right, large and fine litter have accumulated due to redistribution by water.

6.8 Soil Surface Resistance to Erosion (Indicator 8)

What: This indicator assesses the resistance of the soil surface to erosion by water, including raindrop impact (Figure 13). Soil surface texture and minerology influence potential soil stability. In general, coarse-textured soils (i.e., sandier soils) are less stable than fine-textured soils (i.e., more clayey soils). Soil stability is usually increased when soil organic matter and biological soil crusts are present.

Why: Soils with high aggregate stability values are generally less susceptible to water erosion (Barthes and Roose 2002). Susceptibility to wind erosion also declines with an increase in soil organic matter (Fryrear et al. 1994) and biological soil crust cover (Belnap and Gillette 1998).

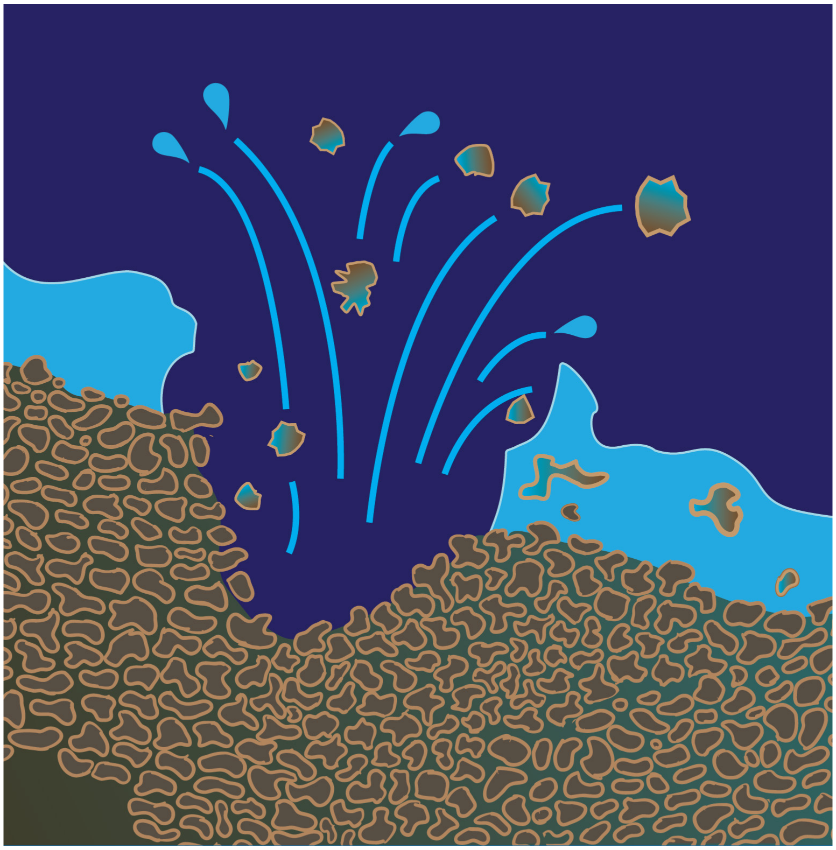


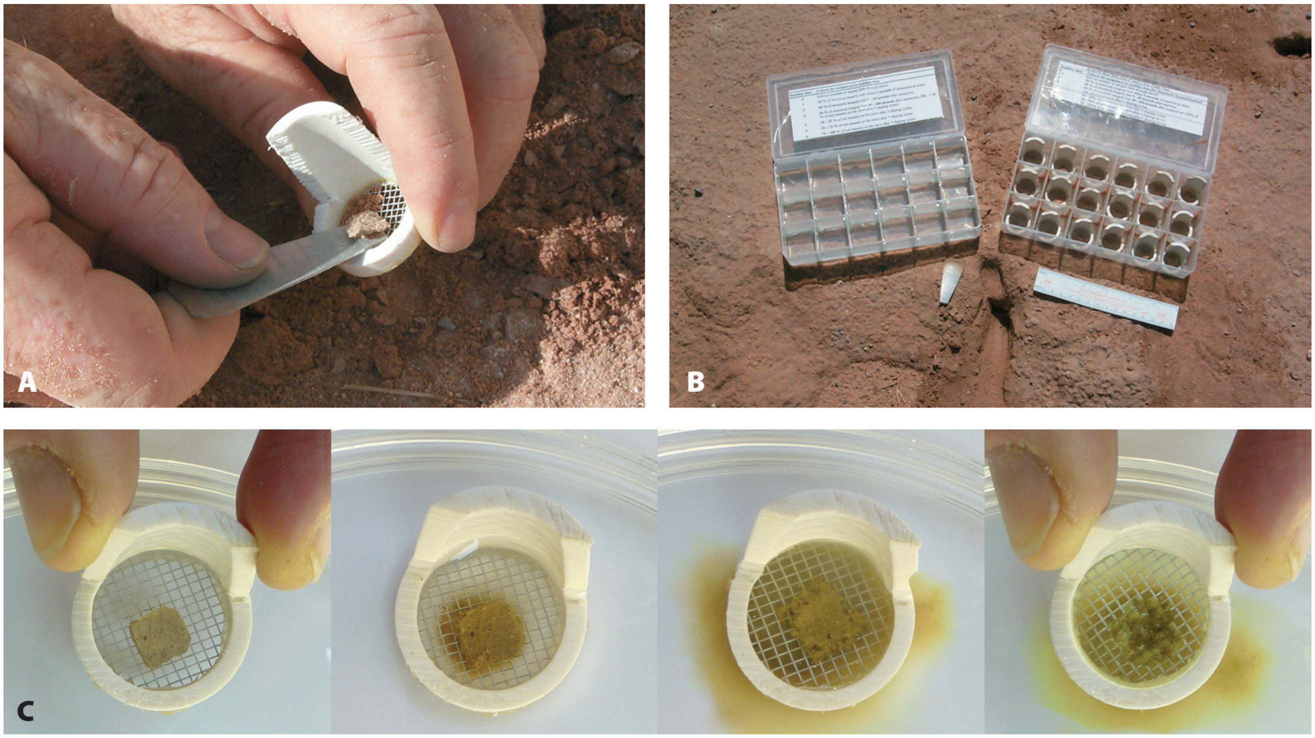
Figure 13. An illustration demonstrating raindrop impact. Soil particles can detach from the soil surface due to raindrop impact, resulting in erosion.

How it is described: Soil surface resistance to erosion is assessed by testing the stability or cohesion of small soil surface samples when they are rapidly submerged in water (Figure 14). Using a soil stability test kit, 18 soil surface samples should be collected along predetermined locations on a transect or step-point transect. When collecting samples, use the Soil Stability Test Data Sheet (Herrick et al. 2017) to note whether each sample was collected from an interspace or from under perennial plant canopy. Test the samples and assign stability values from 1 (unstable) to 6 (stable). Next, calculate the average stability values for samples taken under perennial plant canopy, and in plant interspaces. Note observations connected to high or low stability values, such as values of "1" due to disaggregated soils on an anthill or around an animal burrow or bare area, or higher values associated with biological soil crusts.

If a soil stability kit is not available, the "bottle cap test" can be used to estimate stability using three sample classes (see Appendix 9 of TR 1734-6). Due to the limited stability classes derived from the bottle cap test, it is not recommended for reference sheet development or DIRH assessments intended for management applications.

Completed section of DIRH Evaluation Form for Indicator 8.

8. Soil Surface Resistance to Erosion	
Soil Stability Values/ # of samples:	Perennial Plant Canopy Average: 4.3 Samples: 7 Interspace Average: 3.7 Samples: 11
Notes (association of high or low stability values with soil crusts, bare areas, recent weather, and disturbance):	Photos taken ☐
Under canopy samples included 3 moss-covered samples. Interspace values range from 1 around animal burrows to 6 where lichen soil crusts are present. Undisturbed samples without biotic crust were 3-4 stability scores.	



Original sample After 5 seconds After 5 minutes After 5 dips

Figure 14. Images demonstrating the collection and testing of soil aggregates using a soil stability test kit. See Herrick et al. 2017 for comprehensive instructions.

A. Collection of a soil surface sample into a soil stability testing sieve.
B. A complete soil stability kit with 18 soil samples collected.
C. Example of a soil sample “melting” after submersion and dipping in water.

6.9 Soil Surface Loss and Degradation (Indicator 9)

What: Soil surface loss and degradation includes reduction in soil surface horizon depth, organic matter content, porosity, detrimental changes to soil structure, and excessive soil deposition. Reduction of soil organic matter content is reflected in lighter soil colors. Soil surface loss and degradation can result from wind or water erosion as well as deposition of unstructured or poorly structured soil. Wind and water erosion are natural processes that may be increased by changes in the disturbance regime and/or increased storm intensity.

In arid and semi-arid rangelands, soil organic matter content is typically concentrated near the surface, making this layer relatively darker in color when compared to subsurface soils. When severe erosion occurs, the surface horizon may be nearly or totally lost. In the case of substantial soil deposition, the soil surface may be buried. In soils with good structure, pores of various sizes are visible within the aggregates. Structural degradation is reflected in more massive, homogeneous soil surface horizons, which are associated with a reduction in infiltration rates (Warren et al. 1986).

Soil degradation can also be caused indirectly. For example, reductions in soil organic matter can result from changes in plant community composition that decrease the amount of plant matter that decomposes and is incorporated into the soil. Consequent reductions in organic matter may lead to structural degradation and decreased soil stability, increasing vulnerability to accelerated erosion.

Why: Soil surface characteristics are important because they influence water infiltration and available plant nutrients. Soil surface thickness, structure, and organic matter content are key determinants of site potential and are critical considerations for management and restoration. Loss or degradation of the soil surface can lead to reduced infiltration, increased runoff, additional soil erosion, limitations to seed germination, plant establishment, and soil water holding capacity. Soil surface loss and degradation are signs of long-term changes in rangeland health.

How it is described: Soil surface loss and degradation is observed and described after digging two or more soil pits, one under a shrub or other perennial plant canopy and one in an interspace location. At a minimum, the soil pits should be deep enough to identify and describe the first significant change in color and structure (i.e., horizon; Figure 15). Deeper pits are recommended because additional soil characteristics can be observed and recorded, which may enable soil component or ecological site identification in addition to the information required to describing this indicator. Digging additional small holes in multiple locations is recommended to verify that the two primary soil pits are representative of the evaluation area.

The following information is recorded for each soil pit:

Thickness of surface horizon – Record surface horizon depth in centimeters.

Surface and subsurface soil colors – Soil colors are described in three components: hue, value, and chroma. The soil color is most consistently documented by comparing a moistened soil sample to a standard color reference such as a Munsell soil color chart or using the soil color

Figure 15. Images of a soil test pit with a tape measure (left), and samples removed from different horizons within a soil pit (right), showing different color and structure.

Completed section of DIRH Evaluation Form for Indicator 9.

<table>
<tr><th colspan="5">9. Soil Surface Loss and Degradation</th></tr>
<tr><td rowspan="8">Dig at least two soil pits, one under a typical perennial plant or plant patch, and one in interspace; take a photo of the top 35 cm of each pit and complete the table to the right. Subsurface soil color is recorded at 10 cm below the bottom of the surface (A) horizon, or 35 cm below the soil surface if the bottom of the surface horizon cannot be identified.</td><td colspan="2">Criteria</td><td>Plant canopy</td><td>Interspace</td></tr>
<tr><td>Depth of surface (A) horizon</td><td>☐ in ☒ cm</td><td>18</td><td>12</td></tr>
<tr><td colspan="2">Color of surface (A) horizon (moist)</td><td>7.5YR 4/2</td><td>7.5YR 4/3</td></tr>
<tr><td rowspan="3">Soil surface structure</td><td>Type</td><td>Granular</td><td>Single grain</td></tr>
<tr><td>Size</td><td>Fine</td><td>-</td></tr>
<tr><td>Grade</td><td>Moderate</td><td>-</td></tr>
<tr><td colspan="2">Subsurface soil color (moist)</td><td>2.5 YR 5/3</td><td>2.5 Y 5/3</td></tr>
<tr><td>Depth of subsurface color</td><td>☐ in ☒ cm</td><td>28</td><td>22</td></tr>
<tr><td colspan="4">Notes (describe any buried surface horizon; proportion of area affected by soil loss or deposition; association with slope, bare areas, recent weather, and disturbance):</td><td>Photos taken ☒</td></tr>
<tr><td colspan="5">Interspaces appear to have thinner, lighter-colored A horizon. These soil characteristics suggest loss of organic matter and a degraded surface horizon.</td></tr>
</table>

tool in the LandPKS app (be sure to follow color calibration instructions if using the app).

- When recording soil colors, observers should remove sunglasses and compare soil samples to the color reference under evenly distributed light without sun glare.
- Surface and subsurface colors should be recorded from a minimum of two soil pits, one under perennial plant canopy and one in interspaces.
- Record subsurface color at 10 cm below the bottom of the surface (A) horizon or at 35 cm from the soil surface if the bottom of the surface horizon cannot be identified.
- If a restrictive layer prevents digging to the prescribed depth, record the color in the 5 cm just above the restrictive layer.
- Always record the depth of the subsurface soil color sample.

Soil surface structure – Describe the structure type, size, and grade of soil in the top 10 cm of soil. See Appendix 3 and Table A3.1 for soil structure descriptions.

It is helpful to make notes of soil conditions across the evaluation area. For example, if the surface horizon is thinner in areas between plant canopies, make a note and estimate the proportion of the evaluation area affected. If significant deposition is present, document the thickness of both the deposited layer and the buried surface horizon.

6.10 Effects of Plant Community Composition and Distribution on Infiltration (Indicator 10)

What: Infiltration, for purposes of DIRH, encompasses both the entry of water into the soil and movement of water into the soil profile (i.e., percolation). This indicator describes aspects of vegetation composition, structure, and/or spatial distribution that typically affect the soil's infiltration capacity, and the amount of time water is retained on the soil surface.

Why: Vegetation composition and distribution are strongly related to patterns of infiltration and water redistribution on semi-arid rangelands (Pueyo et al. 2013). The ability of a site to capture and store precipitation can be positively or negatively influenced by changes in plant community composition, structure, and distribution. Plant rooting patterns, height, and basal area, as well as litter production and associated decomposition processes can all affect infiltration (NRCS 2022; Figure 16; Figure 18). Reduced infiltration capacity is likely to result in a corresponding increase in runoff.

How it is described: The DIRH Functional/Structural Groups Worksheet provides the basis for describing this indicator (Appendix 2). If cover data are collected, note the total foliar cover as well as cover values for the dominant and subdominant plant groups. List the dominant and subdominant functional/structural groups and indicate how each group is distributed across the evaluation area (i.e., clumped, scattered, or evenly distributed). Minor functional/structural groups should also be listed if they substantially contribute to plant community composition and structure (e.g., five minor groups that collectively contribute > 30% of the foliar cover or production in the evaluation area should be documented). Additional information about the dominant and subdominant functional/structural groups can be recorded, such as basal cover and/or diameter of perennial bunchgrasses, and height and growth form of shrubs. See Indicator 12 for a discussion of plant functional/structural groups and additional information on completing the Functional/Structural Groups Worksheet.

Completed section of DIRH Evaluation Form for Indicator 10.

10. Effects of Plant Community Composition and Distribution on Infiltration

List the dominant and subdominant FS groups and indicate their distribution in the evaluation area, and any optional indicators.

Functonal/ Structural Group	Distribution			Optional Indicators			
	Scattered	Clumped	Even	Basal cover (%)	Average height	Dominant growth form	Other:
					☐ in ☒ cm		Location
Deep-rooted bunchgrasses		X		4			Under shrubs
Non-sprouting shrubs			X	2	42	Spreading	
Perennial forbs	X			0			

Notes (Vegetation age classes; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Non-sprouting shrubs (sagebrush) dominate the evaluation area; nearly all are mature shrubs with very few seedlings noted. Deep-rooted perennial bunchgrasses mostly occur under shrub cover; perennial forbs are scattered throughout. Evergreen tree seedlings (western juniper) are scattered in trace amounts.

6.11 Compaction Layer (Indicator 11)

What: A compaction layer is a near-surface layer of dense soil caused by the application of weight or pressure at the soil surface. Evidence of compacted soils includes restricted plant roots, which may be found growing laterally at the upper boundary of the compaction layer. Changes in soil structure (e.g., from blocky to massive) may also be indicative of a compaction layer (Figure 17). Differences in compaction are often observed in plant interspaces and under perennial plant canopies, particularly shrub canopies. Naturally occurring

Figure 16. Four images showing varying plant community composition and distribution. The area shown in the upper left is dominated by juniper with low vegetation cover between trees. In the upper right, a cheatgrass-dominated field with low cover of perennial herbaceous and woody plants. In the lower right, a slope is dominated by a mixture of shrubs and robust, evenly distributed perennial bunchgrasses. In the lower left, a desert grassland with cacti and shrubs.

Figure 17. Images showing the effects of soil compaction. Roots can grow laterally when they are unable to penetrate compacted soils (left); soils can form a compaction layer with massive structure (right).

soil horizons such as duripan, claypan, or petrocalcic layers are not considered to be compaction layers.

Why: Compaction layers restrict water percolation (Thurow et al. 1988), plant growth (Wallace 1987), and nutrient cycling (Hassink et al. 1993), potentially reducing infiltration, which in turn increases runoff and affects plant composition and production.

How it is described: Compaction layers can be detected and evaluated by digging holes (generally less than 30 cm deep) and observing the soil structure and root morphology. Once a compaction layer has been observed, the spatial extent of the layer may be estimated by simply probing the soil with a sharp rod or shovel and feeling for the compaction layer. This indicator is classified based on the spatial extent of compaction and how strongly developed the compaction layer is, as judged by its thickness and density. It is also helpful to note the proportion of the site affected by the compaction layer, whether any restriction of roots and/or water infiltration is observed, and association with bare areas and disturbance. If any naturally occurring soil horizons such as a duripan, claypan, or petrocalcic horizon are present in the evaluation area, do not include these in the description of this indicator. However, it is important to note the presence of such a layer and document that it was not included in assessment of the compaction layer.

Completed section of DIRH Evaluation Form for Indicator 11.

11. Compaction Layer					
Distribution	Extensive	Widespread	Moderately widespread	[✓ Not widespread]	No compaction layer present
Development (thickness and density)	Strong	Moderate to strong	[✓ Moderate]	Weak	
Notes (Extent, distribution, thickness, density, evidence of restricted roots (i.e., lateral roots) or water infiltration; association with bare areas and disturbance; describe any soil layer that could be mistaken for a compaction layer such as petrocalcic, caliche or durpian and note that it was not included in the description of the compaction layer):					Photos taken ☒
There is one well-defined animal trail through the evaluation area with moderate compaction layer, affecting less than 10% of the evaluation area. Some root restriction of perennial grasses was observed directly adjacent to the trail with lateral roots at about 10cm from the soil surface. There are no natural restrictive soil layers noted.					

6.12 Functional/Structural Groups (Indicator 12)

What: Functional/structural groups are plant species (including nonvascular plants such as visible biological soil crusts) that are grouped together based on similar growth forms or ecophysiological roles. Note that plant species may serve similar functional and structural roles whether they are native or nonnative. Nonnative plants that may be invasive are addressed by the invasive plants indicator (Section 6.16). Similarly, "invasiveness" is not a characteristic that is used to define or separate functional/ structural groups.

Function typically refers to the ecophysiological role that plants and biological soil crusts play on a site. This may include the plant's life cycle (e.g., annual, monocarpic perennial, or perennial), phenology, photosynthetic pathway, nitrogen-fixer associations, sprouting ability, and water infiltration (including biological soil crusts).

Structure refers to plant growth forms (e.g., trees, vines, shrubs, grasses, forbs, succulents, and nonvascular plants such as visible biological soil crusts) within the community. Structure may be subdivided by grouping species with similar growth forms based on height, growth patterns (e.g., bunch, sod-forming, or spreading through long rhizomes or stolons), root structure (e.g., fibrous or tap), rooting depth, or sprouting ability (Figure 18).

Why: Plant community resistance to invasive plants and resilience to disturbances are enhanced through a mixture of functional and structural plant groups (Pokorny et al. 2005; Chambers et al. 2017) and biological soil crusts (Belnap et al. 2001; Reisner et al. 2013). Function and structure may be interrelated as evidenced by the effects of plant canopy and rooting structure on precipitation capture and infiltration (i.e., amount and depth).

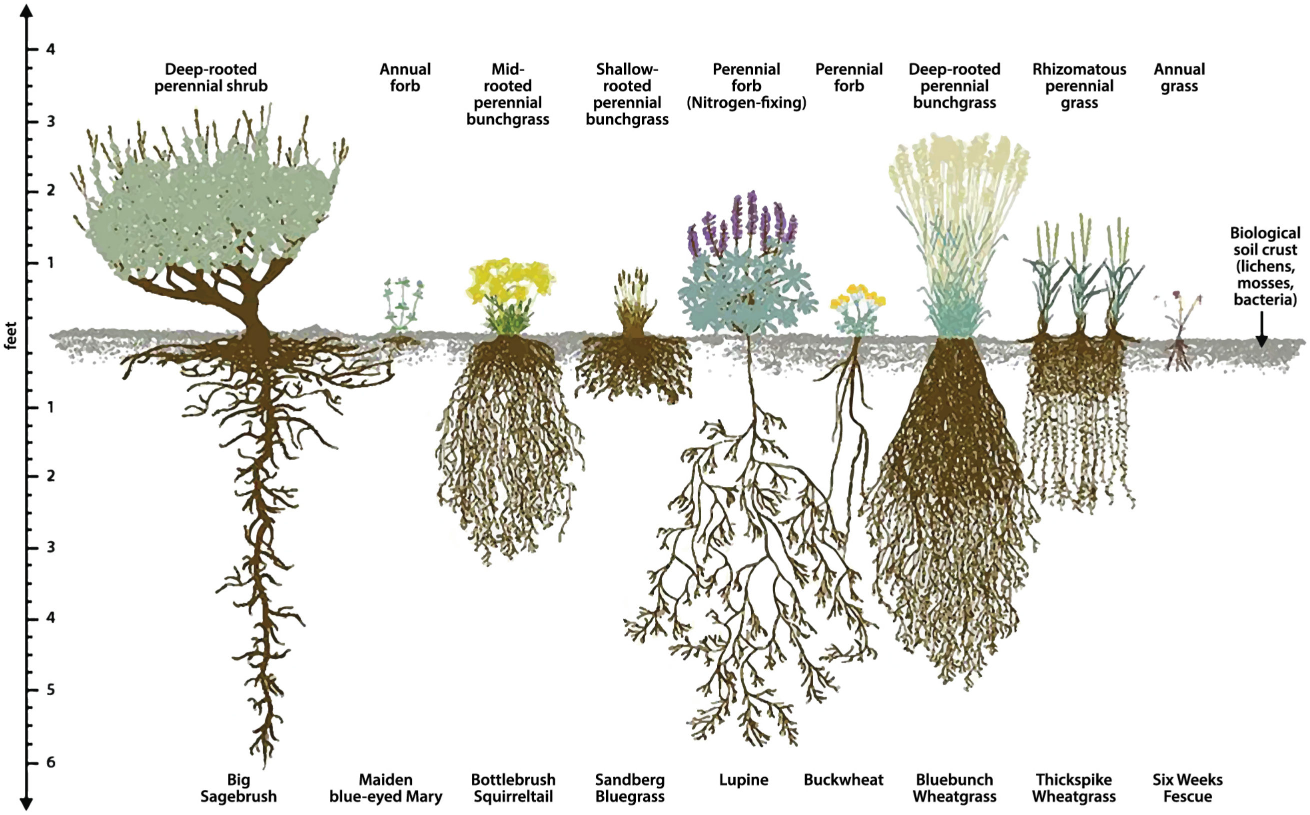


Figure 18. Examples of differing above- and below-ground vegetation structure. From left to right: deep-rooted perennial shrub, annual forb, mid-rooted perennial bunchgrass, shallow-rooted perennial bunchgrass, nitrogen-fixing perennial forb, perennial forb, deep-rooted perennial bunchgrass, rhizomatous perennial grass, annual grass, and biological soil crust (adapted from Sage Grouse Initiative 2016).

How they are described: Functional/structural (FS) groups are described based on their relative dominance in the evaluation area, which can be defined in terms of relative proportions of foliar cover, annual production, or aboveground biomass. For general discussion, the term "size per unit area" is used to refer to the relative amount of cover, production, or biomass of each plant group, as well as the relative dominance category. Use the DIRH Functional/Structural Groups Worksheet (Appendix 2) to document the FS groups in the evaluation area and assign each FS group in the area to a relative dominance category. Foliar cover for each FS group can be calculated from point intercept data. Relative dominance based on annual production may also be recorded if such annual production estimates are collected in the evaluation area. Relative dominance based on biomass is used less frequently because it is more difficult to measure and does not correspond to commonly used methods or datasets. The relative dominance categories are defined as follows:

- **Dominant** – Species or FS groups with the greatest size per unit area in the plant community.
- **Subdominant** – Species or FS groups within a plant community with less size per unit area than dominant plants and generally greater than 10% of the community composition.
- **Minor** – Species or FS groups within a plant community with less size per unit area than subdominant plants and generally greater than 1% and less than 10% of the community composition.
- **Trace** – Species or FS groups that represent rare contributions to the measurable plant community composition (e.g., less than 1% of the composition).

Additional notes about vegetation age classes, distribution patterns, and phenology may be made in the notes field of the evaluation form. See Appendix 2 for an example of a completed Functional/Structural Groups Worksheet.

Completed section of DIRH Evaluation Form for Indicator 12.

12. Functional/Structural Groups *Complete and attach Functional/Structural Groups Worksheet (strongly recommended).*	
Notes (Vegetation ages classes; association with slope, bare areas, recent weather, and disturbance):	Photos taken ☐
See attached F/S worksheet and Indicator 10 and 16 notes for plant community composition and distribution.	

6.13 Dead or Dying Plants and Plant Parts (Indicator 13)

What: Dead or dying plants and plant parts (i.e., stems, branches, and leaves) are a natural phenomenon in all perennial plant communities. For example, many perennial bunchgrasses species tend to develop a dead center with live leaves and stems forming an outside ring as the grasses age. Likewise, a shrub may have dead branches, although most of the plant is alive (Figure 19).

Why: For plant communities to be maintained, individuals, species, and groups of plants need to regenerate at the rate that others die. The natural disturbance regime affects plant lifespans and may also affect the proportion of dead plant parts. For example, a single or multiyear drought may result in more dead or dying plants or plant parts than periods of average precipitation. Improper management during drought periods can increase the amount of dead or dying plants or plant parts above what would have naturally occurred during a drought (Thurow and Taylor 1999).

How they are described: This indicator is described based on the extent or proportion of dead or dying perennial plants or plant parts in all FS groups in the evaluation area. If dead or dying plants or plant parts are more than "rare" in any FS group in the evaluation area, list the group and indicate the extent of die-out within the group. If die-out appears to be occurring in patches, note the patch size, which may be larger than the DIRH evaluation area.

Figure 19. Examples of dead or dying plants or plant parts. A bunchgrass with a dead center (above). A stand of Wyoming big sagebrush (*Artemisia tridentata ssp. Wyomingensis*) with dead plants and plant parts (below).

Completed section of DIRH Evaluation Form for Indicator 13.

13. Dead or Dying Plants or Plant Parts

List FS groups with occasional to extensive dead or dying plants or plant parts; indicate extent, patch size and suspected cause.

Extent (all perennials)	Extensive (> 51%)	Widespread (25–50%)	[✓ Moderate (11–25%)]	Occasional (2–10%)	None or rare (≤ 1%)

Functional/Structural Group	**Extent within each affected FS group**				**Patch Size**	**Suspected cause**
	Extensive (> 51%)	Widespread (25–50%)	Moderate (11–25%)	Occasional (2–10%)		
Non-sprouting shrubs		X				Old stand
Perennial bunchgrasses			X			

Notes (affected species; proportion of dead plant parts from LPI; association with recent weather and disturbance): Photos taken ☒

Mortality of about 25% of mature sagebrush plants; many dead branches on most live sagebrush. 36% of sagebrush cover hits are dead plants or plant parts. Most perennial bunchgrasses in shrub interspaces have dead centers (about 20% of all bunchgrasses in evaluation area). Little to no mortality note in other FS groups.

The suspected cause of die-out can also be recorded. Proportions of dead and dying plants can be described using line-point intercept data and recorded in the notes field, along with effects of recent weather and disturbance.

The following points should be considered when describing this indicator:

- Dormant plants (at the end of their growing season) are not considered dead or dying unless there are obvious signs that parts of the plants are dead (e.g., portions of bunchgrass crowns that are decomposing or can be easily plucked out of the ground).
- Perennial plants (including dead plants) are only considered when they are physically present in the evaluation area.
- Vigor and reproductive capability of perennial plants are not included in the description of this indicator because they are described under indicator 17.

Evidence of plant damage due to insects or diseases should be noted in connection to dead or dying plant parts. For example, Aroga moths can periodically defoliate sagebrush, resulting in patches of dead or dying plants. In some areas, biological control agents may be the cause of dead or dying target weed species; for example, the knapweed root borer (Figure 20), is released in North America to control invasive knapweed species.

Figure 20. Image of a knapweed root borer (*Cyphocleonus achates*). Photo credit: Laura Parsons, University of Idaho, PSES, Bugwood.org

6.14 Litter Cover and Depth (Indicator 14)

What: Litter is the uppermost layer of organic debris on the soil surface—essentially the freshly fallen or slightly decomposed vegetal material (SRM 1998). Litter includes leaves, stems, and branches that are detached from the plant. Plant parts that are dead but still attached to the plant are considered standing dead, not litter. Litter may be in varying degrees of decomposition, but it is still composed of recognizable plant parts (e.g., grass leaves and seedheads). The two main types of litter are woody litter and herbaceous litter (Figure 21).

Figure 21. Examples of woody litter (top left) and herbaceous litter (top right). The bottom image shows an evaluator measuring the depth of herbaceous litter.

Completed section of DIRH Evaluation Form for Indicator 14.

14. Litter Cover and Depth

Total litter cover (%) 23 Woody litter cover (%) 5 Herbaceous litter cover (%) 18

Average litter depth under canopy: 3 Average litter depth in interspaces: 0.5 ☐ ☒ cm

Notes (litter source(s); association with plant canopy, bare areas, recent weather, and disturbance): Photos taken ☐

Herbaceous litter is a mixture of perennial and annual grasses and sagebrush leaves. Woody litter is mostly sagebrush branches. More litter cover under shrub canopy, litter is thin and scattered between shrubs.

If dead, detached plant material is so decomposed that the plant parts cannot be recognized, it is considered duff, which is not included as part of the litter cover and depth indicator. For areas where duff is a prevalent component of ground cover, it may be accounted for by incorporating it in the DIRH assessment as an optional indicator (Section 6.18).

Why: Litter provides a source of soil organic material and raw materials for onsite nutrient cycling (Whitford 1996), helps moderate the soil microclimate, provides food for microorganisms, and plays a role in enhancing erosion resistance by dissipating the energy of raindrops and obstructing overland flow (Thurow et al. 1988). After wet years, a larger amount of herbaceous litter may be expected. In contrast, less litter would be expected the first growing season after a wildfire. The amount of litter present at a site can be reduced by other recent disturbances or land uses, such as livestock grazing or off-road vehicles.

How it is described: This indicator is described by measuring the percent cover of herbaceous and woody litter present in the evaluation area. Litter > 5 mm in diameter should be recorded as woody litter, and litter < 5 mm in diameter should be recorded as herbaceous litter when collecting cover data. Litter cover can be calculated from point intercept data by counting the total number of points that have litter recorded in any layer, and dividing those litter hits by the total number of pin drops. The average litter depth is also recorded; litter depth can be estimated (Figure 21), or it can be measured along predetermined locations on a transect tape or step-point transect.

6.15 Annual Production (Indicator 15)

What: Annual production is the net quantity of aboveground vascular plant material produced within a growing season or year.

Why: Annual production represents the energy captured by plants through the process of photosynthesis, given recent weather conditions, and is directly linked to the ecological process of energy flow.

How it is described: Annual production is described in pounds per acre or kilograms per hectare. Multiple approaches can be used to estimate annual production as described in the Annual Production – Additional Resources text box (page 43). The total harvest and weight unit methods are relatively rapid, and often used for IIRH assessments (Figure 22). Instructions and forms for these methods are provided in Appendix 8 of TR 1734-6.

Regardless of the method used, to be comparable to standardized data, production estimates should:

- Not include standing dead vegetation produced in previous growing seasons.
- Only include live tissue (woody stems) produced in the current year's growing season(s).
- Include standing dead plants produced during the current growing season(s) (e.g., annuals).

Figure 22. Images showing total harvest and weight unit methods for measuring annual production. A field technician clips grass in a small hoop (above) and weighs a weight unit with a spring scale (below) to estimate annual production.

Completed section of DIRH Evaluation Form for Indicator 15.

15. Annual Production	
Annual production: 645 ☒ pounds/acre ☐ kg/hectare	**Growing conditions:** ☐ Favorable ☒ Normal ☐ Unfavorable
Notes (annual production source(s); association recent weather and disturbance):	Photos taken ☒
Annual production is about 50% non-sprouting shrubs (sagebrush), 35% from perennial grasses, 10% annual grasses, and 5% perennial forbs and other F/S Groups.	

- Include all species (e.g., native, seeded, and invasive) that are or were alive during the growing season(s) in which the assessment is conducted.
- Account for growing conditions, phenology and grazing of plants at the time the estimate is being made.

If annual production is estimated by species or functional/structural group, the production for each group can be recorded on the DIRH Functional/Structural Groups Worksheet and used to determine relative dominance of FS groups for Indicator 12.

ANNUAL PRODUCTION – ADDITIONAL RESOURCES

Estimating total annual production for most purposes of DIRH does not require determining production or composition by species or functional/structural group. However, this may be desirable when more detailed data are needed, such as for developing reference sheets. A suitable approach for measuring total annual production is included in Appendix 8 of TR 1734-6. This approach should be used unless observers are skilled at ocular production estimates or another measurement methodology is required based on project objectives.

Additional methods and detailed guidance and forms to record data are available in the “National Range and Pasture Handbook” (NRCS 2022), “Inventory and Monitoring: Ecological Site Inventory” technical reference (Habich 2001), and “Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems Volume II” (Herrick et al. 2009).

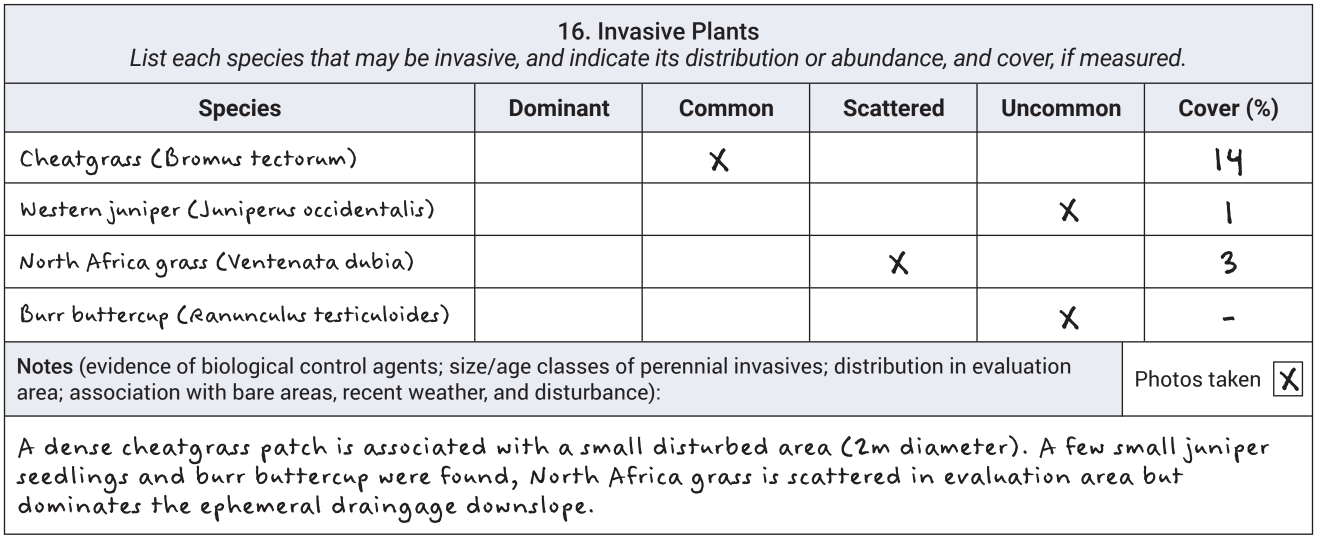
6.16 Invasive Plants (Indicator 16)

What: Invasive plants (for purposes of the IIRH and DIRH protocols) are plant species that have the potential to become dominant or codominant if their establishment and growth are not actively controlled by natural disturbances or management interventions (Figure 23). Usually, invasive plants are nonnative species. However, native species may also be categorized as invasive if they would only occur as trace or minor components under the natural disturbance regime but may become dominant or subdominant if not controlled by natural disturbances or management interventions.

Why: Invasive plants may impact an ecosystem’s composition and abundance of species, community dynamics, and the processes by which energy and nutrients move through the ecosystem. Invasive species may adversely affect a site by modifying hydrology (e.g., western juniper), changing soil chemistry (e.g., salt cedar/tamarisk in riparian areas) or influencing nutrient and disturbance cycles (e.g., increased nitrogen cycling and wildfire frequency in areas invaded by cheatgrass; Stark and Norton, 2015).

Figure 23. Examples of invasive plants. Western juniper (*Juniperus occidentalis*) (above) is a species native to the Western United States that may be considered invasive in shrub and grassland ecological sites. Spotted knapweed (*Centaurea stoebe*) (below) is a perennial forb species native to eastern Europe that is widely considered to be invasive in rangelands of the Western United States and appears on many noxious weeds lists. Photo credit: Konrad Kauer.

Completed section of DIRH Evaluation Form for Indicator 16.



16. Invasive Plants

List each species that may be invasive, and indicate its distribution or abundance, and cover, if measured.

Species	Dominant	Common	Scattered	Uncommon	Cover (%)
Cheatgrass (Bromus tectorum)		X			14
Western juniper (Juniperus occidentalis)				X	1
North Africa grass (Ventenata dubia)			X		3
Burr buttercup (Ranunculus testiculoides)				X	-

Notes (evidence of biological control agents; size/age classes of perennial invasives; distribution in evaluation area; association with bare areas, recent weather, and disturbance):

Photos taken ☒

A dense cheatgrass patch is associated with a small disturbed area (2m diameter). A few small juniper seedlings and burr buttercup were found, North Africa grass is scattered in evaluation area but dominates the ephemeral draingage downslope.

How they are described: Identifying plant species to include when describing this indicator may be challenging if the ecological site and hence the plants with potential to invade that site are unknown. However, local knowledge can be used to identify species that are generally considered to be invasive in the area. List any species within the evaluation area that may be invasive and indicate whether they are dominant, common, scattered, or uncommon. Calculate and record percent cover of each invasive species that is detected by cover data collected in the evaluation area. Density of individuals counted in quadrats or belt transects (BLM 1999, Herrick et al. 2009) can also be a useful way to quantify invasive plants. It is also helpful to note any evidence of disease, insect damage, biological control agents (Figure 20), age or size class of perennial invasives, distribution of each invasive species in the evaluation area, and their association with bare areas, recent weather, and disturbance.

The following guidance is applied when identifying potentially invasive plants to describe this indicator:

- When it is uncertain whether a plant species is invasive, it is preferable to include it in the DIRH assessment so it can be considered later when more information is available.
- Local or state agency offices may maintain lists of species that are considered invasive or have criteria identifying invasive species in the area of interest.
- The state noxious weeds list should be consulted when identifying invasive species. Nonnative, noxious weeds should be included when describing this indicator. Native plants that are on the noxious weed list due to toxicity to livestock should not be included.
- Nonnative plant species should be included if it is uncertain whether or not they are invasive.
- Nonnative species that have been intentionally introduced may be categorized as invasives in some situations. Such species that only dominate the areas where they were planted are not considered invasive. However, intentionally introduced species are considered invasive when they have demonstrated the ability to spread into and dominate areas where they were not sown. For example, crested wheatgrass (*Agropyron cristatum*) is a perennial grass species commonly seeded on rangelands in the Western United States. This species is not particularly invasive in the warm and dry portions of the Great Basin but can be invasive in parts of the northern Great Plains.
- Native plants may be included. Native plants that may normally be present only in minor or trace amounts but tend to become dominant and control ecological processes when the natural disturbance regime changes (e.g., juniper or mesquite increasing, or pine trees establishing in mountain meadows in absence of fire) should be included.

6.17 Vigor with an Emphasis on Reproductive Capability of Perennial Plants (Indicator 17)

What: Plant vigor relates to the robustness of a plant in comparison to other individuals of the same species. Vigor is reflected primarily by the size of the plant and its parts in relation to the plant's age and the local environment in which it is growing (SRM 1998). Seed production is related to plant vigor since healthy plants are better able to produce adequate quantities of viable seed than are plants that are stressed or dying (Hanson and Stoddart 1940; Goebel and Cook 1960). Similarly, the production of tillers, rhizomes, or stolons may decline in density and size as plant vigor declines (Goebel and Cook 1960). Since the vigor of perennial plants is closely related to reproductive capability, nonreproductive characteristics of perennial grasses, forbs, and shrubs may be used as a surrogate for reproductive capability during the assessment if reproductive structures are not developed. Useful nonreproductive characteristics include leaf or stem color, size of a plant crown or basal diameter, leaf or twig length and density, plant height, and annual production (Figure 24).

Figure 24. Images showing examples of plant vigor. The antelope bitterbrush (*Purshia tridentata*) in good (upper left), and poor (upper right) vigor, and bluebunch wheatgrass (*Pseudoroegeneria spicata*) in good (lower left) and poor (lower right) vigor.

Completed section of DIRH Evaluation Form for Indicator 17.

17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants
List each dominant, subdominant, and minor functional/structural group that shows reduced vigor and/or reproductive capability and indicate the degree of reduction for each, and percent of the group affected.

Functonal/ Structural Group	Vigor Reduced:				Reproductive capability reduced:				Percent affected
	Extremely	Greatly	Moderately	Slightly	Extremely	Greatly	Moderately	Slightly	
Non-sprouting shrubs			X				X		60
Perennial bunchgrasses		X			X				80

Notes (affected species; association with recent weather and disturbance; observed vigor indicators such as color, size, height, leader length, inflorescences, seed production, basal diameter): Photos taken ☒

Sagebrush stand within the evaluation area appears to be >50 years old, and combined with drought conditions, shows reduced vigor and reproductive capability, as shown by short leaders and minimal seed production. Most perennial bunchgrasses have dead centers, and only about 20% appear to have produced seed this growing season.

Why: A plant's reproductive capability is dependent on having adequate vigor and the ability to reproduce given the constraints of climate and herbivory. Inflorescence (e.g., seed stalks) and flower production are basic measures of reproductive potential for sexually reproducing plants; clonal production (e.g., tillers, rhizomes, or stolons) are measures for vegetatively reproducing plants. Adequate seed production maintains plant populations when sexual reproduction is the primary mechanism of individual plant replacement at a site.

How it is described: The criteria for describing this indicator emphasize the vigor and reproductive capability of the plants within the dominant and subdominant perennial plant functional/structural groups present in the evaluation area. For each perennial FS group that appears to have reduced vigor and/or reproductive capability, record the group name and the degree of reduction in vigor and reproductive capability. The severity of the reduced vigor and reproductive capability, as well as the proportions of individuals and species affected should all be considered when selecting the best descriptive category for each affected group. The percent of the group affected should also be recorded. Recruitment is not included when classifying this indicator, but evidence of recruitment (seedlings, young plants, or vegetative spread) of perennial native or seeded plants should be recorded in the notes. Notes should also include the observed indicators of vigor (e.g., leader length, plant height, bunchgrass crown diameter, production of seeds and/or inflorescences), apparent effects of recent weather and disturbance, and proportion of reproductive plants for each perennial FS group.

6.18 Optional Indicators

The 17 indicators of rangeland health must be described to complete a DIRH assessment. Additional indicators may be identified and described to add value to the assessment. It is recommended that optional indicators are ecologically, not management, focused. For example, indicators specific to suitability for livestock, wildlife, or special status species are not appropriate for assessing the overall health of a land unit. The criteria and quantitative indicators used to classify and describe each optional indicator should be clearly defined prior to using them in an assessment. Because the DIRH protocol is designed for rangelands, it is especially important to consider adding optional indicators when applying the protocol to forests, wetlands, or other types of land. Examples of optional indicators that may be applied in some areas are slumps (as described in SSSA 1997) (Figure 25) or mass movement (also described in SSSA 1997). These indicators may be appropriately applied in areas that

Figure 25. Example of a large soil slump, or mass wasting, resulting from thawing permafrost. Photo credit: National Park Service.

have an inherent risk for slumps, rockslides, or debris flows. In woodland or forested systems, additional indicators such as duff (i.e., decayed plant material no longer recognizable as litter), and dead/down woody material may be appropriate. Biological soil crusts (see text box on page 24) are another example of an optional indicator that may be appropriate where these crusts play a particularly important biological or physical role.

6.19 Before Leaving the Evaluation Area

Because DIRH is a moment-in-time assessment, it is important to ensure that all data and documentation are complete and organized before leaving the evaluation area. Once all indicator measurements and observations have been completed, review the DIRH Evaluation Form and ensure that notes are complete and legible. Check that all data forms are complete with dates, observer names, and the evaluation area’s identifying information (e.g., location coordinates, site name) so they can be associated with the correct DIRH assessment. Raw data for any quantitative indicators used in the DIRH assessment should be maintained so it can be referred to later. Refill any soil pits that have been dug and remove flagging tape or other markers before leaving the field.

7. After Completing the Assessment

DIRH assessments may be used for a variety of objectives including prioritizing monitoring, informing models, enhancing interpretation of quantitative data, supporting adaptive management, facilitating communication, providing a basis for completing an IIRH assessment, and developing rangeland health reference sheets and evaluation matrices. Below are examples of how DIRH may support these various objectives. It is likely that additional applications of DIRH will be developed over time as this protocol is more broadly implemented.

7.1 Prioritizing Monitoring and Interpreting Quantitative Monitoring Data

Managers may review the indicator classes and descriptions to help identify resource concerns and select long-term monitoring locations and appropriate monitoring methods and indicators (See text box on page 7, Relationship of DIRH to Monitoring). Quantitative data collected as part of the DIRH assessment may be used as the baseline for long-term quantitative monitoring.

Because many of the DIRH indicators reflect ecosystem processes such as runoff, they can also be used to help interpret quantitative data from commonly used monitoring methods. For example, measurements such as bare ground and distribution of canopy gaps are limited in their ability to describe rangeland health and condition when used in isolation. However, considering these measurements together with qualitative erosion indicators such as water flow patterns, rills, pedestals and terracettes can provide insight into past and current soil erosion on a site, and potentially detect future vulnerabilities to degradation that could be missed by quantitative data alone (Jablonski et al. 2021).

DIRH assessments completed in conjunction with repeated, standardized quantitative data collection may also help describe how erosion indicators are changing through time in response to management actions and disturbance. This may be particularly relevant in areas that have had major soil and vegetation alteration, such as reclamation areas, vegetation treatments, or wildfire affected areas. By using repeated quantitative measurements and DIRH indicators together in statistical models, we may also predict how DIRH indicators may respond to changes in soil and vegetation across the landscape and through time, and better define relationships between quantitative indicators and ecological processes.

7.2 Adaptive Management

While the DIRH protocol is not intended to be used to determine the cause of resource concerns, it may assist land managers in identifying areas that are at risk of degradation and where resource problems or management opportunities exist. When DIRH assessments are intended to be used to inform adaptive management, collection of robust quantitative data is strongly recommended. Documenting recent weather, disturbance, and management information may provide clues about the causes of suspected resource issues. In this context, DIRH may help inform short-term adaptive management decisions or adjustments such as additional land treatments or further site mitigation. When using DIRH assessments to assist with post-disturbance adaptive management decisions (e.g., wildfire recovery), efforts should be made to review any pre-disturbance data available for the evaluation area or disturbance footprint. If there are similar undisturbed areas nearby, these areas may be used to make comparisons for data interpretation.

7.3 Completing IIRH Assessments

In some cases, it may be possible to complete an IIRH assessment using a DIRH assessment that includes detailed notes, photos, and appropriate supplemental information and quantitative data. When using DIRH assessments to rate indicators and attributes to complete IIRH assessments, teams of two or more individuals who collectively have IIRH training and locally-relevant experience, and knowledge of soils, vegetation, and disturbance relationships are recommended to ensure quality and consistency of the resulting IIRH assessments. The ecological site must be identified, and an appropriate reference sheet with detailed indicator descriptions must be used. The team should verify that methods used to derive quantitative indicator values for the DIRH assessment are comparable to the methods used to derive the values provided in the reference sheet. Supplemental information, especially disturbance and recent weather prior to the DIRH assessment are critical for understanding the status of the evaluation area relative to the natural range of temporal variability. The team must use professional judgement on a case-by-case basis to determine the validity of completing an IIRH assessment using a previously completed DIRH assessment. A copy of the DIRH assessment, including supporting documentation, should be kept with the resulting IIRH assessment.

7.4 Reference Sheet Development and Revision

The DIRH protocol provides a structured method for collecting information for each indicator that can be used when developing and revising reference sheets (Herrick et al. 2019). The overall process for developing and revising reference sheets, and a checklist of information to include for each indicator, can be found in Appendix 1 of TR 1734-6. The quantitative information, indicator classifications, and items listed in each notes field of the DIRH Evaluation Form correspond with information identified in the reference sheet checklist. In the United States, rangeland health reference sheets are developed for ecological sites, and incorporated as part of each ecological site description. Reference sheet developers should also refer to the “Interagency Ecological Site Handbook for Rangelands” (Caudle et al. 2013) and “National Ecological Site Handbook” (NRCS 2017) for guidance on collecting data for ecological site description development.

When conducting DIRH assessments intended for developing or revising reference sheets, the ecological site and/or soils must be identified for each evaluation area. This verification can either be done during the DIRH assessment, or after the fact, provided that enough soils and site data are collected to conclusively identify the soil component and/or ecological site. It is also important that the entire evaluation area represents a single reference community phase within one ecological site.

DIRH data and descriptions used for reference sheets should reflect sites that are judged to be in/near reference condition or meet the criteria for ecological reference areas. An ecological reference area is defined as “a landscape unit in which ecological processes are functioning within a natural range of variability and the plant communities have adequate resistance to and resiliency after most natural disturbances” (Pellant et al. 2020). Ecological sites that have more than one distinct community phase in the reference state should be described using multiple DIRH evaluation areas to fully capture the natural range of variability for the site. DIRH evaluation areas representative of each of these reference community phases should be described for incorporation into the reference sheet. Each DIRH evaluation area used for reference sheet development should be assigned to the reference community phase it best represents.

Detailed supplemental information is also critical for DIRH assessments used for reference sheet development. Information about recent weather and disturbance helps reference sheet authors to integrate the DIRH assessment in the context of the natural range of variability for the ecological site. When using DIRH assessments to inform reference sheet development, multiple assessments representing the range of spatial and temporal variability (e.g., elevation, precipitation, aspect, natural disturbance) for the ecological site should be used, as well as professional knowledge and other data sources (e.g. additional quantitative monitoring locations and historical records).

7.5 Evaluation Matrix Development

The IIRH protocol uses an evaluation matrix to rate departure of the indicators relative to reference sheet descriptions. While IIRH assessments often use the generic matrix provided in TR 1734-6, Appendix 2, ecological site-specific matrices are recommended (Table 2). Guidance for developing ecological site-specific evaluation matrices is provided in Appendix 2 of TR 1734-6. When used in non-reference areas, DIRH is an ideal method for documenting indicator conditions to inform development of ecological site-specific evaluation matrices.

Table 2. Example of an evaluation matrix for bare ground in a New Mexico ecological site. This evaluation matrix includes both site-specific (recommended) and generic descriptors of departure from the reference condition, which is described in the None to Slight column.

Indicator 4 Bare Ground	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Ecological Site-Specific Descriptor	Greater than 75% bare ground with bare ground patches connected; only occasional areas where ground cover is contiguous. Ground cover mostly patchy and sparse.	51–75% bare ground. Bare ground patches are large (> 50 cm diameter) and usually connected.	31–50% bare ground. Bare ground patches are 25–50 cm and sporadically connected.	20–30% bare ground. Bare ground patches > 25 cm diameter but rarely connected. Bare ground patches associated with surface disturbance are larger and are rarely connected.	Less than 20% bare ground occurring in patches < 25 cm diameter. Larger bare ground patches also associated with ant mounds and small mammal disturbances.
Generic Descriptor	Substantially higher than expected. Bare ground patches are large and frequently connected.	Much higher than expected. Bare ground patches are large and occasionally connected.	Moderately higher than expected. Bare ground patches are moderate in size and sporadically connected.	Slightly higher than expected. Bare ground patches are small and rarely connected.	Reference sheet narrative inserted here.

First, a reference sheet with complete indicator descriptions must be available. The reference sheet descriptions represent the “none-to-slight” departure category for each indicator in the matrix. If a state and transition model has been developed for the ecological site, note the state and community phase each evaluation area best represents. Typically, indicators representative of increasing departure from reference will be found in evaluation areas that are in alternate stable states. Use DIRH assessments from as many of the states and community phases described for the ecological site as possible to develop the evaluation matrix. It is also important that robust supplemental information is available for each evaluation area, and that the ecological site has been conclusively determined.

7.6 Education and Communication

When DIRH assessments are completed with the goal of illustrating concepts and indicators in the field, the results can be used for additional discussion or group exercises. For example, assessments completed by separate groups within the same evaluation area can be compared and differences in indicator descriptions and classifications can be discussed. Completed assessments can be used to guide conversations about how each indicator may be affecting ecological processes, and interacting with each other, and how they are affected by weather, disturbance, and management history. DIRH assessments may also be used as a baseline for additional class exercises such as developing a monitoring plan or combining them with other data to develop a restoration strategy.

7.7 Informing Erosion Models

DIRH assessments may provide data necessary to run erosion models and assist in model interpretation. First, ensure that indicator measurements are defined similarly for DIRH and erosion models. For example, bare ground values should be derived using similar definitions and calculations to ensure that they are comparable (see text box page 24). If cover data have been collected using a multi-layer point-intercept method (e.g., line-point intercept, cover stick or step-point intercept), then the indicators can usually be recalculated to be consistent with other model data. For example, satellite-derived datasets are based on first-hit cover rather than all layers.

DIRH data may also be used qualitatively by comparing the erosion-related indicators with model predictions. While erosion model outputs are usually expressed as annual averages, most soil erosion (both wind and water) occurs during periodic, high intensity events, particularly when these events occur where there is a high proportion of bare ground. Therefore, erosion at any given point in time may be higher or lower than the average. Information on recent storm characteristics can help with interpreting DIRH assessments. Consider that medium-term indicators (e.g., pedestals) to long-term indicators (e.g., soil surface loss and degradation) may more closely match the long-term predictions generated by erosion models and that short-term indicators, such as litter movement, may be more difficult to verify with erosion models. Wheeler et al. (2024) offer additional ideas for integrating IIRH assessments and erosion models, many of which may also be applied using DIRH assessments.

8. Appendices

8.1 Appendix 1: Checklists for Describing Indicators of Rangeland Health

	Describing Indicators of Rangeland Health Tasks Workflow/Checklist*	✓
Before going to the field	Identify evaluator(s).	
	Select evaluation area(s).	
	Assemble soils information and ecological site description(s) (if available).	
	Gather available information about management actions, disturbance history, and recent weather at evaluation areas (e.g., fire history, vegetation treatments, precipitation records).	
At the evaluation area	Delineate evaluation area.	
	Dig a soil pit (≥ 35 cm, where soil depth allows) near the center of the evaluation area. Identify soil components and/or ecological site if possible.	
	Describe the evaluation area using the DIRH Evaluation Area Description Form or alternate forms (e.g., AIM Plot Characterization and Plot Observation forms).	
	Evaluator(s) should independently observe indicators throughout the evaluation area.	
	Use the Functional/Structural Groups Worksheet to record plant species and document the relative dominance of functional/structural groups for the evaluation area using cover data and/or annual production data, or ocular estimates.	
	Test soil stability and record results on the DIRH Evaluation Form.	
	Dig a second soil pit (≥ 35 cm, where soil depth allows) and complete the Soil Surface Loss and Degradation indicator data table for this pit, as well as the pit used for the evaluation area description (one should be under perennial plant canopy, and one should be in in an interspace between perennial plants).	
	Collect cover data (line-point intercept or other method) and record bare ground, litter cover, biological soil crust, and foliar cover values on the DIRH Evaluation Form and Functional/Structural Groups Worksheet.	
	Collect canopy gap; record proportion of gaps in each size class on DIRH Evaluation Form (optional).	
	Measure or estimate annual production, using appropriate methods and forms, and record on the DIRH Evaluation Form. Annual production estimates by functional/structural group may also be recorded on the Functional/Structural Groups Worksheet.	
	Collect additional quantitative data and take photos. List any additional methods.	
	Describe the 17 indicators using the classes and criteria included on the evaluation form for each indicator. Include detailed notes addressing the criteria in parentheses in the notes field.	

* Specific references, equipment, and forms will vary depending on project objectives and protocols. Blanks are provided for additional items that may be needed for specific projects.

Describing Indicators of Rangeland Health References, Field Equipment, and Forms Checklist*	✓
Recommended References and Supplemental Information	
Ecological site description (if available)	
Soil survey information (if available)	
Technical Reference 1734-9 “Describing Indicators of Rangeland Health”	
Technical Reference 1734-6, Version 5 “Interpreting Indicators of Rangeland Health”[1]	
Technical Reference 1734-8 “Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems: Second Edition” Volume 1[2]	
Noxious weed and sensitive species lists	
Supplemental information (recent weather, disturbance, land treatment, and management history)	
Soil color reference (Munsell Soil Color book or other reference or mobile app)	
Other references for selected methods:	
Equipment	
Soil stability kit and deionized water	
Transect tape(s), stakes, flagging tape, and pin flags	
Shovel/sharpshooter spade/soil auger/soil knife	
Annual production hoops, paper bags, rubber bands, gram scale(s), compass, and clippers	
Camera and photocard	
Clipboard and pencils	
Water for soil texturing, hydrochloric acid, soil sieve, and tape measure	
Electronic data capture device, batteries, chargers, etc.	
Other necessary equipment for selected methods:	

* Specific references, equipment, and forms will vary depending on project objectives and protocols. Blanks rows are provided for additional items that may be needed for specific projects.

[1] Pellant et al. 2020.; [2]Herrick, et al. 2017.

Describing Indicators of Rangeland Health References, Field Equipment, and Forms Checklist*	✓
Forms	
DIRH Evaluation Area Description form(s) **OR** Plot Characterization Data Sheet(s)[2] **AND** Plot Observation Data Sheet(s)[2]	
DIRH Evaluation Form(s)	
DIRH Functional/Structural Groups Worksheet(s)	
IIRH Field Form(s) for estimating annual production[1] **OR** other form for selected annual production estimation method	
Soil Stability Test Data Sheet(s)[2]	
Line-Point Intercept Data Sheet(s)[2]	
Gap Intercept Data Sheet(s)[2]	
Other data forms for selected methods:	

* Specific references, equipment, and forms will vary depending on project objectives and protocols. Blanks rows are provided for additional items that may be needed for specific projects.

[1] Pellant et al. 2020.; [2]Herrick, et al. 2017.

8.2 Appendix 2. Describing Indicators of Rangeland Health Forms

This appendix includes three forms for the Describing Indicators of Rangeland Health protocol:

1. Describing Indicators of Rangeland Health Evaluation Area Description (one page). This form is used to describe the physical features of the evaluation area and record supplemental information. The Plot Characterization Data Sheet and Plot Observation Data Sheet in the "Monitoring Manual for Shrubland, Grassland, and Savanna Ecosystems" (Herrick et al. 2017), or other similar forms may be substituted for this evaluation area description form based on project objectives.
2. Describing Indicators of Rangeland Health Functional/Structural Groups Worksheet (one page). Completing this form is strongly recommended to document the kinds and amounts of vegetation in each evaluation area. Foliar cover measurements and annual production estimates for each FS group can also be recorded on this form.
3. Describing Indicators of Rangeland Health Evaluation Form (four pages). This form, or an electronic equivalent, is used for every DIRH assessment to record the indicator observations and related quantitative measurements.

Following the set of blank forms, an example set of completed forms is provided for reference.

This appendix does not include forms for recommended quantitative data collection methods. The current versions of these forms and/or electronic equivalents should be obtained from the appropriate reference sources prior to going to the field to complete a DIRH assessment (see Table 1 and the checklist in Appendix 8.1).

Describing Indicators of Rangeland Health — Evaluation Area Description

Evaluation area name or ID:		**Date:**
Management unit:	**State:**	**Office:**

Observer(s):

Criteria used to select evaluation area:

Location description/directions:

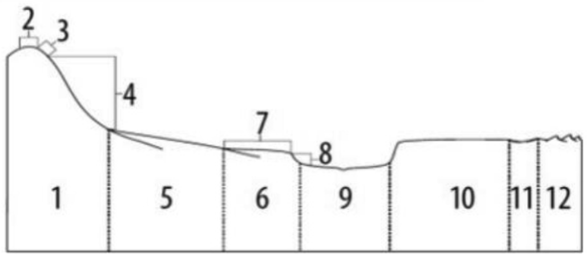
Size of evaluation area:		**UTM Zone:** **Datum:**		**Position by GPS?** ☐ **Yes** ☐ **No**
Township **Range**	**OR**	**UTM E** **m**	**OR**	**N. Latitude**
Section **¼ Section**		**N** **m**		**W. Longitude**

Climatic and Physical Characteristics

Elevation	☐ **ft** ☐ **m**	**Aspect**		**Slope Shape and Percent**		**%**
Average annual precipitation	☐ **cm** ☐ **in**		**Vertical (downslope)**	☐**Convex**	☐**Concave**	☐**Linear**
Seasonal precipitation distribution			**Horizonal (across-slope)**	☐**Convex**	☐**Concave**	☐**Linear**

Landscape Unit/Position (see diagram)			
1. Hill/Mountain		7. Tread	
2. Summit		8. Riser	
3. Shoulder		9. Floodplain/Basin	
4. Backslope		10. Flat/Plain	
5. Alluvial Fan		11. Playa	
6. Terrace		12. Dune	
Other (list)			

Landscape Unit/Position Diagram



Soil Pit Description

Measurement Units	☐ **cm** ☐ **in**	**Soil pit depth**		**Parent material**	

Required				**Recommended**					
				Rock fragment type[1] & volume (%)					
Soil Horizon	Depth	Color (moist)	Texture	Gravel	Cobble	Stone	Clay (%)	Eff.[2]	Structure

Soil and/or Ecological Site *(Complete section if the soil map unit component and/or ecological site can be identified)*

Ecological Site name:		Ecological Site ID:
Soil Survey:	Soil Map Unit:	Soil Component:

Supplemental Information

Recent weather (last two years): ☐ **drought** ☐ **normal** ☐ **wet**

Natural disturbance type(s) and date(s):

Wildlife, livestock, recreation, or other uses:

Offsite influences:

[1] Rock fragment size classes: Gravel – 2–25 mm; Cobble – 26–250 mm; Stone 251–600 mm.

[2] Soil effervescence (Eff.) codes: NE – non-eff; VS - very slighly eff.; SL – slighly eff.; ST – strongly eff.; V – violently eff.

DESCRIBING INDICATORS OF RANGELAND HEALTH: Functional/Structural (FS) Groups Worksheet

Site/Plot ID:

Date:

Observer(s):

Abbreviated instructions (numbers correspond to fields in the table):
For additional information on functional/structural groups and relative dominance, refer to TR 1734-6.
1. Observe and list the plant FS groups present in the evaluation area.
2. Record the species within each FS group present in the evaluation area. List unknown species by genus (if known) or tally within the group they appear to belong to.
3. For each FS group, indicate the relative dominance category[1] in the evaluation area and indicate whether dominance is based on cover or production.
4. Record foliar cover for each FS group if measured.
5. Record annual production values by FS group if estimated. Indicate whether estimates are in pounds (lb) or kilograms (kg).
6. Determine biological soil crust dominance based on cover, rather than production. List life forms (e.g. lichen, moss), rather than the number of individual species.

1) F/S Group	2) Species List	3) Relative Dominance[1]	4) Foliar Cover (%)	5) Production
		Based on: ☐ Cover ☐ Production		☐ lb/ac ☐ kg/ha
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		
6) Visible biological soil crusts *(relative dominance by cover)*		☐ Dominant ☐ Minor ☐ Subdominant ☐ Trace		**Not applicable**

[1] **Dominant:** Functional/structural groups with the greatest size per unit area in the plant community.
Subdominant: Functional/structural groups within a plant community with less size per unit area than dominant plants and generally greater than 10% of the community composition.
Minor: Functional/structural groups within a plant community with less size per unit area than subdominant plants and generally greater than 1% and less than 10% of the community composition.
Trace: Functional/structural groups that represent rare contributions to the measurable plant community composition (e.g., less than 1% of the composition).

Describing Indicators of Rangeland Health Evaluation Form — Page 1

Evaluation area name or ID:		Date:
Management unit:	State:	Office:
Observer(s):		

Quantitative Methods					Sample Size
Cover:	☐ Line-Point Intercept	☐ Step-Point Intercept	☐ Cover Stick	☐ Other:	
Gap Measurements:	☐ Canopy Gap Intercept	☐ Basal Gap Intercept	☐ Other:		
Annual Production:	☐ Double Sampling	☐ Total Harvest	☐ Weight Units	☐ Ocular Estimate	

Instructions: For each criterion listed under each indicator, circle the description that best matches observations within the evaluation area. Complete specified fields for quantitative indicator values and soil observations. Record additional observations for each indicator (suggested items are listed in parentheses) in each notes field. Additional instructions are provided in italics.

1. Rills

Number	Numerous (> 20/0.4 ha plot)	Moderate (11–20/0.4 ha plot)	Few (5–10/0.4 ha plot)	Very few (< 5/0.4 ha plot)	No rills
Length, width, and depth	Very long (> 5 m); may be wide and deep	Long (2–5 m); may be wide and deep	Moderate length (0.5–2m); may be moderately wide and deep	Minimal length (0.25–0.5 m), width, and depth	
Distribution	In both exposed and vegetated areas	Mostly in exposed and occasionally vegetated areas	Mostly in exposed and rarely in vegetated areas	Only in exposed areas	

Notes (average length, width, and depth; association with slope, bare areas, recent weather and disturbance): Photos taken ☐

2. Water Flow Patterns

Extent	Extensive (> 50% of area)	Widespread (25–50% of area)	Common (10–25% of area)	Infrequent (< 10% of area)	No water flow patterns
Size	Very Long (> 15 m) and wide	Long (6–15 m) and wide	Moderately long (1.5–6 m)	Short (< 1.5 m)	
Erosional/ Depositional areas	Widespread	Common	Minor	Few	
Connectivity	Frequent	Occasional	Infrequent	Rare	

Notes (number per unit area; lenght and width; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

3. Pedestals and/or Terracettes

Extent of pedestals	Extensive	Widespread	Common	Uncommon	No pedestals
Root exposure	Frequent	Common	Occasional	Rare	
Extent of terracettes	Widespread	Common	Uncommon	Scarce	No terracettes

Notes (number per unit; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Describing Indicators of Rangeland Health Evaluation Form — Page 2

Evaluation area name or ID:

Date:

4. Bare Ground

Bare ground (percent)	________%				
Bare ground patch diameter	Very large (> 2 m)	Large (1–2 m)	Moderate (0.25–1 m)	Small (0.1–0.25 cm)	Very small (< 0.1 m)
Bare ground patch connectivity	Frequent	Occasional	Infrequent	Rare	Never
Proportion of gaps in each size class (recommended)	Canopy Gaps: > 200 cm: ______% Basal Gaps > 200 cm: ______%	101–200 cm: ______% 101–200 cm: ______%	51–100 cm: ______% 51–200 cm: ______%	25–50 cm: ______% 25–50 cm: ______%	

Notes (connectivity, patch size; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

5. Gullies

Depth and/or width	Substantial	Moderate	Slight	Minimal	No gullies
Perennial vegetation on banks and bottom	Sporadic or none	Intermittent	Occasional	Mostly vegetated	
Annual vegetation on banks and bottom	Sporadic or none	Intermittent	Occasional	Mostly vegetated	
Nickpoints	Numerous	Common	Occasional	Few	
Bank and bottom erosion and/or downcutting	Substantial	Moderate	Slight	Minimal	

Number of gullies in evaluation area:

Number of headcuts in evaluation area:

Notes (headcuts outside of evaluation area; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

6. Wind-Scoured and Depositional Areas

Extent of wind-scoured areas	Extensive (> 50% of area)	Common (26–50% of area)	Occasional (10–25% of area)	Infrequent & few (< 10% of area)	No wind-scoured areas
Connectivity of wind-scoured areas	Frequent	Occasional	Infrequent	Rare or never	
Size of depositional areas	Substantial	Moderate	Minor	Minimal or trace	No deposition

Notes (proportion of site affected; deposition source; association with bare areas, depth or size of depositional areas, recent weather, and disturbance:): Photos taken ☐

7. Litter Movement

Distance of fine litter movement	Very long (> 6 m)	Long (3–6 m)	Moderate (1.5–3 m)	Short (0.6–1.5 m)	None or very short (< 0.6 m)
Distance of large litter movement	Long (> 3 m)	Moderate (1.5–3 m)	Short (0.6–1.5 m)	Very short (< 0.6 m)	None
Size of litter accumulations	Substantial	Moderate	Small	Minimal	None

Notes (proportion of litter moved; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Describing Indicators of Rangeland Health Evaluation Form — Page 3

Evaluation area name or ID:	Date:

8. Soil Surface Resistance to Erosion

Soil Stability Values/ # of samples: Perennial Plant Canopy Average: _______ Samples: _______ Interspace Average: _______ Samples: _______

Notes (association of high or low stability values with soil crusts, bare areas, recent weather, and disturbance): Photos taken ☐

9. Soil Surface Loss and Degradation

Dig at least two soil pits, one under a typical perennial plant or plant patch, and one in interspace; take a photo of the top 35 cm of each pit and complete the table to the right. Subsurface soil color is recorded at 10 cm below the bottom of the surface (A) horizon, or 35 cm below the soil surface if the bottom of the surface horizon cannot be identified.

Criteria		**Plant canopy**	**Interspace**
Depth of surface (A) horizon	☐ in ☐ cm		
Color of surface (A) horizon (moist)			
Soil surface structure	**Type**		
	Size		
	Grade		
Subsurface soil color (moist)			
Depth of subsurface color	☐ in ☐ cm		

Notes (describe any buried surface horizon; proportion of area affected by soil loss or deposition; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

10. Effects of Plant Community Composition and Distribution on Infiltration

List the dominant and subdominant FS groups and indicate their distribution in the evaluation area, and any optional indicators.

Functonal/ Structural Group	**Distribution**			**Optional Indicators**			
	Scattered	Clumped	Even	Basal cover (%)	Average height ☐ in ☐ cm	Dominant growth form	Other:

Notes (vegetation age classes; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

11. Compaction Layer

Distribution	Extensive	Widespread	Moderately widespread	Not widespread	No compaction layer present
Development (thickness and density)	Strong	Moderate to strong	Moderate	Weak	

Notes (extent, distribution, thickness, density, evidence of restricted roots (i.e., lateral roots) or water infiltration; association with bare areas and disturbance; describe any soil layer that could be mistaken for a compaction layer such as petrocalcic, caliche, or durpian and note that it was not included in the description of the compaction layer): Photos taken ☐

12. Functional/Structural Groups

Complete and attach Functional/Structural Groups Worksheet

Notes (Vegetation ages classes; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Describing Indicators of Rangeland Health Evaluation Form — Page 4

Evaluation area name or ID: **Date:**

13. Dead or Dying Plants or Plant Parts

List FS groups with occasional to extensive dead or dying plants or plant parts; indicate extent, patch size, and suspected cause.

Extent (all perennials)	Extensive (> 51%)	Widespread (26–50%)	Moderate (11–25%)	Occasional (2–10%)	None or rare (≤ 1%)

Functional/Structural Group	**Extent within each affected FS group**				**Patch Size**	**Suspected cause**
	Extensive (> 51%)	Widespread (26–50%)	Moderate (11–25%)	Occasional (2–10%)		

Notes (affected species; proportion of dead plant parts from LPI; association with recent weather and disturbance): Photos taken ☐

14. Litter Cover and Depth

Total litter cover (%) _______ **Woody litter cover (%)** _______ **Herbaceous litter cover (%)** _______

Average litter depth under canopy: _______ **Average litter depth in interspaces:** _______ ☐ **in** ☐ **cm**

Notes (litter source(s); association with plant canopy, bare areas, recent weather, and disturbance): Photos taken ☐

15. Annual Production

Annual production: __________ ☐ pounds/acre ☐ kg/hectare **Growing conditions:** ☐ Favorable ☐ Normal ☐ Unfavorable

Notes (annual production source(s); association with recent weather and disturbance): Photos taken ☐

16. Invasive Plants

List each species that may be invasive, and indicate its distribution or abundance, and cover, if measured.

Species	**Dominant**	**Common**	**Scattered**	**Uncommon**	**Cover (%)**

Notes (evidence of biological control agents; size/age classes of perennial invasives; distribution in evaluation area; association with bare areas, recent weather, and disturbance): Photos taken ☐

17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants

List each dominant, subdominant, and minor functional/structural group that shows reduced vigor and/or reproductive capability and indicate the degree of reduction for each, and percent of the group affected.

Functonal/ Structural Group	**Vigor reduced:**				**Reproductive capability reduced:**				**Percent affected**
	Extremely	Greatly	Moderately	Slightly	Extremely	Greatly	Moderately	Slightly	

Notes (affected species; association with recent weather and disturbance; observed vigor indicators such as color, size, height, leader length, inflorescences, seed production, basal diameter): Photos taken ☐

Describing Indicators of Rangeland Health — Evaluation Area Description

Evaluation area name or ID: BigSage_042NW

Date: 07/01/2023

Management unit: Willow Creek Mgt. Area

State: ID

Office: Sand Hill FO

Observer(s): A. Smith, B. Jones, C. Carter

Criteria used to select evaluation area: Randomized point within proposed vegetation treatment area.

Location description/directions: Approximately 300m north from county road, 150 m west of Cow Creek drainage in pasture 3 of the Willow Creek allotment.

Size of evaluation area: 1 acre

UTM Zone: 11 Datum: NAD 83

Position by GPS? ☒ Yes ☐ No

Township	Range	OR	UTM E	515340.3	m	OR	N. Latitude
Section	¼ Section		N	4807328.97	m		W. Longitude

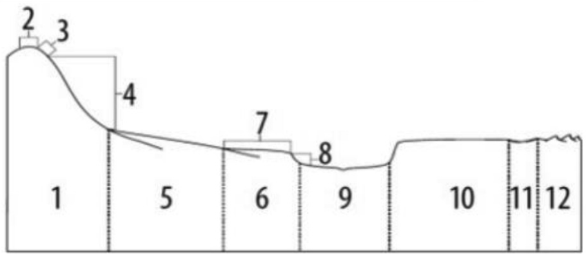
Climatic and Physical Characteristics

Elevation	4,300 ☒ ft ☐ m	Aspect	Southeast	Slope Shape and Percent	6 %
Average annual precipitation	13 ☐ cm ☒ in	Vertical (downslope)	☐Convex	☒Concave	☐Linear
Seasonal precipitation distribution	Winter/spring	Horizonal (across-slope)	☐Convex	☐Concave	☒Linear

Landscape Unit/Position (see diagram)

1. Hill/Mountain		7. Tread	
2. Summit		8. Riser	
3. Shoulder		9. Floodplain/Basin	
4. Backslope		10. Flat/Plain	
5. Alluvial Fan	X	11. Playa	
6. Terrace		12. Dune	
Other (list)			

Landscape Unit/Position Diagram



Soil Pit Description

Measurement Units ☒ cm ☐ in

Soil pit depth 70

Parent material Alluvium

Required				Recommended					
				Rock fragment type¹ & volume (%)					
Soil Horizon	Depth	Color (moist)	Texture	Gravel	Cobble	Stone	Clay (%)	Eff.²	Structure
A	0-8	7.5YR 4/3	Very stony loam	-	5	40	15	NE	granular
B1	8-34	7.5YR 4/2	V. gravelly sandy loam	35	10	-	10	VS	subangular blocky
B2	34-63	2.5YR 5/3	V. cobbly clay loam	10	45	-	35	SL	angular blocky
B3	63-70	2.5YR 5/3	Ext. cobbly loam	-	65	-	10	NE	subangular blocky

Soil and/or Ecological Site *(Complete section if the soil map unit component and/or ecological site can be identified)*

Ecological Site name: Loamy 13-16"

Ecological Site ID: R025XY011ID

Soil Survey: Owyhee

Soil Map Unit: 193

Soil Component: Vitale

Supplemental Information

Recent weather (last two years): Last two years were moderate drought. Winter was near average, but spring precipitation was about 30% below average.

☒ drought ☐ normal ☐ wet

Natural disturbance type(s) and date(s): There are no records of wildfire for this area. Some sagebrush defoliation from Aroga moths is evident, but it is not extensive.

Wildlife, livestock, recreation, or other uses: Pasture was grazed by cattle in April and May this year. Some off-road OHV travel occuring adjacent to the evaluation area. There are several animal burrows in the steeper ara near the SW edge of the evaluation area.

Offsite influences: Evaluation area may be receiving runoff and weed seeds from adjacent road.

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[1] Rock fragment size classes: Gravel – 2–25 mm; Cobble – 26–250 mm; Stone 251–600 mm.

[2] Soil effervescence (Eff.) codes: NE – non-eff; VS - very slighly eff.; SL – slighly eff.; ST – strongly eff.; V – violently eff.

DESCRIBING INDICATORS OF RANGELAND HEALTH: Functional/Structural (FS) Groups Worksheet

Site/Plot ID: BigSage042NW	**Date:** 07/01/23	**Observer(s):** B. Jones

1. Abbreviated instructions (numbers correspond to fields in the table):
2. For additional information on functional/structural groups and relative dominance, refer to TR 1734-6.
3. Observe and list the plant FS groups present in the evaluation area.
4. Record the species within each FS group present in the evaluation area. List unknown species by genus (if known) or tally within the group they appear to belong to.
5. For each FS group, indicate the relative dominance category[1] in the evaluation area and indicate whether dominance is based on cover or production.
6. Record foliar cover for each FS group if measured.
7. Record annual production values by FS group if estimated. Indicate whether estimates are in pounds (lb) or kilograms (kg).
8. Determine biological soil crust dominance based on cover, rather than production. List life forms (e.g. lichen, moss), rather than the number of individual species.

1) F/S Group	2) Species List	3) Relative Dominance[1]	4) Foliar Cover (%)	5) Production
		Based on: ☐ Cover ☒ Production		☒ lb/ac ☐ kg/ha
Non-sprouting shrubs	Wyoming big sagebrush	☒ Dominant ☐ Subdominant ☐ Minor ☐ Trace	26	310
Shallow-rooted perennial bunchgrasses	Sandber bluegrass, bulbous bluegrass, squirreltail	☐ Dominant ☒ Subdominant ☐ Minor ☐ Trace	21	110
Deep-rooted perennial bunchgrasses	Bluebunch wheatgrass, Thurber's needlegrass	☐ Dominant ☒ Subdominant ☐ Minor ☐ Trace	8	120
Sprouting shrubs	Green rabbitbrush	☐ Dominant ☐ Subdominant ☐ Minor ☒ Trace	1	< 5
Perennial forbs	Arrowleaf balsamroot, Hood's phlox, tapertip hawksbeard, unknown astragalus, unknown perennials forbs (3 species)	☐ Dominant ☐ Subdominant ☒ Minor ☐ Trace	4	20
Annual grasses	Cheatgrass, North Africa grass, vulpia	☐ Dominant ☒ Subdominant ☐ Minor ☐ Trace	17	80
Succulents	Prickly pear	☐ Dominant ☐ Subdominant ☐ Minor ☒ Trace	0	< 5
Annual forbs	Storksbill, burr buttercup, unknown annual forbs (2 species)	☐ Dominant ☐ Subdominant ☐ Minor ☒ Trace	2	< 5
		☐ Dominant ☐ Subdominant ☐ Minor ☐ Trace		
6) Visible biological soil crusts *(relative dominance by cover)*	Mosses, lichens	☐ Dominant ☐ Subdominant ☒ Minor ☐ Trace	6	**Not applicable**

[1] **Dominant:** functional/structural groups with the greatest size per unit area in the plant community.
Subdominant: functional/structural groups within a plant community with less size per unit area than dominant plants and generally greater than 10% of the community composition.
Minor: functional/structural groups within a plant community with less size per unit area than subdominant plants and generally greater than 1% and less than 10% of the community composition.
Trace: functional/structural groups that represent rare contributions to the measurable plant community composition (e.g., less than 1% of the composition).

Describing Indicators of Rangeland Health Evaluation Form — Page 1

Evaluation area name or ID: BigSage_042NW		Date: 07/01/2023
Management unit: Willow Creek Mgt. Area	State: ID	Office: Sand Hill FO
Observer(s): A. Smith, B. Jones, C. Carter		

	Quantitative Methods	Sample Size
Cover:	☒ Line-Point Intercept ☐ Step-Point Intercept ☐ Cover Stick ☐ Other:	150 points
Canopy Gaps:	☒ Canopy Gap Intercept ☐ Basal Gap Intercept ☐ Other:	75m, 3 transects
Annual Production:	☐ Double Sampling ☒ Total Harvest ☒ Weight Units ☐ Ocular Estimate	5 plots

Instructions: For each criterion listed under each indicator, circle the description that best matches observations within the evaluation area. Complete specified fields for quantitative indicator values and soil observations. Record additional observations for each indicator (suggested items are listed in parentheses) in each notes field. Additional instructions are provided in italics.

1. Rills

Number	Numerous (> 20/0.4 ha plot)	Moderate (11–20/0.4 ha plot)	Few (5–10/0.4 ha plot)	[✓ Very few (< 5/0.4 ha plot)]	No rills
Length, width, and depth	Very long (> 5 m); may be wide and deep	Long (2–5 m); may be wide and deep	[✓ Moderate length (0.5–2m); may be moderately wide and deep]	Minimal length (0.25–0.5 m), width, and depth	
Distribution	In both exposed and vegetated areas	Mostly in exposed and occasionally vegetated areas	Mostly in exposed and rarely in vegetated areas	[✓ Only in exposed areas]	

Notes (average length, width, and depth; association with slope, bare areas, recent weather and disturbance): Photos taken ☐

Some small rills have formed in the steeper portion of the evaluation area. These are associated with bare ground around animal burrows and dissipate as the slope becomes more gradual.

2. Water Flow Patterns

Extent	Extensive (> 50% of area)	[✓ Widespread (25–50% of area)]	Common (10–25% of area)	Infrequent (< 10% of area)	No water flow patterns
Size	Very Long (> 15 m) and wide	Long (6–15 m) and wide	[✓ Moderate long (1.5–6 m)]	Short (< 1.5 m)	
Erosional/ Depositional areas	Widespread	Common	[✓ Minor]	Few	
Connectivity	Frequent	[✓ Occasional]	Infrequent	Rare	

Notes (number per unit area; lenght and width; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Waterflow patterns are found throughout the evaluation area and are moderately long. However, the flow patterns are somewhat faint in appearance, with only isolated areas of erosion or deposition. They are connected to the rills in the steeper portion of the evaluation area, continuing through the flatter areas.

3. Pedestals and/or Terracettes

Extent of pedestals	Extensive	Widespread	[✓ Common]	Uncommon	No pedestals
Root exposure	Frequent	Common	Occasional	[✓ Rare]	
Extent of terracettes	Widespread	Common	Uncommon	Scares	[✓ No terracettes]

Notes (number per unit; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Pedestalled perennial grasses are found in most shrub interspaces associated with water flow patterns, but they are somewhat muted, and rarely have exposed roots. No terracettes were observed.

Describing Indicators of Rangeland Health Evaluation Form — Page 2

Evaluation area name or ID: BigSage_042NW

Date: 07/01/2023

4. Bare Ground

Bare ground (percent)	27 %				
Bare ground patch diameter	Very large (> 2m)	Large (1–2 m)	[✓ Moderate (0.25–1 m)]	Small (0.1–0.25 cm)	Very small (< 0.1 m)
Bare ground patch connectivity	Frequent	[✓ Occasional]	Infrequent	Rare	Never
Proportion of gaps in each size class (recommended)	Canopy Gaps: > 200 cm: 0 % Basal Gaps > 200 cm: 3 %	101–200 cm: 3 % 101–200 cm: 6 %	51–100 cm: 8 % 51–200 cm: 23 %	25–50 cm: 14 % 25–50 cm: 55 %	

Notes (connectivity, patch size; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Bare ground may be slightly higher than usual due to recent drought, resulting in lower foliar cover and litter production. Bare patches are moderate in size and occasionally connected in shrub interspaces in areas with low perennial plant cover. Some bare patches are associated with animal burrows.

5. Gullies

Depth and/or width	Substantial	Moderate	[✓ Slight]	Minimal	No gullies
Perennial vegetation on banks and bottom	Sporadic or none	Intermittent	[✓ Occasional]	Mostly vegetated	
Annual vegetation on banks and bottom	Sporadic or none	[✓ Intermittent]	Occasional	Mostly vegetated	
Nickpoints	Numerous	Common	Occasional	[✓ Few]	
Bank and bottom erosion and/or downcutting	Substantial	Moderate	[✓ Slight]	Minimal	

Number of gullies in evaluation area: 1

Number of headcuts in evaluation area: 0

Notes (headcuts outside of evaluation area; association with slope, bare areas, recent weather, and disturbance): Photos taken ☒

A portion of a gully is within the evaluation area, ending in the flatter area; there is an active headcut about 100m upslope from the evaluation area. Part of the gully within the evaluation area is about 0.5m deep and 1m wide, and stabalized by perennial herbaceous vegetation.

6. Wind-Scoured and Depositional Areas

Extent of wind-scoured areas	Extensive (> 50% of area)	Common (26–50% of area)	Occasional (10–25% of area)	[✓ Infrequent & few (< 10% of area)]	No wind-scoured areas
Connectivity of wind-scoured areas	Frequent	Occasional	Infrequent	[✓ Rare or never]	
Size of depositional areas	Substantial	Moderate	[✓ Minor]	Minimal or trace	No deposition

Notes (proportion of site affected; deposition source; association with bare areas, depth or size of depositional areas, recent weather, and disturbance:): Photos taken ☐

Depositional areas were noted around large rocks and shrubs. The depositied soils are probably from an upwind area that is recovering from a severe wildfire. Some small areas appear to be wind-scoured where there are larger bare ground patches and lower-stature shrubs.

7. Litter Movement

Distance of fine litter movement	Very long (> 6 m)	Long (3–6 m)	[✓ Moderate (1.5–3m)]	Short (0.6–1.5m)	None or very short (< 0.6 m)
Distance of large litter movement	Long (> 3 m)	Moderate (1.5–3 m)	Short (0.6–1.5 m)	Very short (< 0.6 m)	[✓ None]
Size of litter accumulations	Substantial	Moderate	[✓ Small]	Minimal	None

Notes (proportion of litter moved; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Some herbaceous/fine litter movement is occuring, particularly on steeper slopes and in bare areas. Large/woody litter did not appear to be moving from the litter source. Some small accumulations of fine litter were noted around obstructions and in ponding areas of water flow patterns.

Describing Indicators of Rangeland Health Evaluation Form — Page 3

Evaluation area name or ID: Bigsage_042NW

Date: 07/01/2023

8. Soil Surface Resistance to Erosion

Soil Stability Values/ # of samples: Perennial Plant Canopy Average: 4.3 Samples: 7 Interspace Average: 3.7 Samples: 11

Notes (association of high or low stability values with soil crusts, bare areas, recent weather, and disturbance): Photos taken ☐

Under canopy samples included 3 moss-covered samples. Interspace values range from 1 around animal burrows to 6 where lichen soil crusts are present. Undisturbed samples without biotic crust were 3-4 stability scores.

9. Soil Surface Loss and Degradation

Dig at least two soil pits, one under a typical perennial plant or plant patch, and one in interspace; take a photo of the top 35 cm of each pit and complete the table to the right. Subsurface soil color is recorded at 10 cm below the bottom of the surface (A) horizon, or 35 cm below the soil surface if the bottom of the surface horizon cannot be identified.

Criteria		Plant canopy	Interspace
Depth of surface (A) horizon	☐ in ☒ cm	18	12
Color of surface (A) horizon (moist)		7.5YR 4/2	7.5YR 4/3
Soil surface structure	**Type**	Granular	Single grain
	Size	Fine	-
	Grade	Moderate	-
Subsurface soil color (moist)		2.5 YR 5/3	2.5 Y 5/3
Depth of subsurface color	☐ in ☒ cm	28	22

Notes (describe any buried surface horizon; proportion of area affected by soil loss or deposition; association with slope, bare areas, recent weather, and disturbance): Photos taken ☒

Interspaces appear to have thinner, lighter-colored A horizon. These soil characteristics suggest loss of organic matter and a degraded surface horizon.

10. Effects of Plant Community Composition and Distribution on Infiltration

List the dominant and subdominant FS groups and indicate their distribution in the evaluation area, and any optional indicators.

Functonal/ Structural Group	**Distribution**			**Optional Indicators**			
	Scattered	Clumped	Even	Basal cover (%)	Average height ☐ in ☒ cm	Dominant growth form	Other: Location
Deep-rooted bunchgrasses		X		4			Under shrubs
Non-sprouting shrubs			X	2	42	Spreading	
Perennial forbs	X			0			

Notes (Vegetation age classes; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

Non-sprouting shrubs (sagebrush) dominate the evaluation area; nearly all are mature shrubs with very few seedlings noted. Deep-rooted perennial bunchgrasses mostly occur under shrub cover; perennial forbs are scattered throughout. Evergreen tree seedlings (western juniper) are scattered in trace amounts.

11. Compaction Layer

Distribution	Extensive	Widespread	Moderately widespread	[✓ Not widespread]	No compaction layer present
Development (thickness and density)	Strong	Moderate to strong	[✓ Moderate]	Weak	

Notes (Extent, distribution, thickness, density, evidence of restricted roots (i.e., lateral roots) or water infiltration; association with bare areas and disturbance; describe any soil layer that could be mistaken for a compaction layer such as petrocalcic, caliche or durpian and note that it was not included in the description of the compaction layer): Photos taken ☒

There is one well-defined animal trail through the evaluation area with moderate compaction layer, affecting less than 10% of the evaluation area. Some root restriction of perennial grasses was observed directly adjacent to the trail with lateral roots at about 10cm from the soil surface. There are no natural restrictive soil layers noted.

12. Functional/Structural Groups

Complete and attach Functional/Structural Groups Worksheet (strongly recommended).

Notes (Vegetation ages classes; association with slope, bare areas, recent weather, and disturbance): Photos taken ☐

See attached F/S worksheet and Indicator 10 and 16 notes for plant community composition and distribution.

Describing Indicators of Rangeland Health Evaluation Form — Page 4

Evaluation area name or ID: BigSage_042NW

Date: 07/01/2023

13. Dead or Dying Plants or Plant Parts

List FS groups with occasional to extensive dead or dying plants or plant parts; indicate extent, patch size and suspected cause.

Extent (all perennials)	Extensive (> 51%)	Widespread (25–50%)	[✓ Moderate (11–25%)]	Occasional (2–10%)	None or rare (≤ 1%)

Functional/Structural Group	**Extent within each affected FS group**				**Patch Size**	**Suspected cause**
	Extensive (> 51%)	Widespread (25–50%)	Moderate (11–25%)	Occasional (2–10%)		
Non-sprouting shrubs		X				Old stand
Perennial bunchgrasses			X			

Notes (affected species; proportion of dead plant parts from LPI; association with recent weather and disturbance): Photos taken ☒

Mortality of about 25% of mature sagebrush plants; many dead branches on most live sagebrush. 36% of sagebrush cover hits are dead plants or plant parts. Most perennial bunchgrasses in shrub interspaces have dead centers (about 20% of all bunchgrasses in evaluation area). Little to no mortality note in other FS groups.

14. Litter Cover and Depth

Total litter cover (%) 23 **Woody litter cover (%)** 5 **Herbaceous litter cover (%)** 18

Average litter depth under canopy: 3 **Average litter depth in interspaces:** 0.5 ☐ in ☒ cm

Notes (litter source(s); association with plant canopy, bare areas, recent weather, and disturbance): Photos taken ☐

Herbaceous litter is a mixture of perennial and annual grasses and sagebrush leaves. Woody litter is mostly sagebrush branches. More litter cover under shrub canopy, litter is thin and scattered between shrubs.

15. Annual Production

Annual production: 645 ☒ pounds/acre ☐ kg/hectare **Growing conditions:** ☐ Favorable ☒ Normal ☐ Unfavorable

Notes (annual production source(s); association recent weather and disturbance): Photos taken ☒

Annual production is about 50% non-sprouting shrubs (sagebrush), 35% from perennial grasses, 10% annual grasses, and 5% perennial forbs and other F/S Groups.

16. Invasive Plants

List each species that may be invasive, and indicate its distribution or abundance, and cover, if measured.

Species	Dominant	Common	Scattered	Uncommon	Cover (%)
Cheatgrass (Bromus tectorum)		X			14
Western juniper (Juniperus occidentalis)				X	1
North Africa grass (Ventenata dubia)			X		3
Burr buttercup (Ranunculus testiculoides)				X	-

Notes (evidence of biological control agents; size/age classes of perennial invasives; distribution in evaluation area; association with bare areas, recent weather, and disturbance): Photos taken ☒

A dense cheatgrass patch is associated with a small disturbed area (2m diameter). A few small juniper seedlings and burr buttercup were found, North Africa grass is scattered in evaluation area but dominates the ephemeral draingage downslope.

17. Vigor with an Emphasis on Reproductive Capability of Perennial Plants

List each dominant, subdominant, and minor functional/structural group that shows reduced vigor and/or reproductive capability and indicate the degree of reduction for each, and percent of the group affected.

Functonal/ Structural Group	**Vigor Reduced:**				**Reproductive capability reduced:**				**Percent affected**
	Extremely	Greatly	Moderately	Slightly	Extremely	Greatly	Moderately	Slightly	
Non-sprouting shrubs			X				X		60
Perennial bunchgrasses		X			X				80

Notes (affected species; association with recent weather and disturbance; observed vigor indicators such as color, size, height, leader length, inflorescences, seed production, basal diameter): Photos taken ☒

Sagebrush stand within the evaluation area appears to be >50 years old, and combined with drought conditions, shows reduced vigor and reproductive capability, as shown by short leaders and minimal seed production. Most perennial bunchgrasses have dead centers, and only about 20% appear to have produced seed this growing season.

8.3 Appendix 3: Describing and Hand-Texturing Soils

Texture class is one of the first things determined after digging a soil pit and beginning the soil determination process. Texture is related to weathering and parent material. The differences in soil horizons may be due to the differences in texture of their respective parent materials (NRCS 2024).

Texture class can be determined fairly easily in the field by feeling the sand particles and estimating silt and clay content by flexibility and stickiness. There is no field mechanical-analysis procedure that is as accurate as the fingers of an experienced specialist, especially if standard samples are available. One must be familiar with the composition of the local soils. If local soil composition is not considered, it can lead to incorrect results (NRCS 2024). For example:

- In some environments, clay aggregates form that are so strongly cemented together that they feel like fine sand or silt.
- In humid climates, iron oxide is the cement. In desert climates, silica is the cement. In arid regions, lime can be the cement. It takes prolonged rubbing to show that they are clays and not silt loams.
- Some soils derived from granite contain grains that resemble mica but are softer. Rubbing breaks down these grains and reveals that they are clay. These grains resist dispersion, and field and laboratory determinations may disagree.
- Many soil conditions and components previously mentioned cause inconsistencies between field texture estimates and standard laboratory data. These include, but are not limited to, the presence of cements, large clay crystals, and mineral grains. If field and laboratory determinations are inconsistent, one or more of these conditions is suspected.

The figures and table on the following pages can assist with hand-texturing soils and describing soil structure, rock fragment content, and effervescence. Mobile apps such as LandPKS can also help users with the process of describing and texturing soils and documenting observations.

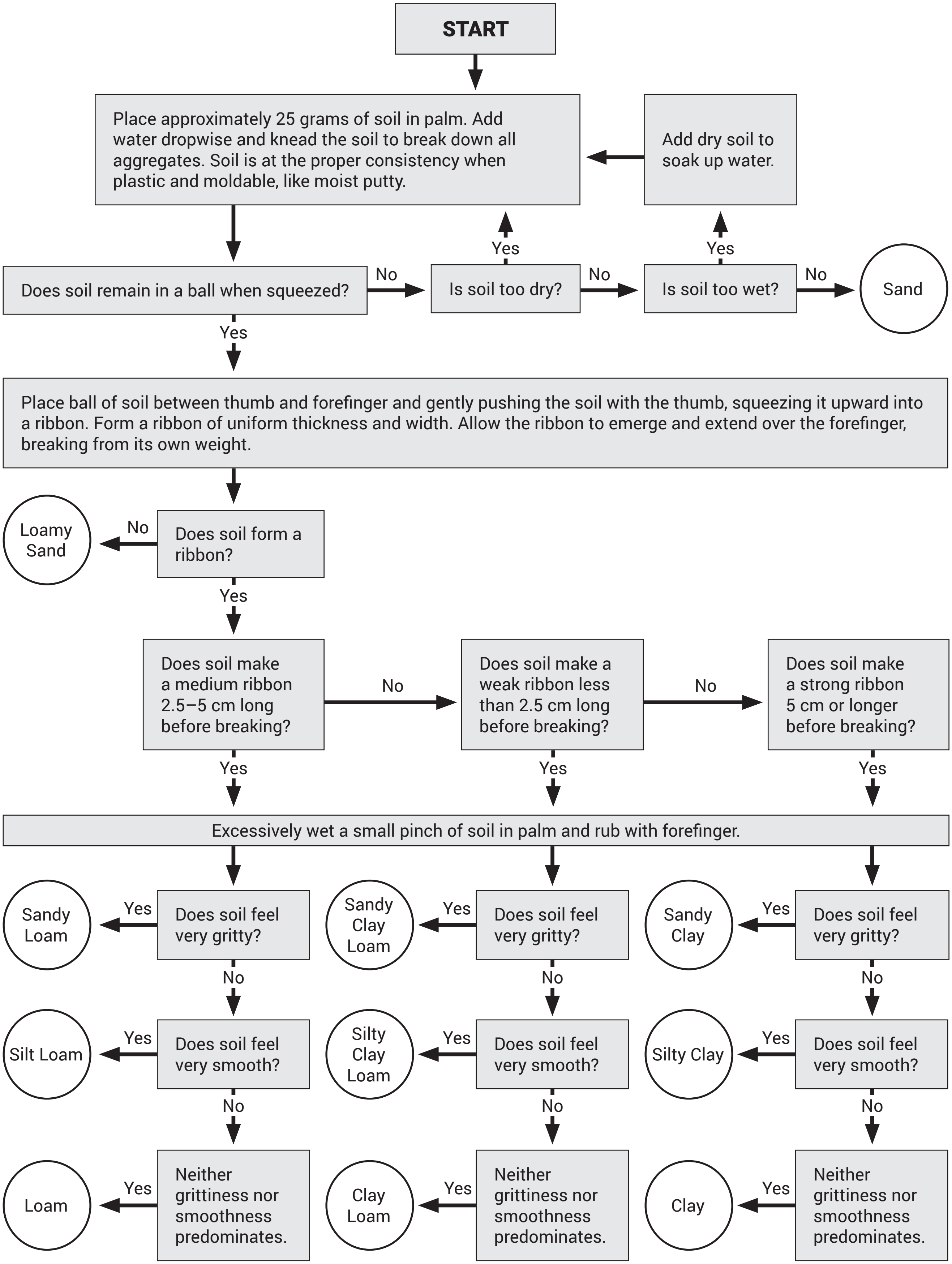
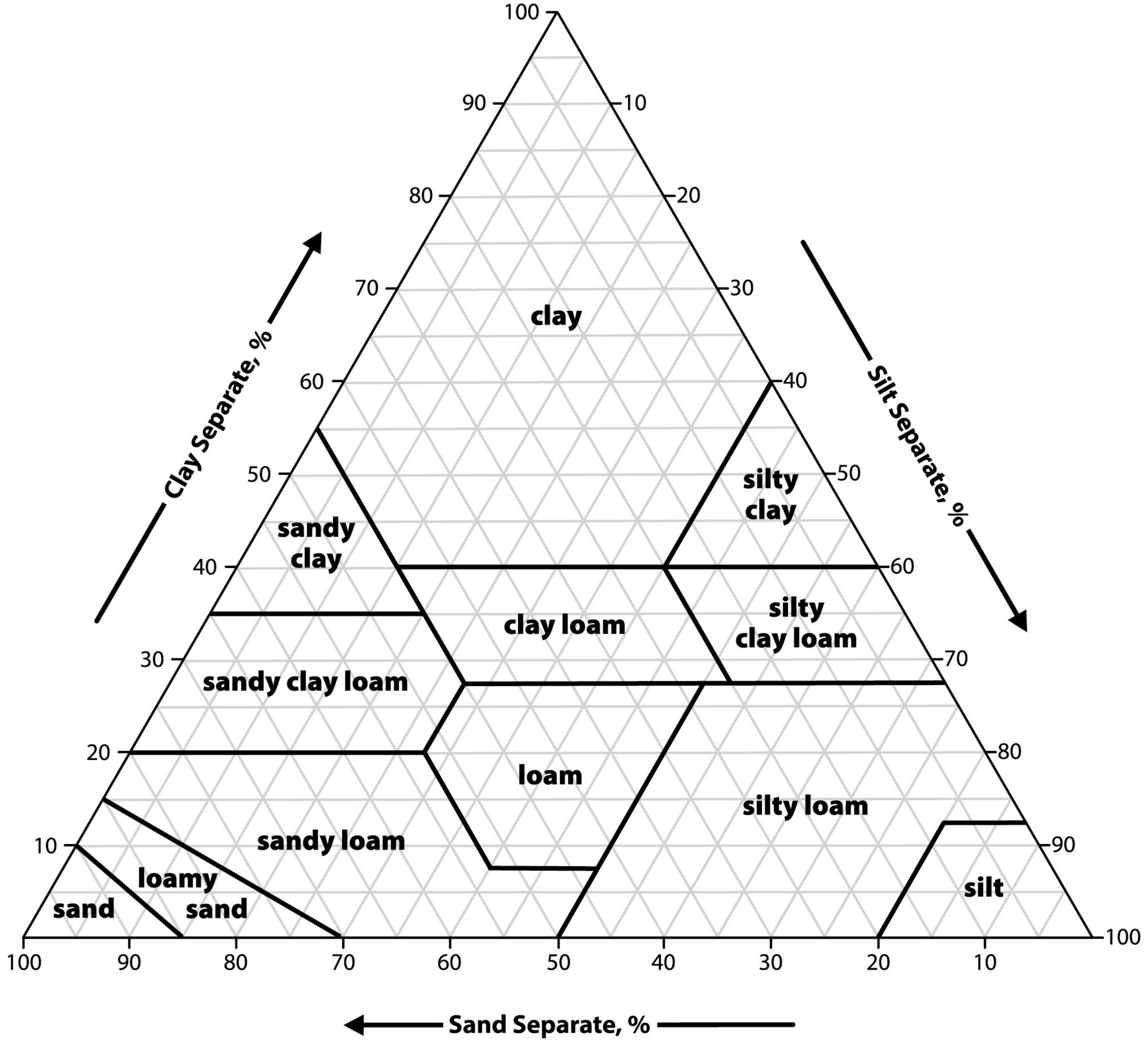


Figure A3.1. A flow diagram for selecting soil texture by feel analysis (Thien 1979). Other texturing methods and keys may be used as well (e.g., Salley et al. 2018).



Texture modifiers: Conventions for using "Rock Fragment Texture Modifiers" and for using textural adjectives that convey the "% volume" ranges for **Rock Fragments - Size and Quantity**

Fragment Content % by Volume	Rock Fragment Modifier Usage
< 15	No texture adjective is used (noun only) (e.g., loam).
15 to < 35	Use adjective for appropriate size (e.g., gravelly).
35 to < 60	Use "very" with the appropriate size adjective (e.g., very gravelly).
60 to < 90	Use "extremely" with the appropriate size adjective (e.g., extremely gravelly).
≥ 90	No adjective or modifiers. If ≤10% fine earth, use the appropriate noun for the dominant size class (e.g., gravel).

Figure A3.2. A soil textural triangle and table of soil texture modifiers (NRCS 2019).

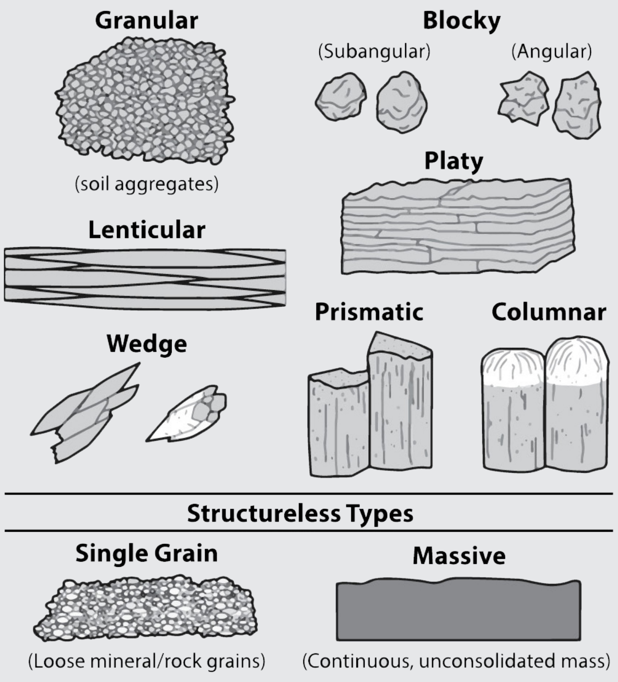
Table A3.1. Table of common soil descriptors. A. Effervescence classes for describing the entire soil matrix using 1 molar hydrochloric acid (Soil Science Division Staff 2017); B. Soil structure classes by size and shape; C. Examples of soil structure types; D. Soil structure grades and descriptions; and E. Particle size classes.

A. Effervescence class	Criteria
Noneffervescent	No bubbles form
Very slightly effervescent	Few bubbles form
Slightly effervescent	Numerous bubbles form
Strongly effervescent	Bubbles form low foam
Violently effervescent	Thick foam forms quickly

B. Soil Structure Classes by Size and Shape

Class	Platy and granular (MM)	Prismatic, columnar, and wedge (mm)	Blocky and lenticular
Very Fine	< 1	< 10	< 5
Fine	1 to < 2	10 to < 20	5 to <10
Medium	2 to < 5	20 to < 50	10 to < 20
Coarse	5 to < 10	50 to < 100	20 to 50
Very coarse	≥ 10	100 to < 500	≥ 50
Extremely coarse	N/A	≥ 500	N/A

C. Examples of Soil Structure Types



D. Soil Structure Grades and Descriptions

Weak	The units are barely observable in place. When they are gently disturbed soil material parts into a mixture of whole and broken units, the majority of which exhibit no planes of weakness.
Moderate	The units are well formed and evident in undisturbed soil. When disturbed, the soil material parts into a mixture of mostly whole units, some broken units, and material that is not in the units. Peds part from adjoining peds to reveal nearly entire faces that have properties distinct from those of fractured surfaces.
Strong	The units are distinct in undisturbed soil. They separate cleanly when the soil is disturbed. When removed, the soil material separates mainly into whole units. Peds have distinctive surface properties.

E. USDA Particle Size Classes

FINE EARTH			ROCK FRAGMENTS		
Class	Subclass	Size (mm)	Class	Subclass	Size (mm)
Clay	Fine	< 0.0002	Gravel	Fine	2–5[1]
	Coarse	0.0002–0.002			
Silt	Fine	0.002–0.02		Medium	5–20
	Coarse	0.02–0.05			
Sand	Very Fine	0.05–0.1		Coarse	20–76
	Fine	0.1–0.25			
	Medium	0.25–0.5	Cobbles	-	76–250
	Coarse	0.5–1.0	Stones	-	250–600
	Very Coarse	1.0–2.0	Boulders	-	> 600

[1] Note that particles from 2-5 mm are considered gravel (rock) for purposes of soil description and identification. Only fragments ≥ 5 mm are recorded as rock for purposes of calculating ground cover.

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