National Resources Inventory
Rangeland Resource Assessment

United States Department of Agriculture
Natural Resources Conservation Service

Bare Ground, Intercanopy Gaps, and Soil Aggregate Stability

October 2010

About the Data

Estimates presented here are based upon rangeland data collected on-site as part of the National Resources Inventory (NRI). Rangeland is defined by the NRI as a *Land cover/use* category on which the climax or potential plant cover is composed principally of native grasses, grasslike plants, forbs or shrubs suitable for grazing and browsing, and introduced forage species that are managed like rangeland. This would include areas where introduced hardy and persistent grasses, such as crested wheatgrass, are planted and such practices as deferred grazing, burning, chaining, and rotational grazing are used, with little or no chemicals or fertilizer being applied. Grasslands, savannas,

The National Resources Inventory (NRI) is a statistical survey of natural resource conditions and trends on non-Federal land in the United States. Non-Federal land includes privately owned lands, tribal and trust lands, and lands controlled by state and local governments.

The NRI rangeland results presented here address current conditions. In the future, the NRI rangeland survey sample will include revisited sites. This will allow estimates for change in rangeland resource conditions to be made.

The findings are presented here for bare ground, intercanopy gaps, and soil aggregate stability. The primary purpose of these quantitative data is to establish a baseline for long-term monitoring. As the current NRI rangeland sample sites are revisited, changes from the baseline data will be evaluated to monitor long-term trends. These data can also be used now to help support general interpretations of the findings of the rangeland health assessments. For example, areas of east-central Texas that show high levels of departure from reference soil and site stability conditions also have relatively low percentages of bare ground. Together, this information reflects soil degradation despite relatively high current vegetative cover in this region.

Bare ground, intercanopy gaps, and soil aggregate stability data reflect differences in the land's potential and in its current condition. For example, bare ground percentages are generally higher and soil aggregate stability is generally lower in arid regions, such as the southwestern United States, due to lower potential plant production, which is limited by low precipitation and high evapotranspiration. Within each region, the potential of the land varies with soil, topography and climate. This variability is reflected in the Ecological Site Descriptions

many wetlands, some deserts, and tundra are considered to be rangeland. Certain communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also included as rangeland.

These results are based upon NRI rangeland data collected in the field on rangeland during the period 2003-2006. Current estimates cover non-Federal rangeland in 17 western states (extending from North Dakota south to Texas and west) and to a limited extent in Florida and Louisiana.

The findings presented here are obtained from three types of data:

- **Bare ground** - The percent of bare ground is determined from the line-point intercept at 3-foot intervals along two intersecting 150-foot transects (Herrick et al. 2005).

(http://esis.sc.egov.usda.gov/).

Bare Ground

Bare ground is defined as soil that is not protected by plants (including lichens and moss), litter, standing dead vegetation, gravel, or rocks. Areas with high percentages of bare ground (soil) are at greater risk of runoff and erosion. Bare soil lacks protection from impacts of raindrops, detachment by wind, and temperature increases from exposure to the sun.

Intercanopy Gaps

Open spaces between canopies of plants are more prone to wind and water erosion, especially when the gaps contain high percentages of bare ground. Wind velocity near the soil surface is higher in large gaps making the soil more vulnerable to saltation (the process of soil particles being lifted and returned to the surface, dislodging other particles) and redistribution. In large gaps, soil particles picked up by moving water have little to prevent them from being carried down slope. Wind and water erosion degrade the soil and in higher concentrations can impact both the hydrology of a site and its biotic community.

Soil Aggregate Stability

Soil aggregate stability is a recognized indicator of soil quality and rangeland health. Field tests of soil aggregate stability can provide an indication of current conditions--soil structure may begin to deteriorate rapidly as the soil surface is subjected to destructive forces such as repeated raindrop impacts, machinery traffic, cultivation, and trampling, particularly if there are no organic matter inputs (roots and litter) that support regeneration of soil aggregates. Wind and water erosion can also degrade and remove the more stable aggregates that often occur at the soil surface in rangelands, exposing less stable aggregates below.

- **Plant intercanopy gaps** - Intercanopy gaps are measured using the line intercept transect protocol, an on-site method to record all foliar gaps of at least 1-foot in length along two intersecting 150-foot transects (Herrick et al. 2005).
- **Soil aggregate stability** - A rangeland soil stability test is conducted in the field. Soil (~ 1/4" or 6mm diameter) samples are exposed to rapid wetting (USDA-NRCS 2010; Herrick et al. 2001). Soil samples are rated on a scale from one to six based on a combination of ocular observations of slaking during the first 5 min following immersion in distilled water, and the percent remaining on a 1.5-mm sieve after five dipping cycles at the end of the 5-minute period.

These quantitative data may be used to support the findings in the

Soil aggregates are comprised of groups of soil particles that are bound together by biological agents such as fungi, bacteria, blue-green algae (cyanobacteria), and root exudates. Potential soil aggregate stability is determined by soil texture (soil particle size) and mineralogy, and the type and amount of organic matter inputs. Stable soil aggregates are integral to optimum infiltration capacity and resistance to water erosion. Aggregate stability is a good indicator of soil organic matter content and biological activity, and is correlated with soil nutrient cycling. Unstable aggregates are susceptible to dispersal during rainstorms and may form a hard physical crust on some soils when the soil dries. Physical crusts can restrict plant seedling emergence and are associated with decreased infiltration, higher runoff and soil loss.

Key Findings

- Values reflect differences in both site potential and current status. Bare ground (Figures 1-5, Tables 1-2), gap values (Figures 6-9, Table 3) are inherently higher and soil aggregate stability (Figure 10, Table 4) is lower in more arid parts of the country.

- At the national level, these patterns reflect two factors: (1) potential production (and therefore plant cover and soil stabilizing organic matter inputs) is lower in more arid regions; and (2) resilience, or the capacity of these systems to resist and recover from historic degradation, is also lower.

- Interpreting spatial patterns in these variables together with the results of the rangeland health assessments can be used to help identify the general types of management interventions that are more likely to have a positive impact in different parts of the country. Specific management recommendations require interpretation of both types of data in the context of additional information and knowledge about specific

rangeland health assessments, as well as form a baseline of rangeland conditions. When current NRI rangeland on-site sample locations are revisited, changes from this baseline data will be evaluated.

Quality assurance and statistical procedures are designed/developed to ensure data are scientifically legitimate. Irrespective of the scale of analysis, margins of error must be considered. Margins of error (at the 95 percent confidence level) are presented for all NRI estimates.

About the Protocols

The findings presented here are derived using data collected for three field protocols:

Line point intercept data are utilized in summaries of non-native plant species, non-native invasive herbaceous species, native

locations within each region.

- The percent of non-Federal rangeland with high levels of bare ground (Figure 1-5, Tables 1-2)and/or covered by intercanopy gaps of at least 1 m or 2 m (Figures 6-7, Table 3) are more extensive in arid regions. Larger gaps are generally associated with higher rates of wind and water erosion and lower ability of the soil to capture and retain moisture from rainfall and melting snow. Gap openings are susceptible to invasion by exotic species. Intercanopy gaps with high percentages of bare ground (Figures 8-9, Table 3) are especially vulnerable to erosion and establishment of invasive plants.

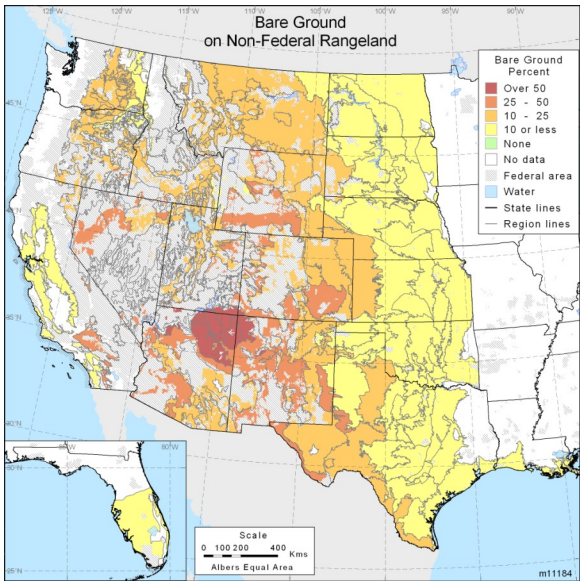
- Soil aggregate stability data (Figure 10, Table 4) provide indications of soil's ability to resist erosion, absorb rain-fall and snow-melt, and provide structure and nutrients needed to support plants. Soil aggregate stability is rated from 1 to 6, where ratings of 5 and 6 are associated with more stable soils and healthier soil functions. Although ratings of 4 or less can indicate areas of concern, these data should not be used alone to make conclusions concerning the health of these areas. The lower the stability ratings the more unstable the aggregates. The result is less stable soil aggregates which can be less resistant to water and wind erosion.

invasive woody species, and bare ground. Line point intercept data are collected along two intersecting 150-foot transects centered on each sample location. Data collectors record plant species, litter, lichen, moss, rock fragment, bedrock, and/or bare soil present at each 3-foot interval.

Line intercept for intercanopy gaps data are used to identify areas with large foliar intercanopy gaps which have more exposure to erosion and may provide opportunity for invasive plants to become established. Data collectors record lengths of plant intercanopy gaps along the two intersecting 150-foot transects.

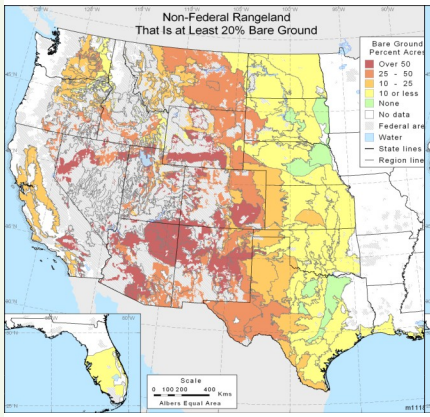
Soil aggregate stability is a recognized indicator of soil quality and rangeland health. Data collectors immerse soil surface peds collected at the sample site in water and subject the soil peds to five dipping cycles.

Figure 1. Bare ground on non-Federal rangeland

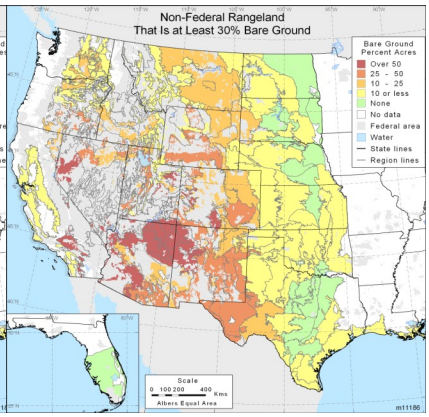


Figures 2-3. Non-Federal rangeland that is at least 20 or 30 percent bare ground

2. At least 20%



3. At least 30%



Soil stability is rated based on the outcomes of these water exposure techniques. Ratings range from 1 (very unstable) to 6 (very stable).

About the Maps

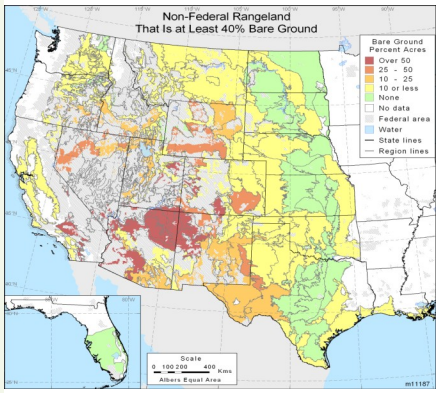
The are constructed with NRI rangeland data collected in the field on rangeland during the period 2003-2006. The mapping regions are based on Common Resource Area (CRA) boundaries; in some cases CRAs were combined to include more sample sites. Regions without non-Federal rangeland are described as "No data". Areas of Federal land are depicted with cross-hatching. Legend categories differ by map theme (e.g., bare ground, soil aggregate stability).

Bare Ground and Foliar Canopy Gap Maps

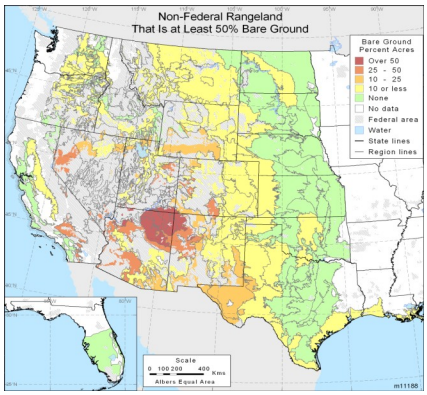
The bare ground and canopy gap maps present the percent by classes (none, 10% or less, 10-25%, 25-50%, over 50%) of non-Federal rangeland for

Figures 4-5. Non-Federal rangeland that is at least 20, 30, 40, or 50 percent bare ground

4. At least 40%

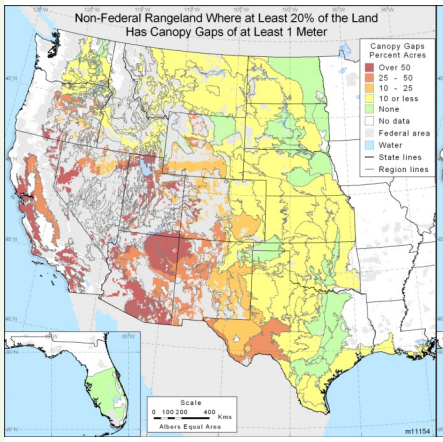


5. At least 50%

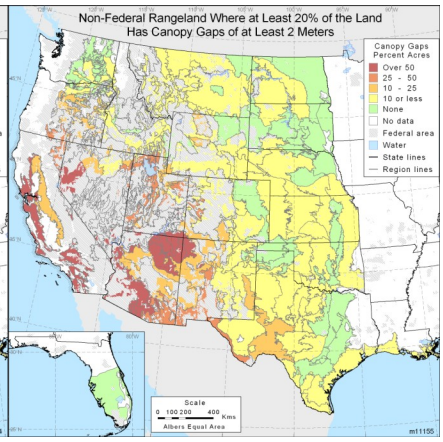


Figures 6-7. Non-Federal rangeland where at least 20 percent of the land has canopy gaps of at least 1 or 2 meters

6. Gaps at least 1 m



7. Gaps at least 2 m



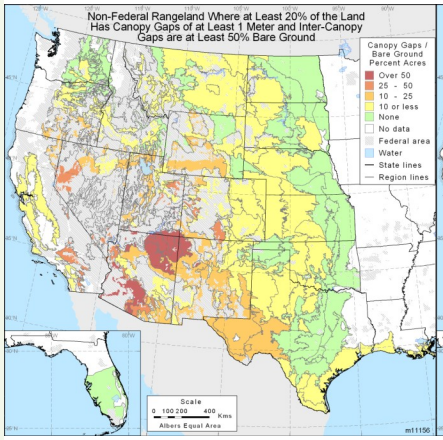
the average proportion of bare ground; where at least 20, 30, 40, or 50 percent is bare ground; where at least 20 percent of the area is covered with intercanopy gaps of at least 1 or 2 meters in size; and where at least 20 percent of the area is covered with intercanopy gaps of at least 1 or 2 meters in size and intercanopy gaps are at least 50 percent bare ground.

Soil Aggregate Stability Maps

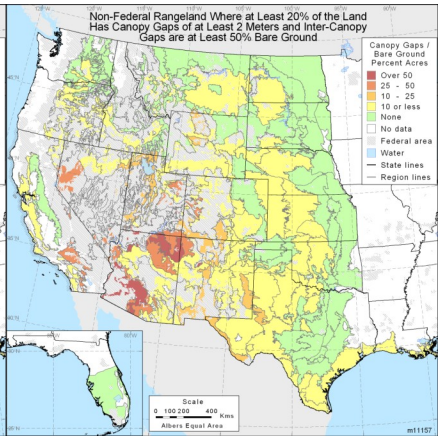
The soil aggregate stability maps present the percent by classes (none, 25% or less, 25-50%, 50-75%, over 75%) of non-Federal rangeland where soil aggregate stability ratings are 4 or less, indicating less stable *soil*.

Figures 8-9. Non-Federal rangeland where at least 20 percent of the land has canopy gaps of at least 1 or 2 meters and the intercanopy gaps are at least 50 percent bare ground

8. 50% bare ground in gaps of at least 1 m



9. 50% bare ground in gaps of at least 2 m



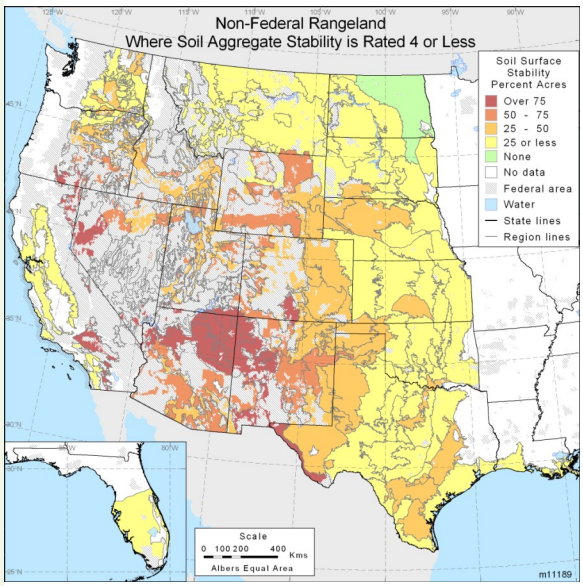
About the Maps

The mapping regions are based on Common Resource Area (CRA) boundaries; in some cases CRAs were combined to include more sample sites. Regions without non-Federal rangeland are described as "No data". Areas of Federal land are depicted with cross-hatching. Legend categories differ by map theme (e.g., bare ground, soil aggregate stability).

Bare Ground and Foliar Canopy Gap Maps

The bare ground and canopy gap maps present the percent by classes (none, 10% or less, 10-25%, 25-50%, over 50%) of non-Federal rangeland for the average proportion of bare ground; where at least 20, 30, 40, or 50 percent is bare ground; where at least 20 percent of the area is covered with intercanopy gaps of at least 1 or 2 meters in size; and where at least 20 percent of the area is covered with intercanopy gaps of at least 1 or 2 meters in size and

Figure 10. Non-Federal rangeland where soil aggregate stability ratings are 4 or less indicating unstable soil.



Soil aggregate stability ratings[1]

1 = 50% of structural integrity lost, (melts) within 5 seconds of immersion in water or soil too unstable to sample (falls through the sieve).

2 = 50% of structural integrity lost, (melts) 5–30 seconds after immersion

3 = 50% of structural integrity lost, (melts) 30–300 seconds after immersion or < 10% remains on the sieve after five dipping cycles.

4 = 10–25% of original soil material remains on the sieve after five dipping cycles

5 = 25–75% of original soil material remains on the sieve after five dipping cycles

6 = 75–100% of original soil material remains on the sieve after five dipping cycles

intercanopy gaps are at least 50 percent bare ground.

Soil Aggregate Stability Maps

The soil aggregate stability maps present the percent by classes (none, 25% or less, 25-50%, 50-75%, over 75%) of non-Federal rangeland where soil aggregate stability ratings are 4 or less, indicating less stable soil.

Importance to the Nation

Bare ground, intercanopy gap size, and soil aggregate stability data provide baseline information for rangeland ecosystems. These data support the interpretations of the qualitative rangeland health summaries. Land managers and policy makers need this information to support strategic decisions and to identify the ecosystem processes that must be restored to improve the land to profitability.

Tabular Results

Estimates presented here are based upon rangeland data collected on-site as part of the National Resources Inventory (NRI), a sample survey based upon scientific statistical principles and procedures. These results are based upon NRI rangeland data collected in the field on rangeland during the period 2003 to 2006 and address current conditions. These estimates cover non-Federal rangeland in 17 western states (extending from North Dakota south to Texas and west) and to a limited extent in Florida and Louisiana.

Margins of error are reported for each NRI estimate and must be considered at all scales of analysis. The margin of error is used to construct the 95 percent confidence interval for the estimate. The lower bound of the interval is obtained by subtracting the margin of error from the estimate; the upper bound is obtained by adding the margin of error to the estimate. A 95 percent confidence interval means that in repeated samples from the same population, 95 percent of the time the true underlying population parameter will be contained within the lower and upper bounds of the interval. In the following tables, if there are instances where the margin of error is greater than or equal to the estimate, the confidence interval includes zero and the estimate should not be used. In those cases, the estimate in the table is replaced by the word “Trace.”

Table 1. Bare Ground on Non-Federal Rangeland, by State, with Margins of Error

State	Percent Bare Ground on Non-Federal Rangeland *Percent*
Arizona	38.7 ±3.4
California	20.1 ±8.4
Colorado	23.8 ±2.0
Florida	3.7 ±2.5
Idaho	13.7 ±1.6
Kansas	6.6 ±0.7
Louisiana	Trace
Montana	14.9 ±1.7
Nebraska	4.9 ±0.6
Nevada	35.9 ±5.2
New Mexico	28.7 ±2.3
North Dakota	2.8 ±0.6
Oklahoma	3.5 ±0.7
Oregon	14.7 ±2.2
South Dakota	3.1 ±0.7
Texas	10.3 ±1.2
Utah	23.9 ±4.0
Washington	13.3 ±2.4
Wyoming	21.1 ±3.0
Nation	16.5 ±0.6

Notes: Estimates where margins of error are at least as large as the estimates are denoted as “Trace.”

Table 2. Percent of Non-Federal Rangeland That Is at Least 20, 30, 40, or 50 Percent Bare Ground, by State, with Margins of Error

State	At least 20%	At least 30%	At least 40%	At least 50%
	Percent	*Percent*	*Percent*	*Percent*
Arizona	68.7 ±5.6	58.8 ±5.8	48.5 ±6	36.1 ±5.6
California	37.6 ±16.3	23.4 ±14.8	19.0 ±14.0	Trace
Colorado	51.0 ±5.9	28.8 ±6.2	17.8 ±3.9	7.1 ±2.8
Florida	Trace	0 NA	0 NA	0 NA
Idaho	23.4 ±7.0	10.8 ±3.4	2.9 ±2.5	Trace
Kansas	7.5 ±1.9	3.8 ±2.0	Trace	Trace
Louisiana	0 NA	0 NA	0 NA	0 NA
Montana	28.1 ±6.7	12.1 ±3.8	4.0 ±2.1	1.9 ±1.5
Nebraska	5.1 ±2.2	1.8 ±1.5	Trace	0 NA
Nevada	69.1 ±11.1	55.9 ±10.0	40.4 ±12	23.6 ±11.9
New Mexico	61.1 ±5.0	44.0 ±5.6	28.1 ±5.9	15.8 ±5.3
North Dakota	2.6 ±1.6	0.5 ±0.4	Trace	Trace
Oklahoma	3.1 ±2.1	Trace	Trace	Trace
Oregon	23.5 ±9.9	13.4 ±6.3	6.4 ±3.9	3.1 ±2.3
South Dakota	3.3 ±2.1	1.4 ±1.1	0.7 ±0.6	Trace
Texas	16.7 ±3.7	8.9 ±3.0	5.0 ±1.7	3.2 ±1.0
Utah	47.5 ±9.2	30.3 ±12.8	20.9 ±9.3	12.0 ±6.4
Washington	20.5 ±8.9	8.2 ±5.0	3.7 ±2.9	Trace
Wyoming	40.0 ±6.8	22.1 ±5.7	15.7 ±5.2	8.8 ±3.7
Nation	30.3 ±1.6	19.4 ±1.3	12.9 ±1.1	7.8 ±1.0

Notes: Estimates where margins of error are at least as large as the estimates are denoted as “Trace.”

Table 3. Percent of Non-Federal Rangeland Where at Least 20 Percent of the Land Has Intercanopy Gaps of at Least 1 or 2 Meters; and Where at Least 20 Percent of the Land Has Intercanopy Gaps of at Least 1 or 2 Meters and the Intercanopy Gaps Are at Least 50 Percent Bare Ground, by State, with Margins of Error

State	Intercanopy gaps of at least 1 m	Intercanopy gaps of at least 2 m	50% bare ground in intercanopy gaps of at least 1 m	50% bare ground in intercanopy gaps of at least 2 m
	Percent	*Percent*	*Percent*	*Percent*
Arizona	65.9 ±5.0	54.6 ±5.0	38.2 ±5.2	33.4 ±5.9
California	71.8 ±6.5	65.9 ±7.6	15.3 ±11.9	14.4 ±12.2
Colorado	11.4 ±3.3	6.1 ±2.5	6.8 ±2.6	3.8 ±2.1
Florida	0 NA	0 NA	0 NA	0 NA
Idaho	5.9 ±3.9	1.0 ±0.9	Trace	Trace
Kansas	1.4 ±1.1	1.1 ±1.0	Trace	Trace
Louisiana	0 NA	0 NA	0 NA	0 NA
Montana	2.1 ±1.1	0.5 ±0.4	0.9 ±0.6	Trace
Nebraska	Trace	Trace	Trace	Trace
Nevada	59.0 ±11.3	44.5 ±12.4	28.7 ±11.1	20.3 ±11.8
New Mexico	21.5 ±4.8	12.7 ±2.9	15.1 ±4.2	8.0 ±2.5
North Dakota	Trace	Trace	Trace	Trace
Oklahoma	Trace	Trace	Trace	Trace
Oregon	15.6 ±4.9	8.7 ±4.3	6.3 ±2.9	3.7 ±3.6
South Dakota	0.6 ±0.4	Trace	0.6 ±0.5	Trace
Texas	10.6 ±2.6	5.0 ±1.6	4.1 ±1.7	2.1 ±1.2
Utah	54.6 ±11.8	40.8 ±12.6	21.8 ±8.0	18.8 ±5.9
Washington	Trace	Trace	Trace	Trace
Wyoming	9.3 ±5.5	4.1 ±2.0	7.3 ±5.4	2.9 ±2.0
Nation	17.8 ±1.1	12.7 ±0.8	8.6 ±1.0	6.1 ±0.9

Notes: Estimates where margins of error are at least as large as the estimates are denoted as “Trace.”

Table 4. Percent of Non-Federal Rangeland Where Soil Aggregate Stability Is Rated 4 or Less, by State, with Margins of Error

State	Soil Aggregate Stability Is Rated 4 or Less *Percent*
Arizona	67.1 ±5.1
California	45.2 ±15.9
Colorado	35.3 ±5.5
Florida	21.0 ±16.5
Idaho	27.8 ±6.0
Kansas	7.8 ±2.4
Louisiana	Trace
Montana	12.7 ±2.6
Nebraska	28.5 ±4.2
Nevada	67.1 ±11.5
New Mexico	60.6 ±7.6
North Dakota	1.3 ±1.1
Oklahoma	19.3 ±4.9
Oregon	41.7 ±8.9
South Dakota	6.2 ±2.9
Texas	25.4 ±3.4
Utah	43.3 ±9.7
Washington	16.7 ±7.6
Wyoming	50.2 ±8.4
Nation	33.3 ±1.3

Notes: Estimates where margins of error are at least as large as the estimates are denoted as “Trace.”

More Information

For more information about the NRI, visit http://www.nrcs.usda.gov/technical/NRI/

For more information on the rangeland data collection protocols see:

Herrick, J.E., J.W. Van Zee, K.M. Havstad, and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico.

Herrick, J.E., W.G. Whitford, A.G. de Soyza, J.W. Van Zee, K.M. Havstad, C.A. Seybold, and M. Walton. 2001. Field soil aggregate stability kit for soil quality and rangeland health evaluations. Catena 44:27-35.

Send comments and questions to the NRI Help Desk (nri@wdc.usda.gov).