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Natural Resource Stewardship and Science

Rangeland Health Assessments of Grazing Allotments in Dinosaur National Monument

Focused Condition Assessment Report

Natural Resource Report NPS/DINO/NRR—2021/2218

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ON THE COVER
View of the landscape around an assessment site in the northeast of Dinosaur National Monument.
Photo by Justin Lambert

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1. Introduction and Summary

The ecological condition of the rangelands of the western United States has been, and continues to be, the subject of significant controversy (Sayre 2017). Some stakeholders argue that western rangelands are in better condition than at any time since the mid-19th century, the start of a long period of generally-agreed-upon degradation. Others argue that rangelands continue to be degraded, with increasing stakeholder demands, including energy development, livestock grazing, and recreational use, counteracting improved management and increased research.

Part of the reason for these opposed perspectives is that the assessment of ecological condition on rangelands—for a single location or, especially, across an entire region—is incredibly complex. Fortunately, range scientists have been grappling with this challenge for decades. The most widely adopted assessment approach that has emerged from this work is known as "Interpreting Indicators of Rangeland Health" (IIRH)(Pellant et al. 2018; Pyke et al. 2002).

Before describing IIRH, it is first important to define some key terms. A US government interagency committee has defined rangeland health as "the degree to which the integrity of the soil, vegetation, water, and air as well as the ecological processes of the rangeland ecosystem are balanced and sustained" (NRCS 2003, p. 4–23). The committee went on to define integrity as the "maintenance of the functional attributes of a locale, including normal variability".

Assessment refers to a point-in-time evaluation of ecosystem function relative to its potential (Herrick et al. 2005). On the other hand, monitoring, which is frequently confused with assessment, refers to measurements (usually quantitative) conducted over time in order to determine trends in targeted key indicators or variables. One way to think of this distinction is that assessment is intended as a management-independent evaluation of standardized indicators, in the way that a baseball umpire might call balls and strikes. Monitoring often incorporates the lessons learned from assessment to identify key indicators that are relevant to management concerns so that adaptation can occur, as a baseball manager might use player statistics to decide whom to play to have the best chance to succeed.

IIRH is a qualitative assessment protocol aimed at evaluating three fundamental attributes of rangeland health, which relate to core ecological processes in rangelands. These attributes are soil and site stability, hydrologic function, and biotic integrity. They are defined as:

- **Soil/site stability:** the capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and/or water, and to recover this capacity when a reduction does occur.

- **Hydrologic function:** the capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

- **Biotic integrity:** the capacity of the biotic community to support ecological processes within the natural range of variability expected for the site, to resist a loss in the capacity to support

> these processes, and to recover this capacity when losses do occur. The biotic community includes plants (vascular and nonvascular), animals, insects, and microorganisms occurring both above and below ground" (Pellant et al. 2018, pp. 14–15).

Because these attributes are difficult (if not impossible) to assess directly, a total of 17 indicators are used to assess them. These indicators are briefly described in Table 1. Each is rated according to a five-class ordinal system, with the degree of departure from a benchmark condition characterized as none to slight (NS), slight to moderate (SM), moderate (M), moderate to extreme (ME), or extreme to total (E).

The benchmark condition for a given location is known as the reference condition and is contained within the Ecological Site Description (ESD). An ecological site is a

> "conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances" (Caudle 2013, p. 12).

ESDs are created by the Natural Resource Conservation Service (NRCS) and maintained within a central repository. Within many, but not all, ESDs is a reference sheet that contains the description of the benchmark conditions for each of the 17 indicators. These reference sheets are developed by NRCS staff familiar with the given ecological site.

This report describes the use of IIRH to assess rangeland health at 44 locations within ten grazing allotments on Dinosaur National Monument, Colorado and Utah. These assessments will be used to aid in crafting individual grazing allotment management plans, identify potential focus areas for management interventions, and guide future monitoring efforts.

Table 1. Indicators used in IIRH (Adapted from Pellant et al. 2018).

Indicator	Description	Attributes[1]			Quantitative data
		S	H	B	
1. Rills	Frequency and spatial distribution of linear erosion rivulets	X	X	–	–
2. Water flow patterns	Amount and distribution of overland flow paths that are identified by litter distribution and visual evidence of soil and gravel movement	X	X	–	–
3. Pedestals and/or terracettes	Frequency and distribution of rocks or plants where soil has been eroded from their base (pedestals), and/or occurrence of erosional terracettes	X	X	–	–
4. Bare ground	Size and connectivity among areas of soil not protected by vegetation, biological soil crusts, litter, standing dead vegetation, or rocks	X	X	–	% bare ground
5. Gullies	Number and size of channels cut into the soil and the amount and distribution of vegetation in the channel	X	X	–	–
6. Wind-scoured areas, blowouts, and/or deposition areas	Frequency of areas where soil is removed from under or around vegetation OR frequency of accumulation areas of soil associated with large structural objects	X	–	–	–
7. Litter movement	Frequency and size of litter displaced by wind and overland flow of water	X	–	–	–
8. Soil surface resistance to erosion	Ability of soils to resist erosion through the incorporation of organic material into soil aggregates	X	X	X	Soil aggregate stability
9. Soil surface loss or degradation	Frequency and size of areas missing all or portions of the upper soil horizons	X	X	X	–
10. Plant community composition and distribution relative to infiltration and runoff	The community composition or distribution of species that restrict the infiltration of water on the site	–	X	–	% composition by F/S group
11. Compaction layer	Thickness and distribution of the structure of the soil near the soil surface (≤15 cm)	X	X	X	–
12. Functional / structural (F/S) groups	Relative dominance of groups, number of groups not expected, total number of groups, and changes in relative dominance of species within groups	–	–	X	Plant foliar and basal cover by F/S group or species

[1] Attributes: S = Soil/site stability, H = Hydrologic function, B = Biotic integrity.

Table 1 (continued). Indicators used in IIRH (Adapted from Pellant et al. 2018).

Indicator	Description	Attributes[1]			Quantitative data
		S	H	B	
13. Dead or dying plants or plant parts	Frequency of dead or moribund (dying) plants or plant parts	–	–	X	–
14. Litter cover and depth	Deviation in the amount of litter	–	X	X	% litter cover
15. Annual production	Amount of aboveground plant production relative to the potential for that year based upon recent climatic conditions	–	–	X	Plant production by F/S group
16. Invasive plants	Abundance and distribution of invasive plants based on a plant's potential to dominate a site to which it is not native, regardless of the plant's status as a noxious weed or exotic species	–	–	X	Invasive plant cover
17. Vigor with an emphasis on reproductive capability of perennial plants	Evidence of inflorescences or of vegetative tiller production relative to the potential for that year based upon recent climatic conditions	–	–	X	–

[1] Attributes: S = Soil/site stability, H = Hydrologic function, B = Biotic integrity.

2. Methods

2.1. Study area

Dinosaur National Monument is a National Park Service unit that straddles the state line between northwest Colorado and northeast Utah, with approximately three-fourths of the monument in Colorado (Figure 1). The monument encompasses 85,141 ha, with elevations ranging from 1,450 m where the Green River exits to 2,750 m on Zenobia Peak in the north. Average annual precipitation and mean annual temperature (1971–2009) range from 215 mm and 8.7 °C at the lower elevations to 475 mm and 3.9 °C at higher elevations (U.S. Geological Survey 2010; U.S. Geological Survey/ PRISM 2010).

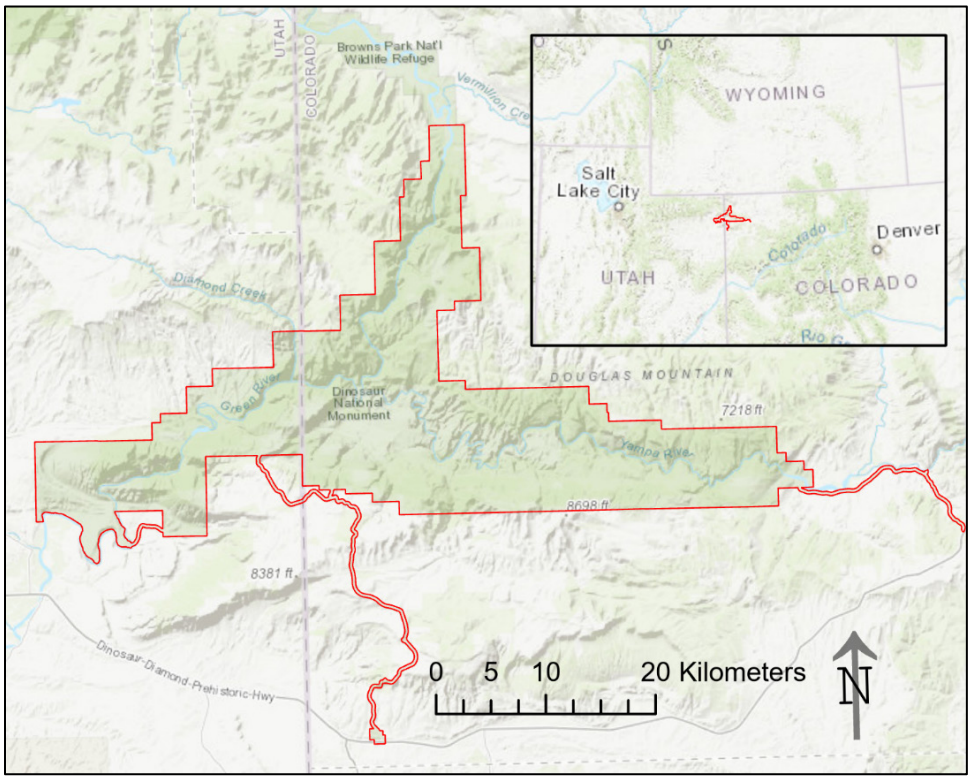

Figure 1. Location and basic geography of Dinosaur National Monument.

Because IIRH requires careful consideration of context, including recent management history and growing conditions, it is important to note that the beginning of the growing season of 2019 was noted by NPS staff and others to have had excellent precipitation. Though it is difficult to quantify precipitation across the monument, data from nearby Jensen, UT, appear to confirm this. A CoCoRaHS (Community Collaborative Rain, Hail and Snow Network) station in Jensen, part of a nationwide network of citizen science precipitation monitoring stations, recorded 174 mm of precipitation, including winter snowfall, during the period from January through May 2019, with 74 mm falling in April and May. According to the National Oceanic and Atmospheric Administration, the 1981–2010 averages for Jensen, UT for those respective periods were 81 mm and 41 mm. Additionally, the crew did not note any extreme weather events, such as late frost, extreme wind, or

prolonged high temperatures, that may affect growing conditions. Therefore, when judgement of recent growing conditions was needed, for example in assessing annual production, the crew assessed the current year as a good to excellent growing season.

Dinosaur National Monument is topographically, geologically, and biogeographically diverse. The monument is on the eastern margin of the Uinta Mountains uplift within the Uinta Basin section of the Colorado Plateaus physiographic province (Coles et al. 2008). Deep canyons created by the Yampa and Green Rivers, which cross the monument, incise rolling plateaus and structural benches to create significant variations in climate and plant community composition over short linear distances.

The ten grazing allotments on DINO total 26,351 ha, or 31% of the total area. In terms of land contained within the monument, they range in size from the 392 ha Massey allotment to the 13,163 ha Blue Mountain/Yampa Bench allotment. This caveat is important, as some allotments are contiguous with significant areas of grazing land adjacent to the monument, including private land and land managed by the Bureau of Land Management and, in some cases, cattle freely move back and forth. Total size within the monument for each allotment is shown in Table 2.

Table 2. Grazing allotments in Dinosaur National Monument (NPS).

Allotment name	Hectares	Assessment sites	Sites per km^2
Big Joe/ West Douglas	1,645	1	0.06
Blue Mountain/ Yampa Bench	13,163	17	0.13
Docs Valley	1,118	2	0.18
Green River	1,049	6	0.57
Harper's Corner	1,717	4	0.23
Massey	392	1	0.26
Murray	827	2	0.24
Round Top	569	2	0.35
Wild Mountain	1,675	2	0.12
Zenobia	4,197	7	0.17

2.2. Sampling

Sampling sites were restricted to the ten grazing allotments and were allocated by NPS staff to strategically assess different management objectives. NPS staff note that they selected these points based on soil type, vegetation community, and ecological site and aimed to capture the variability within and among allotments. Note that the authors had no role in selecting sampling locations and, to preserve the integrity of the IIRH assessment, were not informed of the full set of sample stratification rules. A total of 47 sites were initially assigned. One of these was found to be inaccessible due to its location across the Green River from any land-accessible point, leaving 46 sites to be visited. The location of these sites and the grazing allotments is shown in Figure 2.

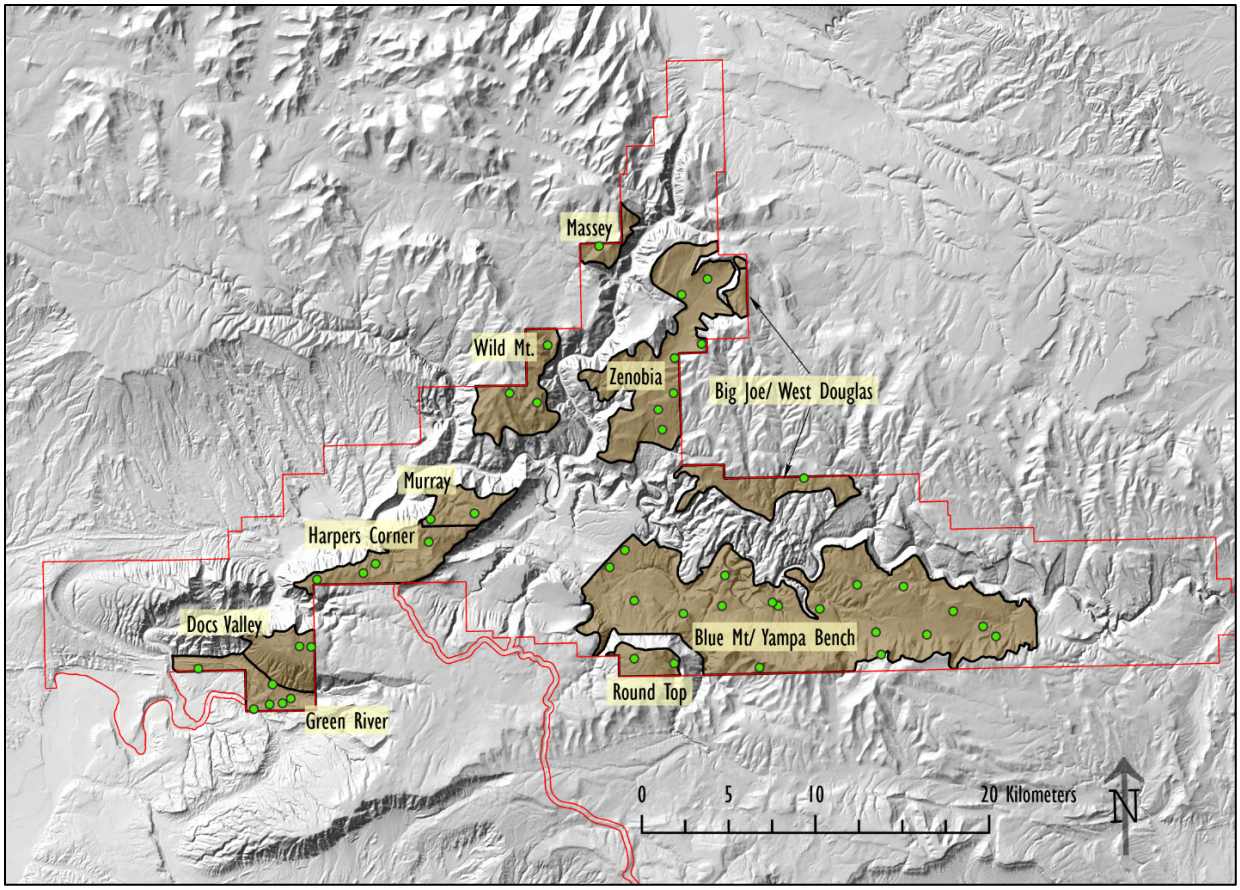

Figure 2. Location of grazing allotments and IIRH assessment sites in Dinosaur National Monument.

2.3. Interpreting Indicators of Rangeland Health

After selection of the evaluation area, the first step in applying the IIRH protocol is to determine the ecological site using soil data, topographic position, and climate. Prior to entering the field, we incorporated existing NPS data and expert consultation from NRCS to identify one to three potential ecological sites for each sample location. In the field, the IIRH crew then dug a soil pit and otherwise collected site verification data to confirm the ecological site. They could then use the associated IIRH reference sheet attached to the Ecological Site Description. All ESDs used in the work are listed in Appendix C.

With the ESD and associated reference sheet in hand, the crew could then follow the IIRH protocol as described in Interpreting Indicators of Rangeland Health, version 5 (Pellant et al. 2018). This protocol is described in an extensive, 203-page technical reference created by numerous ecologists, soil scientists, and other specialists, and published by the Bureau of Land Management National Operations Center. Terminology used in this report is consistent with the IIRH technical reference (Pellant et al. 2018), and may differ slightly from definitions found elsewhere. For example, some invasive plants as specified in IIRH may not be considered invasive according to other definitions. All crew members and one co-author (MF, JL, PM, and JW) attended the official IIRH training in May 2019, while a second co-author (KJ) attended the same training in May 2018.

In some cases, a sampling location may not be identifiable as an extant ecological site, the ESD for the site may not yet be written, or the ESD may exist but not contain an IIRH reference sheet. In all these cases the field crew has the option of then applying the protocol for Describing Indicators of Rangeland Health (DIRH), a descriptive protocol for detailing the status of the 17 indicators in the absence of an ESD or reference sheet.

2.4. Geographic data

We incorporated all relevant geographic data into a GIS using ArcGIS Pro 2.4 (ESRI 2019). This included existing NPS data, such as allotment locations, monument boundaries, and water source locations. We improved this water source dataset by cross-referencing it with an internal NPS report (Williams 2015) that describes the water sources, including usage designations and flow estimates, to assess whether it is usable by livestock. We also integrated other relevant data sources, such as elevation, river locations, and soils, both for field preparation and analysis.

2.5. Data summarization

Due to unequal and generally small sample sizes, whether sorted by grazing allotment or ESD, the usefulness of statistical analysis was limited. At the same time, we have concerns about the appropriateness of converting qualitative IIRH ratings to quantitative data for the purposes of statistical analysis. Therefore, we include no statistical analysis. We did convert rating to numbers for the purpose of summary. To do so, we converted departure from reference condition ratings to an ordinal scale, where none-to-slight equals one and extreme-to-total equals five.

3. Results

3.1. Overview

Of the 46 locations visited, 44 were conclusively associated to an Ecological Site Description with an IIRH reference sheet. Two sites were associated with ecological sites without an existing ESD or IIRH reference sheet, and thus Describing Indicators of Rangeland Health was applied. Because DIRH consists of only qualitative descriptions and no indicator or attribute ratings, all summaries of indicators and attributes will include only these 44 locations. Throughout this section, and unless otherwise indicated, numbers in parentheses following an indicator name or description refer to the indicator numbers found in Table 4.

Distributions of ratings for the 17 indicators and three attributes for all 44 sites are shown in Tables 3 and 4. Some indicators, such as rills (1) and wind-scoured areas (6), were infrequently present or rarely demonstrated a departure from reference condition. Ratings for other indicators, such as annual production (15) and invasive plants (16), were distributed across all of the departure categories.

The patterns for the 17 indicators are reflected in the final attribute ratings. Across the monument, Soil and Site Stability and Hydrologic Function were generally close to reference condition, with more consistent departures from reference condition found for Biotic Integrity. It's important to note that final attribute ratings are made by considering all relevant indicators, context, and general impression of the site rather than a strict quantitative tally, so it is difficult to assign departures for attributes to specific indicators. Nonetheless, for each of the attributes, patterns do emerge.

Of the five sites on which there was a slight to moderate departure from reference condition for Soil and Site Stability, the crew noted that water flow patterns (2) and soil surface resistance to erosion (8) were the key drivers of that departure, leading to some evidence of erosion. Overall, though, there was little broad scale evidence of significant erosional issues.

Of the 14 sites on which there was either a slight to moderate or moderate (one site) departure from reference condition for Hydrologic Function, the crew noted that water flow patterns (2) and soil surface resistance to erosion (8) were once again key drivers. Additionally, plant community composition relative to infiltration (10) was noted as a driver of departure from reference at five sites.

Among the 42 sites that were rated as having at least a slight to moderate departure from reference condition for Biotic Integrity, a wide range of specific reasons was given. However, the key drivers were changes in functional-structural groups (12), the presence or dominance of invasive plants (16), and decreased annual production (15) relative to reference conditions. For those sites that received a rating of moderate to extreme or extreme to total departure from reference, there was always some combination of severe departures for at least two of these indicators.

Maps for the ratings for the 17 indicators and three attributes are in Appendix A. Summary data sheets for the 17 indicators and three attributes for all sites are included in Appendix B.

Table 3. Distributions of ratings for the three attributes for all 44 IIRH sites.

Attribute	Departure from reference condition[1]				
	N-S	S-M	M	M-E	E-T
Soil and Site Stability (S)	39	5	0	0	0
Hydrologic Function (H)	30	13	1	0	0
Biotic Integrity (B)	2	22	16	3	1

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table 4. Distributions of ratings for the 17 indicators for all 44 IIRH sites.

Indicator and related attribute(s)	Attributes rated[1]	Departure from reference condition[2]				
		N-S	S-M	M	M-E	E-T
1. Rills	S, H	42	2	0	0	0
2. Water flow patterns	S, H	29	7	7	1	0
3. Pedestals and/or terracettes	S, H	37	5	2	0	0
4. Bare ground	S, H	36	5	3	0	0
5. Gullies	S, H	42	2	0	0	0
6. Wind-scoured areas, blowouts, and/or deposition areas	S	44	0	0	0	0
7. Litter movement	S	43	0	1	0	0
8. Soil surface resistance to erosion	S. H. B	29	10	3	2	0
9. Soil surface loss or degradation	S, H, B	42	2	0	0	0
10. Plant community composition and distribution relative to infiltration and runoff	H	27	8	7	1	1
11. Compaction layer	S, H, B	37	6	1	0	0
12. Functional / structural groups	B	1	4	17	17	5
13. Dead or dying plants or plant parts	B	40	3	0	1	0
14. Litter cover and depth	H, B	13	18	10	3	0
15. Annual production	B	18	7	13	4	2
16. Invasive plants	B	3	8	12	15	6
17. Vigor with an emphasis on reproductive capability of perennial plants	B	38	5	1	0	0

[1] Attributes: S = Soil/site stability, H = Hydrologic function, B = Biotic integrity.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

3.2. By Grazing Allotment

Mean ratings for attributes were similar across the ten grazing allotments (Table 5). Indeed, the overall patterns described above largely held true within each allotment, with Soil and Site Stability and Hydrologic Function generally close to reference condition and Biotic Integrity, on average, between a slight to moderate and a moderate departure from reference condition. Table 6 shows the average values for the individual indicators among the allotments.

Table 5. Mean attribute ratings for the grazing allotments. Qualitative ratings are converted to an ordinal scale, where none-to-slight equals one and extreme-to-total equals five.

Allotment name	Assessment sites	Attribute[1]		
		S	H	B
Big Joe/ West Douglas	1	1.00	1.00	2.00
Blue Mountain/ Yampa Bench	17	1.18	1.29	2.47
Docs Valley	2	1.00	1.00	2.50
Green River	6	1.17	1.67	3.17
Harpers Corner	4	1.00	1.75	2.50
Massey	1	1.00	1.00	3.00
Murray	2	1.50	1.50	2.50
Round Top	2	1.00	1.00	2.00
Wild Mountain	2	1.00	1.00	2.50
Zenobia	7	1.00	1.29	2.29

[1] Attributes: S = Soil/site stability; H = Hydrologic function; B = Biotic integrity

Table 6. Mean values for indicator ratings among grazing allotments. Qualitative ratings are converted to an ordinal scale, where none-to-slight equals one and extreme-to-total equals five.

	Indicator number																
Allotment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Big Joe/ West Douglas	1.0	1.0	3.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	4.0	1.0	3.0	3.0	4.0	1.0
Blue Mt. /Yampa Bench	1.1	1.5	1.2	1.3	1.1	1.0	1.1	1.1	1.0	1.7	1.1	3.6	1.2	1.8	1.9	3.6	1.2
Docs Valley	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	4.0	1.0	1.0	2.0	4.5	1.0
Green River	1.0	2.2	1.2	1.3	1.2	1.0	1.0	1.5	1.0	2.2	1.2	3.7	1.2	2.3	2.0	3.7	1.3
Harpers Corner	1.0	1.5	1.0	1.8	1.0	1.0	1.0	1.8	1.3	2.0	1.3	3.3	1.0	2.5	1.5	2.8	1.0
Massey	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	2.0	3.0	1.0	3.0	5.0	3.0	1.0
Murray	1.0	2.0	1.0	1.5	1.0	1.0	1.0	3.0	1.5	1.0	1.0	2.5	1.0	2.0	2.0	2.0	1.0
Round Top	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.0	1.0	3.0	1.0	3.0	1.0	1.5	1.0
Wild Mountain	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.5	1.0	1.0	1.5	3.5	1.5	3.0	2.0	3.5	1.0
Zenobia	1.0	1.6	1.3	1.0	1.0	1.0	1.0	1.6	1.0	1.9	1.3	3.4	1.0	1.7	3.4	3.0	1.1

3.2.1. Big Joe/ West Douglas

There was one location assessed within the Big Joe/ West Douglas allotment, with both Soil and Site Stability and Hydrologic Function rated as none-to-slight departures from reference condition, and Biotic Integrity rated as a slight-to-moderate departure from reference condition. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves, are displayed in Figure 3.

The main drivers of the departure from reference condition for Biotic Integrity were changes in functional/structural groups (12) and the presence of invasive plants (16). For F/S groups, rhizomatous grasses had shifted from subdominant to dominant, sprouting shrubs had shifted from dominant to subdominant, and 51–75% of expected species were missing. *Alyssum desertorum* (Stapf), an invasive species, had become prevalent on the site.

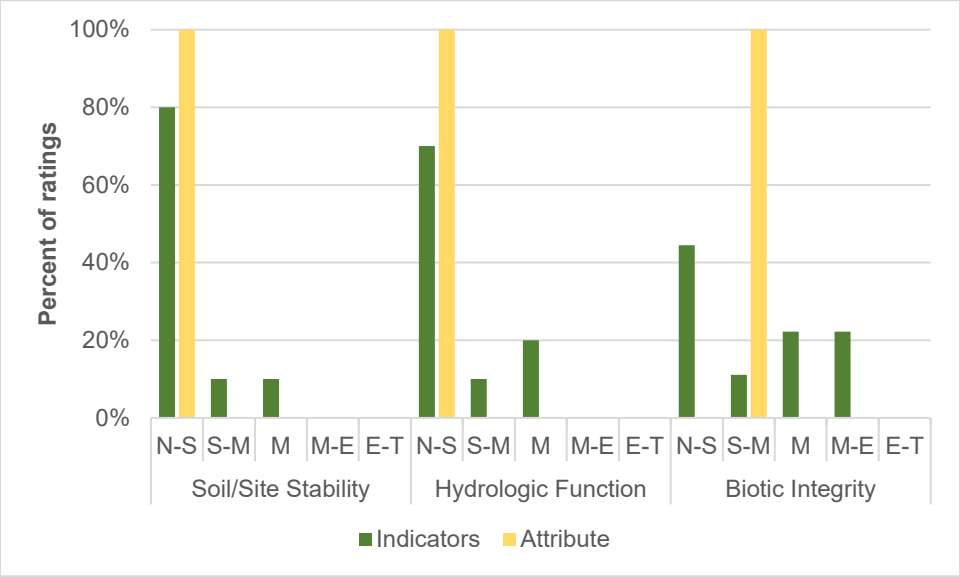

Figure 3. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Big Joe/ West Douglas grazing allotment. Final attribute ratings are also noted.

3.2.2. Blue Mountain/ Yampa Bench

At 13,196 ha, the Blue Mountain/ Yampa Bench allotment is the largest grazing allotment on the monument, more than three times larger than the next largest, Zenobia. Accordingly, it had the largest number of assessment locations at 17. An additional location was assessed using Describing Indicators of Rangeland Health.

Three locations were rated as a slight-to-moderate departure from reference condition for Soil and Site Stability, with none worse than that. These deviations were driven by evidence of erosion in the form of water flow patterns (2), terracettes (3), and some rills (1). Five sites were rated as a slight-to-moderate departure from reference condition for Hydrologic Function, with none worse than that. The same forms of erosional evidence were given as the causes of deviations as well as concerns about infiltration as a result of changes in the plant community (10). Figure 4 shows the distribution of indicator ratings that contributed to the attribute ratings as well as the distribution of final attribute ratings for this allotment.

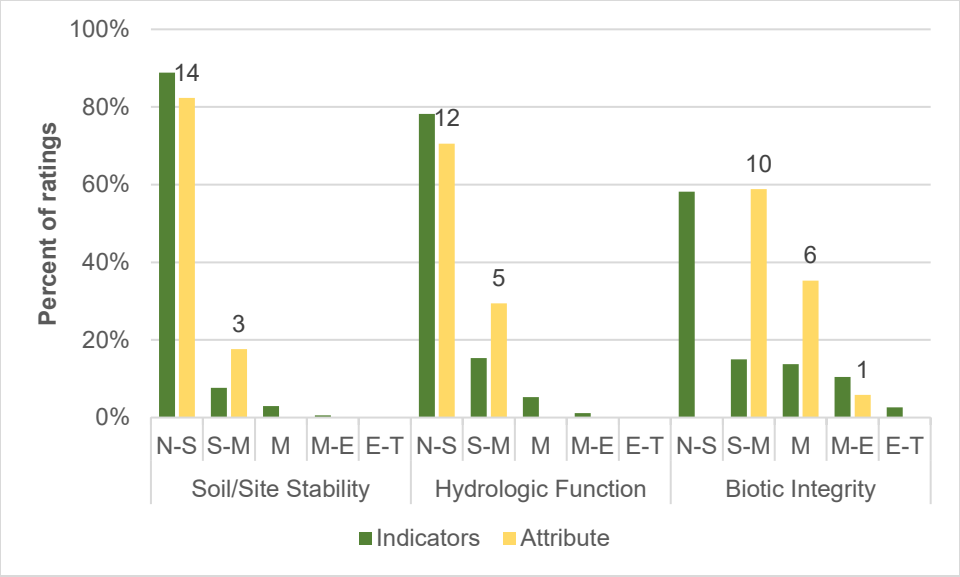

Figure 4. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Blue Mountain/ Yampa Bench grazing allotment. Final attribute ratings are also noted.

As shown in Figure 4, the IIRH results on the Blue Mountain/ Yampa Bench indicated significant concerns regarding Biotic Integrity. These departure ratings were most commonly driven by concerns about shifts in functional/structural group dominance (12), reduced plant diversity, lower than expected annual production (15), and invasive species (16). To provide more insight, the distribution of ratings for the indicators that contribute to the Biotic Integrity rating is displayed in Table 7.

Table 7. Distribution of indicator ratings for Biotic Integrity on the Blue Mountain/Yampa Bench grazing allotment.

	Departure from reference condition[1]				
Indicator and related attribute(s)	**N-S**	**S-M**	**M**	**M-E**	**E-T**
8. Soil surface resistance to erosion	15	2	0	0	0
9. Soil surface loss or degradation	17	0	0	0	0
11. Compaction layer	16	1	0	0	0
12. Functional / structural groups	0	1	7	7	2
13. Dead or dying plants or plant parts	15	1	0	1	0
14. Litter cover and depth	6	8	3	0	0
15. Annual production	7	5	4	1	0
16. Invasive plants	0	1	7	7	2
17. Vigor with an emphasis on reproductive capability of perennial plants	13	4	0	0	0

[1] N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total

The location assessed using Describing Indicators of Rangeland Health was within the riparian zone adjacent to the Yampa River, and could not be conclusively associated with an ESD. The dominant plant species were perennial ferns, horsetails (*Equisetum* spp.), willows (*Salix* spp.), Fremont cottonwood (*Populus fremontii* S. Watson), and boxelder (*Acer negundo* L.). The DIRH assessment noted little evidence of erosion or soil loss, good infiltration capacity, and just a few individuals of invasive species (*Cirsium arvense* (L.) Scop. and *Bromus tectorum*). Overall rangeland health was assessed as high.

3.2.3. Docs Valley

Two locations were assessed within the Docs Valley allotment, with both Soil and Site Stability and Hydrologic Function both rated as none-to-slight departures from reference condition. For Biotic Integrity one location was rated as a slight-to-moderate departure from reference, while the second was rated as a moderate departure from reference condition. The location rated as a slight-to-moderate departure listed invasive species (16), annual production (15), and slight shifts in functional/structural groups (12) as the main drivers. The location rated as a moderate departure listed the heavy presence of Utah juniper (*Juniperus osteosperma* Torr.), which was considered an invasive species on the site, as a key driver. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Docs Valley are displayed in Figure 5.

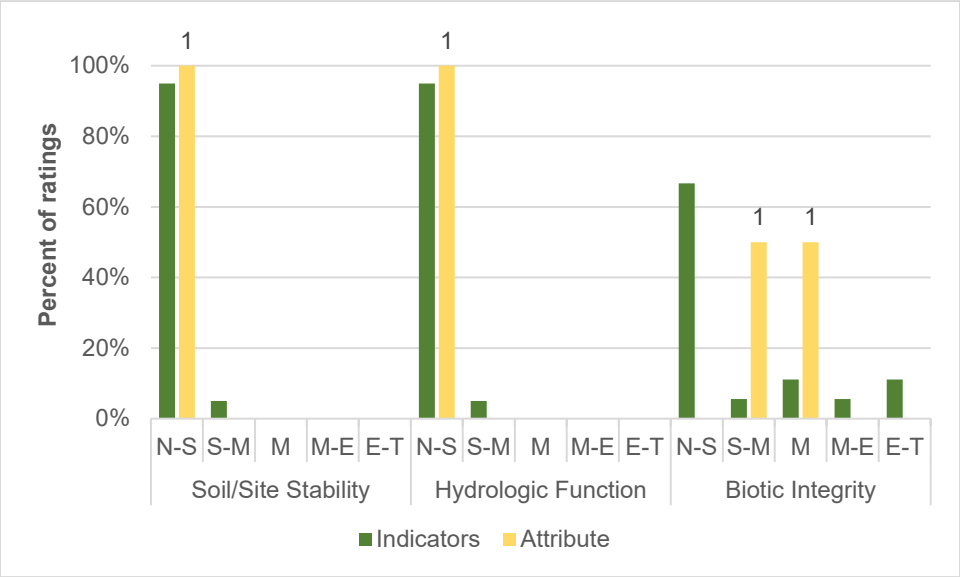

Figure 5. Docs Valley. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Docs Valley grazing allotment. Final attribute ratings are also noted.

3.2.4. Green River

A total of six locations were assessed within the Green River grazing allotment. For Soil and Site Stability, 5/6 locations were rated as none-to-slight departures from reference condition, with the sixth rated as a slight-to-moderate departure due to concerns about several indicators suggesting increased erosion. For Hydrologic Function, three locations were rated as none-to-slight, two as

slight-to-moderate, and one as moderate departure from reference condition. The key drivers for these were the overall weight of evidence (multiple indicators departed from reference) and reduced infiltration capacity (10).

For Biotic Integrity, ratings were across the board, from none-to-slight with one occurrence to moderate with three occurrences to moderate-to-extreme with one occurrence to extreme-to-total, also with one occurrence. The key driver for all of the departures was plant community shifts (12) driven by invasive species such as cheatgrass (16) and consequent losses in species diversity and ecological function. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Green River are displayed in Figure 6.

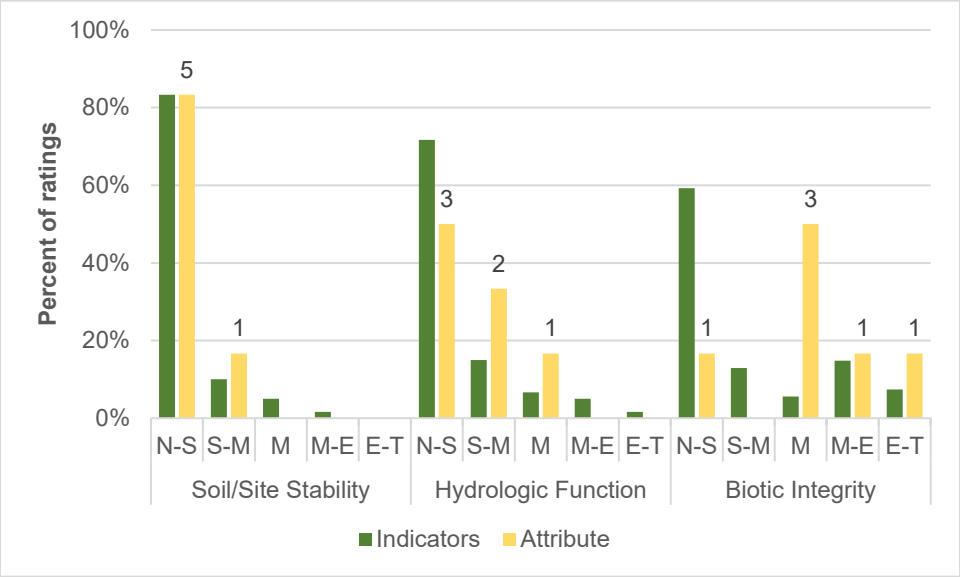

Figure 6. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Green River grazing allotment. Final attribute ratings are also noted.

3.2.5. Harpers Corner

Four locations were assessed on the Harpers Corner grazing allotment. For Soil and Site Stability, all four were rated as none-to-slight departures from reference condition. For Hydrologic Function, one was rated as a none-to-slight departure, and three were rated as slight-to-moderate departures from reference condition. The main drivers of the departures were a shift in infiltration capacity driven by plant community changes (10), litter cover changes (14), and the overall weight of evidence.

For Biotic Integrity, two sites were rated as slight-to-moderate departures and two were rated as moderate departures from reference condition. The key drivers were invasive species (16) becoming subdominant or dominant and other overall changes in functional/structural groups (12). The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Harpers Corner are displayed in Figure 7.

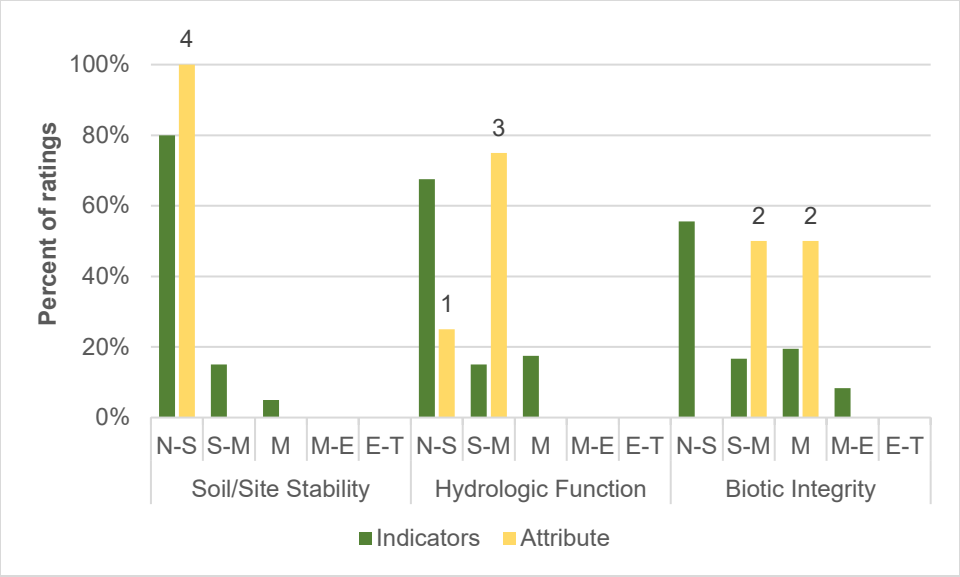

Figure 7. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Harpers Corner grazing allotment. Final attribute ratings are also noted.

3.2.6. Massey

There was one assessment location on the Massey grazing allotment. Both Soil and Site Stability and Hydrologic Function were rated as none-to-slight departures from reference condition. Biotic Integrity was rated as a moderate departure from reference condition based on the weight of evidence for relevant indicators, as reflected in Figure 8, with annual production (15) measured as much lower than expected and other departures from reference condition for functional/structural groups (12), litter cover (14) and invasive species (16).

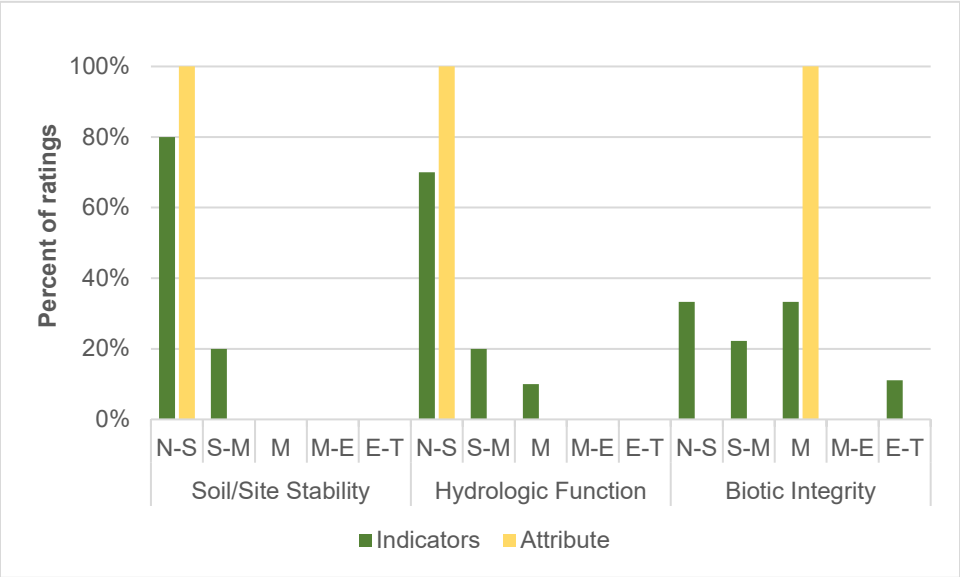

Figure 8. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Massey grazing allotment. Final attribute ratings are also noted.

3.2.7. Murray

Two location on the Murray grazing allotment were assessed. One location (site 10) was rated as none-to-slight for both Soil and Site Stability and Hydrologic Function, and slight-to-moderate departure from reference condition for Biotic Integrity. Deviations in litter cover (14), annual production (15), and invasive species (16), as well as an observed potential for Utah juniper to move into the site were noted as drivers of the rating for Biotic Integrity. The second site in the Murray allotment (site 11) was rated as having slight-to-moderate departures from reference condition for both Soil and Site Stability and Hydrologic Function, with water flow patterns (2) and soil surface resistance to erosion (8) listed as drivers.

Biotic Integrity was rated as a moderate departure from reference condition, with changes in functional/structural groups (12), particularly changes in dominance and losses in species diversity, noted as the key driver. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Murray are displayed in Figure 9.

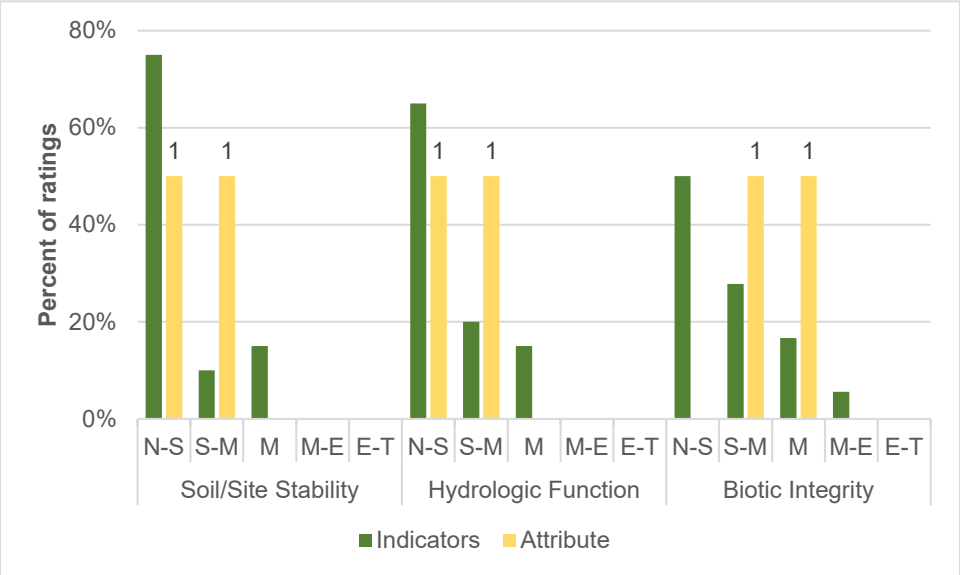

Figure 9. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Murray grazing allotment. Final attribute ratings are also noted.

3.2.8. Round Top

Two sites were assessed on the Round Top grazing allotment. For both Soil and Site Stability and Hydrologic Function, both sites were assessed as having a none-to-slight departure from reference condition. For Biotic Integrity, both sites were assessed as having slight-to-moderate departure from reference condition. The reason for these was relatively minor shifts in functional/structural groups (12). The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Round Top are displayed in Figure 10.

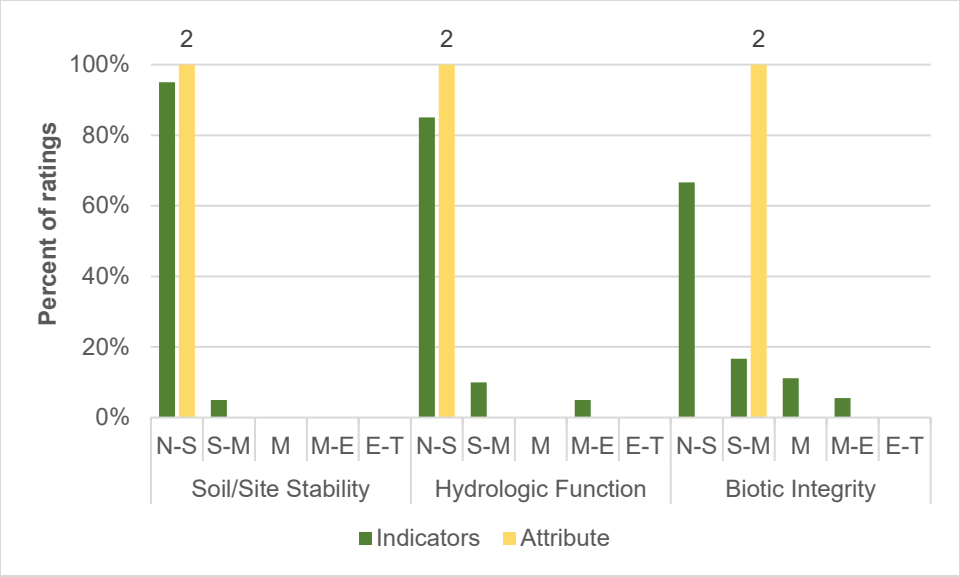

Figure 10. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Round Top grazing allotment. Final attribute ratings are also noted.

3.2.9. Wild Mountain

A total of three locations were assessed on the Wild Mountain grazing allotment, with one of these assessed using DIRH. For the two locations assessed with IIRH, Soil and Site Stability and Hydrologic Function were both assessed as having a none-to-slight departure from reference condition. Biotic Integrity was rated a slight-to-moderate departure from reference condition on one of the sites, and a moderate departure on the other. For both, shifts in functional/structural groups (12) and invasive species (16) were key drivers. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Round Top are displayed in Figure 11.

The site described using DIRH was identified as ESD R034BY338UT, which exists but does not contain an IIRH reference sheet. The DIRH found some evidence of potential for erosion and soil loss, and the presence of cheatgrass suggested there is potential that shifts in the plant communities are leading to a reduction in ecological health.

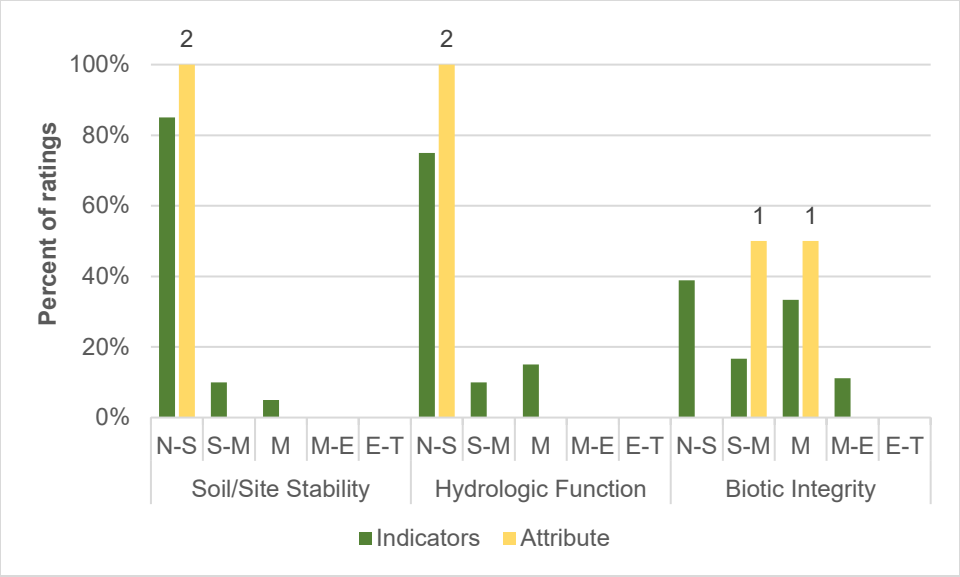

Figure 11. Distribution of indicator ratings that contributed to each of the attribute ratings for the one IIRH sample location on the Wild Mountain grazing allotment. Final attribute ratings are also noted.

3.2.10. Zenobia

A total of seven sites were assessed on the Zenobia grazing allotment. For Soil and Site Stability, all seven sites were rated as a none-to-slight departure from reference condition. For Hydrologic Function, five sites were rated as a none-to-slight departure while the remaining two were rated as a slight-to-moderate departure from reference condition. Compaction (11) and infiltration (10) were concerns on one of the sites, with the other noting general weight of evidence for the attribute.

Departure from reference condition for Biotic Integrity was rated as none-to-slight on one site, slight-to-moderate on four sites, moderate on one site, and moderate to extreme on one site. Key drivers were changes, some significant, in functional/structural group (12), the presence of invasive species (16) and much reduced annual production (15). In fact, annual production was found to be moderately to greatly lower than expected at all Zenobia sites. The distribution of indicator ratings that contributed to the attribute ratings as well as the attribute ratings themselves for Zenobia are displayed in Figure 12.

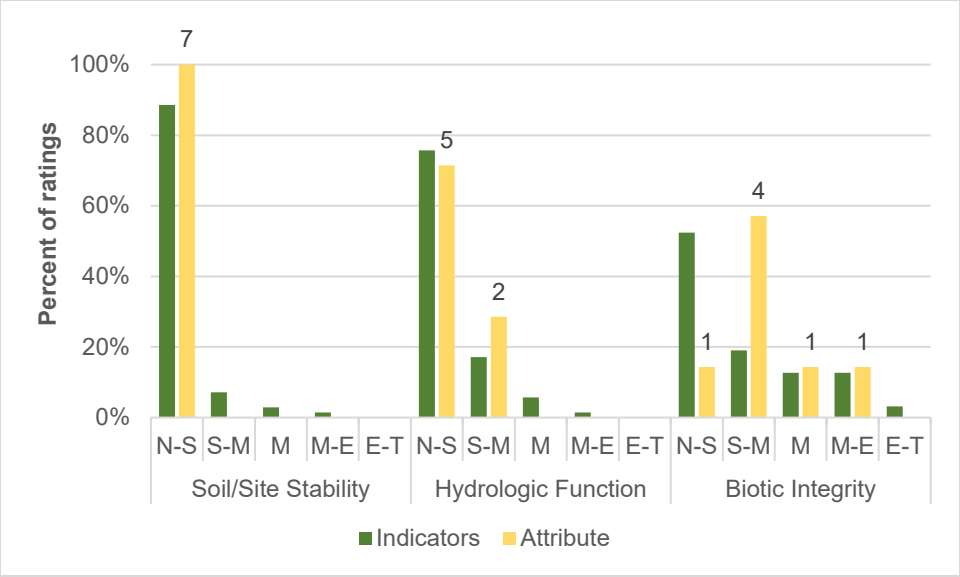

Figure 12. Distribution of indicator ratings that contributed to each of the attribute ratings for the one sample location on the Zenobia grazing allotment. Final attribute ratings are also noted.

3.3. By Ecological Site Description

A total of eighteen Ecological Site Descriptions were used among the 46 assessment sites. One of these lacked a reference sheet, and one site was not identified to an ESD, so seventeen ESDs were split among the 44 IIRH sites. These ESDs, and their total usage count, are listed in Table 8. Table 9 shows the count of these ESDs within each of the grazing allotments.

Patterns for the distribution of attribute ratings, as shown in Table 10, suggest that overall patterns across all sites were mirrored within the individual ESDs. This does not mean that the individual ESDs do not require individual consideration, but only that the IIRH results cannot suggest consistent differences among ESDs for indicator or attribute ratings. Depending on the objectives, future monitoring and management should take the ESD into account, as is detailed in the Discussion.

Table 8. List of Ecological Site Descriptions (ESD) used in the IIRH assessments, along with the number of IIRH points that corresponded to each ESD.

ESD Code	ESD Name	Count
R034BY006UT	Alkali Flat (Greasewood)	2
R034BY212UT	Semidesert Loam (Wyoming Big Sagebrush)	2
R034BY216UT	Semidesert Sandy Loam	1
R034BY225UT	Semidesert Shallow Loam (Wyoming Big Sagebrush)	1
R034BY233UT	Semidesert Shallow Loam (Utah Juniper-Pinyon)	2
R034BY239UT	Semidesert Shallow Sandy Loam (Utah Juniper/Two-Needle Pinyon)	3
R034BY259UT	Semidesert Very Steep Shallow Loam (Pinyon-Juniper)	1
R034BY334UT	Upland Stony Loam (Wyoming Big Sagebrush)	2
R034XY298CO	Rolling Loam	2

Table 8 (continued). List of Ecological Site Descriptions (ESD) used in the IIRH assessments, along with the number of IIRH points that corresponded to each ESD.

ESD Code	ESD Name	Count
R047XA430UT	Mountain Loam (Mountain Big Sagebrush)	14
R047XA461UT	Mountain Stony Loam	3
R047XB312UT	Upland Shallow Clay (Pinyon-Utah Juniper)	1
R047XC320UT	Upland Shallow Loam (Black Sagebrush)	1
R047XC326UT	Upland Shallow Loam (Pinyon-Juniper)	3
R047XC335UT	Upland Stony Loam (Pinyon – Utah Juniper)	3
R047XC446UT	Mountain Shallow Loam (Mountain Big Sagebrush)	2
R047XC460UT	Mountain Stony Loam (Shrub)	1

Table 9. Count of assessment sites by Ecological Site across the grazing allotments.

	Allotment[1]									
ESD Code	BJWD	BMYB	DV	GR	HC	Ma	Mu	RT	WM	Z
R034BY006UT	–	–	–	2	–	–	–	–	–	–
R034BY212UT	–	2	–	–	–	–	–	–	–	–
R034BY216UT	–	–	–	1	–	–	–	–	–	–
R034BY225UT	–	1	–	–	–	–	–	–	–	–
R034BY233UT	–	1	–	1	–	–	–	–	–	–
R034BY239UT	–	1	–	1	–	–	–	–	–	–
R034BY259UT	–	1	–	–	–	–	–	–	–	–
R034BY334UT	–	1	–	–	–	–	–	–	1	–
R034XY298CO	–	2	–	–	–	–	–	–	–	–
R047XA430UT	1	1	1	–	2	1	2	1	1	3
R047XA461UT	–	1	–	–	–	–	–	1	–	1
R047XB312UT	–	1	–	–	–	–	–	–	–	–
R047XC320UT	–	1	–	–	–	–	–	–	–	–
R047XC326UT	–	2	–	–	–	–	–	–	–	1
R047XC335UT	–	2	–	–	–	–	–	–	–	1
R047XC446UT	–	–	1	–	–	–	–	–	–	–
R047XC460UT	–	–	–	–	–	–	–	–	–	1

[1] Allotments: BJWD = Big Joe/ West Douglas; BMYB = Blue Mountain/ Yampa Bench; DV = Docs Valley; GR = Green River; HC = Harpers Corner; Ma = Massey; Mu = Murray; RT = Round Top; WM = Wild Mountain; Z = Zenobia

Table 10. Distribution of IIRH attribute ratings across Ecological Sites. Cells that have attribute ratings (numbers) are also shown in gray.

		Soil and Site Stability[1]					Hydrologic Function[1]					Biotic Integrity[1]				
ESD Code	Ct.	N-S	S-M	M	M-E	E-T	N-S	S-M	M	M-E	E-T	N-S	S-M	M	M-E	E-T
R034BY006UT	2	1	1	–	–	–	–	2	–	–	–	–	–	1	1	–
R034BY212UT	2	2	–	–	–	–	1	1	–	–	–	–	2	–	–	–
R034BY216UT	1	1	–	–	–	–	–	–	1	–	–	–	–	–	–	1
R034BY225UT	1	1	–	–	–	–	1	–	–	–	–	–	–	1	–	–
R034BY233UT	2	2	–	–	–	–	2	–	–	–	–	–	–	2	–	–
R034BY239UT	3	2	1	–	–	–	2	1	–	–	–	1	–	2	–	–
R034BY259UT	1	1	–	–	–	–	1	–	–	–	–	–	1	–	–	–
R034BY334UT	2	2	–	–	–	–	2	–	–	–	–	–	2	–	–	–
R034XY298CO	2	2	–	–	–	–	2	–	–	–	–	–	1	1	–	–
R047XA430UT	14	13	1	–	–	–	10	4	–	–	–	–	8	5	1	–
R047XA461UT	3	3	–	–	–	–	3	–	–	–	–	–	3	–	–	–
R047XB312UT	1	–	1	–	–	–	–	1	–	–	–	–	1	–	–	–
R047XC320UT	1	1	–	–	–	–	–	1	–	–	–	–	–	–	1	–
R047XC326UT	3	2	1	–	–	–	1	2	–	–	–	–	1	2	–	–
R047XC335UT	3	3	–	–	–	–	3	–	–	–	–	–	3	–	–	–
R047XC446UT	2	2	–	–	–	–	1	1	–	–	–	–	–	2	–	–
R047XC460UT	1	1	–	–	–	–	1	–	–	–	–	1	–	–	–	–

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate, M-E = Moderate to extreme; E-T = Extreme to total

3.4. Compromised Sites and Key Drivers

In this section we will review, on an allotment by allotment basis, all assessment sites that may require further consideration, integrating ESD-relevant information. For this, we will consider "ecologically compromised" all sites where at least one of the three attributes was rated as a moderate or greater departure from reference condition. Note that this term is not used to suggest anything other than its IIRH rating. Figure 13 shows all such sites, and Table 11 summarizes their location by allotment. Note that the sole site on the Big Joe/ West Douglas and the two sites assessed on the Round Top allotment did not qualify as compromised.

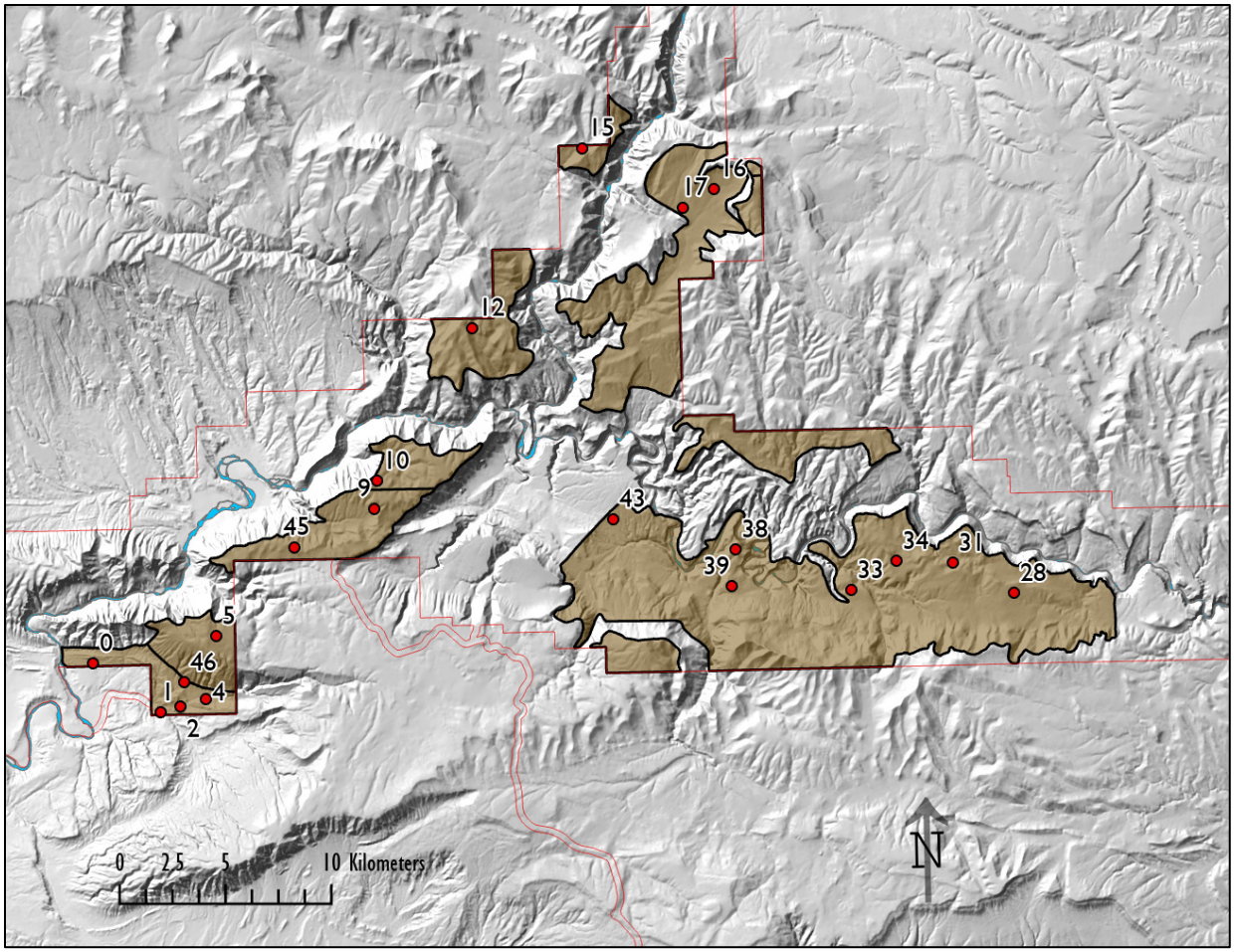

Figure 13. Assessment sites where at least one of the three IIRH attributes was rated as a moderate or greater departure from reference condition.

Table 11. Distribution of sites with a moderate or greater departure from reference condition for at least one of the IIRH attributes.

Allotment name	Hectares	Assessment sites	Compromised sites	Percent compromised
Big Joe/ West Douglas	1,645	1	0	0%
Blue Mountain/ Yampa Bench	13,163	17	7	41%
Docs Valley	1,118	2	1	50%
Green River	1,049	6	5	83%
Harper's Corner	1,717	4	2	50%
Massey	392	1	1	100%
Murray	827	2	1	50%
Round Top	569	2	0	0%
Wild Mountain	1,675	2	1	50%
Zenobia	4,197	7	2	29%

3.4.1. Blue Mountain/ Yampa Bench

All seven ecologically compromised sites on the Blue Mountain/ Yampa Bench allotment were classified as such because of departures from reference condition for Biotic Integrity. Table 12 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for these sites, with six different ESDs accounted for among those sites.

Table 12. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference condition for sites in the Blue Mountain/Yampa Bench grazing allotment.

		Attribute and indicators									
Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
28	R047XC320UT	M-E	N-S	N-S	N-S	E-T	M-E	M	M	E-T	N-S
31	R047XC326UT	M	N-S	N-S	N-S	M	S-M	N-S	M	M	N-S
33	R047XC326UT	M	N-S	N-S	N-S	E-T	N-S	M	M	E-T	N-S
34	R034XY298CO	M	N-S	N-S	N-S	M-E	N-S	S-M	S-M	M-E	N-S
38	R034BY239UT	M	N-S	N-S	N-S	M-E	N-S	S-M	S-M	M-E	S-M
39	R034BY233UT	M	N-S	N-S	N-S	M-E	N-S	S-M	N-S	M	S-M
43	R034BY225UT	M	N-S	N-S	N-S	M	N-S	S-M	N-S	M-E	S-M

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (also shown in shaded gray); M-E = Moderate to extreme (also shown in shaded gray); E-T = Extreme to total (also shown in shaded gray)

Site 28 is an *Upland Shallow Loam (Black Sagebrush)* Ecological Site, toward the eastern end of the allotment on the broad, mostly flat bench at an elevation of 2,030 m. The reference plant community on this site is dominated by perennial bunchgrasses and non-sprouting shrubs with low annual production in the range of 136 to 272 kg per acre, with an average of approximately 192 kg. The IIRH assessment found that this community is now dominated by cheatgrass and alyssum, both invasive species. Perennial grasses are now a minor component and the non-sprouting shrubs are a trace component, with 95% of the black sagebrush (*Artemisia nova* A. Nelson) standing dead. Annual production in this good growing year was estimated at 118 kg, well below expected.

Site 31 is an *Upland Shallow Loam (Pinyon-Juniper)* Ecological Site, on a treed slope (35% slope) within a series of slopes and benches that lead to the Yampa River, but still well above the river at 1,914 m. The reference plant community is a pinyon-juniper woodland with an understory of shrubs and perennial bunchgrasses with expected annual production between 227 and 499 kg per acre, with an average of approximately 340 kg. The IIRH assessment found that, though this site is overall mostly healthy, shifts in functional/structural groups and annual production were significant enough to warrant a moderate departure rating for Biotic Integrity. While the pinyon-juniper component is thriving, the expected dominant sprouting shrubs are now subdominant and invasive species have become minor to subdominant components of the system. Lastly, annual production was measured at 230 kg, below expectation in a good growing year.

Site 33 is an *Upland Shallow Loam (Pinyon-Juniper)* Ecological Site, toward the top of a rolling hill in the divided landscape above the Yampa River, at an elevation of 1,844 m and a 6% slope. The reference plant community is the same as for site 31. The IIRH assessment found that the expected dominant shrub broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britton & Rusby) is now a minor component of the site and that invasive alyssum and cheatgrass are now dominant and subdominant, respectively, in the understory. Note that, though it is listed as a dominant in the IIRH reference sheet for this ecological site, we think this may be an error. Broom snakeweed is a common component of early seral communities in many rangeland ecosystems, so is not likely to be a dominant species in a reference state for this ecological site or similar ones. Annual production was measured at 181 kg, well below expected in a strong growing year.

Site 34 is a *Rolling Loam* Ecological Site*,* in a shrub dominated flat within the divided bench landscape above the Yampa River, at an elevation of 1,911 m. Note that this ESD is described by the old rangeland site description (dated August 1975) but that an IIRH reference sheet dated from January 2005 has been developed for the site. NPS data identified the site as Rolling Loam. The IIRH reference sheet indicates that this site should be dominated by cool season bunchgrasses, with cool season rhizomatous grasses, shrubs, and forbs as subdominants. Annual production should range from 227 to 454 kg per acre, with an average of 363 kg. The IIRH assessment found that, instead of grasses, shrubs are dominant on the site, and that 1/3 of expected species are missing. Additionally, cheatgrass and alyssum are common throughout the site, and production was measured at 299 kg, lower than expected for this site.

Site 38 is a *Semidesert Shallow Sandy Loam (Utah Juniper/Two-Needle Pinyon)* Ecological Site, on a flat ridge, 500 m from the Yampa River but separated from it by a steep cliff, at an elevation of 1,872 m and a slope of 10%. The reference plant community consists of a pinyon-juniper woodland with an understory of drought-deciduous shrubs such as alderleaf mountain mahogany (*Cercocarpus montanus* Raf.) and black sagebrush. Subdominants understory plants include bunchgrasses and non-drought-deciduous shrubs. Annual production is expected to be 113 kg to 204 kg per acre. While the tree community is intact, drought-deciduous shrubs are missing and grasses and other shrubs are minor. Cheatgrass has become common throughout and contributed to an increase in litter. Annual production was estimated at 125 kg, below expectation, and the juniper on site were without fleshy cones (often mistakenly referred to as “berries”), unlike most of the junipers in the allotment.

Site 39 is a *Semidesert Shallow Loam (Utah Juniper-Pinyon)* Ecological Site, on a broad, lightly sloped bench above the Yampa River, at an elevation of 1,737 m and a slope of 13%. The reference plant community is a pinyon-juniper woodland with an understory of sprouting shrubs and perennial bunchgrasses. Annual production is expected to be between 68 kg and 181 kg per acre, with an average of approximately 125 kg. While in many ways a healthy site, shrubs were almost entirely missing from the site, with invasive species scattered throughout and juniper lacking in reproductive vigor.

Site 43 is a *Semidesert Shallow Loam (Wyoming Big Sagebrush)* Ecological Site, on a broad, gently rolling slope with many small drainages at the western edge of the allotment, at an elevation of 1,750 m and a slope of 13%. The reference plant community is dominated by non-sprouting shrubs (namely, big sagebrush, *Artemisia tridentata* Nutt.), perennial bunchgrasses, and perennial forbs. Annual production ranges from 113 kg to 227 kg per acre, with an average of 170 kg. The IIRH assessment found that rabbitbrush (*Chrysothamnus* sp.) is dominant while the sagebrush is subdominant. Additionally, cheatgrass is present in "islands of dominance", and several young juniper seedlings are present, indicating the potential for further plant community shifts. The bunchgrasses were noted to be subdued in their vigor, and the sagebrush less vigorous than expected.

3.4.2. Docs Valley

The one compromised site on the Docs Valley grazing allotment was classified as such due to a moderate departure from reference condition for Biotic Integrity, though there were minor concerns about water flow patterns and other erosional evidence. Table 13 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Site 5 is a *Mountain Shallow Loam (Mountain Big Sagebrush)* Ecological Site, on a broad flat hilltop surrounded by slopes that lead to the Green River, at an elevation of 2,332 m and a slope of 0–5%. The reference plant community is dominated by a non-sprouting shrub (big sagebrush) with an understory of other shrubs, perennial grasses, and forbs. At this higher elevation with greater precipitation, annual production ranges from 408 kg to 771 kg per acre, with an average of 612 kg per year. As shown in Table 12, the main concerns with this site regarded shifts in the plant community, namely that both pinyon and juniper are dominant, and that cheatgrass and alyssum are scattered. However, given that the trees were well-established, the crew raised concerns that this ESD, though the most appropriate based on soil, climate, and topography, seemed inaccurate in its evaluation of the reference plant community. Additionally, given the broad diversity of native perennial grasses and forbs, and good ratings for other Biotic Integrity indicators, the crew was conflicted about the final rating. However, it is also not responsible to conclude that the rating of juniper as invasive in the reference sheet was incorrect. We encourage further consideration of ecological dynamics in this location.

Table 13. Distribution of indicator ratings that contributed to moderate or worse Biotic Integrity ratings for sites in the Docs Valley grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. Res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
5	R047XC446UT	M	N-S	N-S	N-S	E-T	N-S	N-S	N-S	E-T	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

3.4.3. Green River

Five of the six assessment sites on this allotment qualified as ecologically compromised. One of the sites was rated a moderate or greater departure from reference condition for both Hydrologic Function and Biotic Integrity, while the rest were classified as such because of a poor Biotic Integrity rating alone. Tables 14 and 15 show the indicator ratings that contributed to the respective attribute ratings for this allotment.

Table 14. Distribution of indicator ratings that contributed to Hydrologic Function ratings of moderate or greater departure from reference for sites in the Green River grazing allotment.

Site ID	ESD Code	Hydrologic Function[1]	1. Rills[1]	2. Water flow patterns[1]	3. Peds. and/or terr.[1]	4. Bare grnd.[1]	5. Gullies[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	10. Infiltration[1]	11. Compaction[1]	14. Litter cover[1]
0	R034BY216UT	M	N-S	N-S	N-S	S-M	N-S	M-E	N-S	E-T	N-S	M-E

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Table 15. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Green River grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
0	R034BY216UT	E-T	M-E	N-S	N-S	E-T	N-S	M-E	M	E-T	M
1	R034BY239UT	M	N-S	N-S	N-S	M	N-S	S-M	N-S	M-E	N-S
2	R034BY006UT	M-E	N-S	N-S	S-M	M-E	N-S	M-E	N-S	E-T	N-S
4	R034BY006UT	M	N-S	N-S	N-S	M-E	S-M	S-M	N-S	E-T	N-S
46	R034BY233UT	M	N-S	N-S	N-S	M-E	N-S	N-S	M-E	S-M	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 0 is a *Semidesert Sandy Loam* Ecological Site and is on a broad plain that slopes down toward the Green River about 1.5 km away. It is at an elevation of 1,537 m, making it the lowest elevation site among the assessment sites, about 75 m above the river. The reference plant community for the site is dominated by sprouting shrubs such as four-wing saltbush (*Atriplex canescens* (Pursh) Nutt.) and winterfat (*Krascheninnikovia lanata* (Pursh) A. Meeuse & Smit), as well as perennial bunchgrasses and forbs. Non-sprouting shrubs such as big sagebrush and warm season grasses may be subdominant. Healthy stands of grasses should prevent issues with erosion and allow for good infiltration. Annual production ranges from 181 kg to 363 kg per acre, with an average of 272 kg.

The IIRH assessment found significant reductions in soil surface resistance to erosion and litter cover as well as significant alterations in the plant community relative to snow and rainfall capture, leading to a reduction in Hydrologic Function. Biotically, the plant community is dominated by invasive species cheatgrass and halogeton (*Halogeton glomeratus* (M. Bieb.) C.A. Mey.). Several functional/structural groups are absent and species diversity is greatly reduced. Annual production was estimated at 147 kg, well below expectation and reproductive vigor was reduced.

Site 1 is a *Semidesert Shallow Sandy Loam (Utah Juniper/Two-Needle Pinyon)* Ecological Site, amid rolling hills with extensive rock outcrops at an elevation of 1,592 m and a slope of 30%. The reference plant community consists of a pinyon-juniper woodland with an understory of drought-deciduous shrubs such as alderleaf mountain mahogany (*Cercocarpus montanus* Raf.) and black sagebrush. Subdominant understory plants include bunchgrasses and non-drought-deciduous shrubs. Annual production is expected to be 113 kg to 204 kg per acre. The IIRH assessment found that, although the tree community is intact, the expected dominant shrubs are subdominant and bunchgrasses minor to trace on the site. Cheatgrass is common throughout the site and alyssum is scattered throughout.

Site 2 is an *Alkali Flat (Greasewood)* Ecological Site, on a shrub-dominated bench above Cub Creek, which is about 90 m away, with significant evidence of regular use by cattle. The elevation is 1,582 m and the site is flat. The reference plant community is dominated by sprouting shrubs such as black greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) and four-wing saltbush as well as perennial grasses and forbs. Expected annual production is 227 kg to 454 kg per acre, with an average of 306 kg. The IIRH assessment found that the expected perennial grasses and forbs are largely absent with cheatgrass instead dominant in the understory, including litter cover of 92%. Shrub cover is as expected, but the loss of perennial grasses and forbs led to significant concerns about the resilience of the site.

Site 4 is an *Alkali Flat (Greasewood)* Ecological Site, on a shrub-dominated bench close to steep hills and rock outcrops, 120 m from Cub Creek, at an elevation of 1,615 m and a slope of 0–5%. It is approximately 600 m away from the historic site known as Josie's Cabin, in an area of evident heavy cattle and human traffic. The reference plant community is the same as for site 2. The IIRH assessment found that big sagebrush has now become dominant, and that the expected dominant shrubs as well as perennial grasses and forbs, totaling 50–75% of expected species, are rare to absent on the site. The understory is dominated by cheatgrass. Though the shrub dynamics are not of great concern, the absence of many species and the dominance of cheatgrass were cause for the rating.

Site 46 is a *Semidesert Shallow Loam (Utah Juniper-Pinyon)* Ecological Site, on the lower part of slope with many drainages, at an elevation of 1,671 m. The reference plant community is a pinyon-juniper woodland with an understory of sprouting shrubs and perennial bunchgrasses. Annual production is expected to be between 68 kg and 181 kg per acre, with an average of approximately 125 kg. The IIRH assessment found that, while the tree community is intact, the expected understory dominants are now minor components, with very little overall understory diversity.

3.4.4. Harpers Corner

Two of the four assessment sites on the Harpers Corner allotment qualify as ecologically compromised, both for moderate departures from reference condition for Biotic Integrity. Table 16 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Table 16. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Harpers Corner grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
9	R047XA430UT	M	S-M	S-M	N-S	M	N-S	N-S	M	M-E	N-S
45	R047XC446UT	M	N-S	N-S	N-S	M-E	N-S	M	N-S	M-E	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 9 is a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, amid rolling, largely shrub-covered hills at an elevation of 2,350 m at a 12% slope. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush (*Purshia tridentata* (Pursh) DC.). Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment found that the perennial bunchgrasses are subdominant, with several species missing, big sagebrush is largely absent from the site, and that invasive species cheatgrass and alyssum are common across the site. Lastly, annual production was estimated at 408 kg, less than half of what would be expected in a good growing season such as this.

Site 45 is a *Mountain Shallow Loam (Mountain Big Sagebrush)* Ecological Site, topographically very similar to site 9, within rolling shrub-covered hills at an elevation of 2,345 m. The reference plant community is dominated by a non-sprouting shrub (big sagebrush) with an understory of sprouting shrubs (such as bitterbrush), perennial grasses, and forbs. Expected annual production ranges from 408 kg to 771 kg per acre, with an average of 612 kg per year. The IIRH assessment found that the sprouting shrubs are minor to trace on the site and alyssum, an invasive, is common throughout. These issues raised enough concern to warrant a moderate departure from reference condition rating for Biotic Integrity.

3.4.5. Massey

The one assessment site on the Massey allotment qualified as ecologically compromised due to being rated a moderate departure from reference condition for Biotic Integrity. Both Soil and Site Stability and Hydrologic Function were rated as a none-to-slight departure from reference condition. Table 17 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Table 17. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Massey grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
15	R047XA430UT	M	S-M	N-S	S-M	M	N-S	M	E-T	M	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 15 is a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, in an open sloped area adjacent to forested hills, much of which have numerous standing burned tree indicating recent fire. The elevation is 2,063 m and the slope ranges from 10–25%. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush. Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment found that the expected dominant shrubs are subdominant, that cheatgrass is scattered throughout, and that other grasses are dominant and vigorously growing. Annual production was measured at 159 kg, well below expected. All told, evidence at the sight suggests a community transition resulting from fire.

3.4.6. Murray

One of the two assessment sites on the Murray allotment qualified as ecologically compromised, due to a moderate departure from reference condition for Biotic Integrity. The other two attributes at the site were rated as slight-to-moderate departures from reference condition. Table 18 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Table 18. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Murray grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. production[1]	16. Invasives[1]	17. Vigor[1]
10	R047XA430UT	M	M	S-M	N-S	M-E	N-S	S-M	N-S	S-M	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 10 is a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, amid rolling shrub-dominated hills at an elevation of 2,430 m at a slope of 16%. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush. Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment found that perennial forbs have become dominant, perennial bunchgrasses are reduced, and soil surface resistance to erosion is significantly lower than expected. Several expected grass species are also missing.

3.4.7. Wild Mountain

One of the two assessment sites on the Wild Mountain allotment qualified as ecologically compromised, due to a moderate departure from reference condition for Biotic Integrity. The other two attributes were rated as a none-to-slight departure from reference condition. Table 19 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Table 19. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Wild Mountain grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
12	R047XA430UT	M	M	N-S	S-M	M-E	N-S	M	M	M-E	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 12 is a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, in moderately broken shrub-dominated terrain with some rock outcroppings, at an elevation of 2,356 m at a slope of 0–10%. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush. Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment found that invasive cheatgrass and alyssum are common throughout the site, and dominant in places, while annual production was measured at 499 kg, much lower than expected. Despite good diversity, these factors, as well as concerns about soil surface resistance to erosion created concerns about plant community resilience.

3.4.8. Zenobia

Two of the seven sites on the Zenobia grazing allotment qualified as ecologically compromised, both due to departures from reference condition for Biotic Integrity, one moderate, one moderate-to-extreme. Table 20 shows the indicators, with their ratings, that contribute to the Biotic Integrity rating for this site.

Table 20. Distribution of indicator ratings that contributed to Biotic Integrity ratings of moderate or greater departure from reference for sites in the Zenobia grazing allotment.

Site ID	ESD Code	Biotic Integrity[1]	8. Soil surf. res. Erosion[1]	9. Soil loss or degr.[1]	11. Compaction[1]	12. F/S groups[1]	13. Dead/dying plant[1]	14. Litter cover[1]	15. Ann. Production[1]	16. Invasives[1]	17. Vigor[1]
16	R047XA430UT	M	N-S	N-S	N-S	M-E	N-S	S-M	S-M	M-E	N-S
17	R047XA430UT	M-E	N-S	N-S	M	E-T	N-S	S-M	E-T	M-E	N-S

[1] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate (shown shaded gray); M-E = Moderate to extreme (shown shaded gray); E-T = Extreme to total (shown shaded gray)

Site 16 is within a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, in a broad shrub-dominated valley surrounded by hills, at an elevation of 2,192 m and a slope of 0–5%. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush. Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment for the site found that bitterbrush is a minor component and perennial grasses subdominant, with cheatgrass dominant. Species diversity was reduced 26–50%.

Site 17 is a *Mountain Loam (Mountain Big Sagebrush)* Ecological Site, southwest of site 16 in the same broad shrub-dominated valley surrounded by hills, at an elevation of 2,141 m and a slope of 0–2%. The reference plant community consists of dominant perennial bunchgrasses and shrubs such as big sagebrush and bitterbrush. Subdominants are rhizomatous grasses and perennial forbs. Expected annual production ranges from 544 kg to 998 kg per acre, with an average of approximately 800 kg. The IIRH assessment found big sagebrush to be largely absent from the site and rabbitbrush dominant, with cheatgrass and alyssum scattered and overall species diversity reduced by >75%. Compaction is widespread on the site. Annual production was estimated at 141 kg, significantly lower than expected.

3.5. Proximity to Water Sources

As a proxy for livestock usage, we tested the influence of distance from water on the attribute ratings. This included distance from all potentially usable natural water sources and all developed water sources (e.g. stock pond, well, or tank). If livestock use is negatively influencing rangeland health, we would hypothesize that distance from water would be inversely related to attribute ratings (Bailey and Provenza 2008). Our analysis found no relationship between distance from water and any IIRH attribute. Figure 14 shows the distribution of watering points relative to assessment locations, and Table 21 summarizes attribute ratings as a function of distance from water.

However, note that all but two assessment sites were within 2 km of a potential watering location, developed or undeveloped. This means that, with respect to assessment locations, we can expect that cattle are relatively evenly distributed, at least regarding distance from water. Further analysis that incorporates a more complex understanding of livestock distribution patterns, such as geographic or agent-based modeling, may provide more insight. However, without off-allotment "control" sites, even this approach may be inconclusive. The best approach for investigating relationships between livestock grazing management and indicators of rangeland health is to develop purposeful monitoring plans that link management decisions to well-crafted ecological and management objectives. See the Discussion for further thoughts on this.

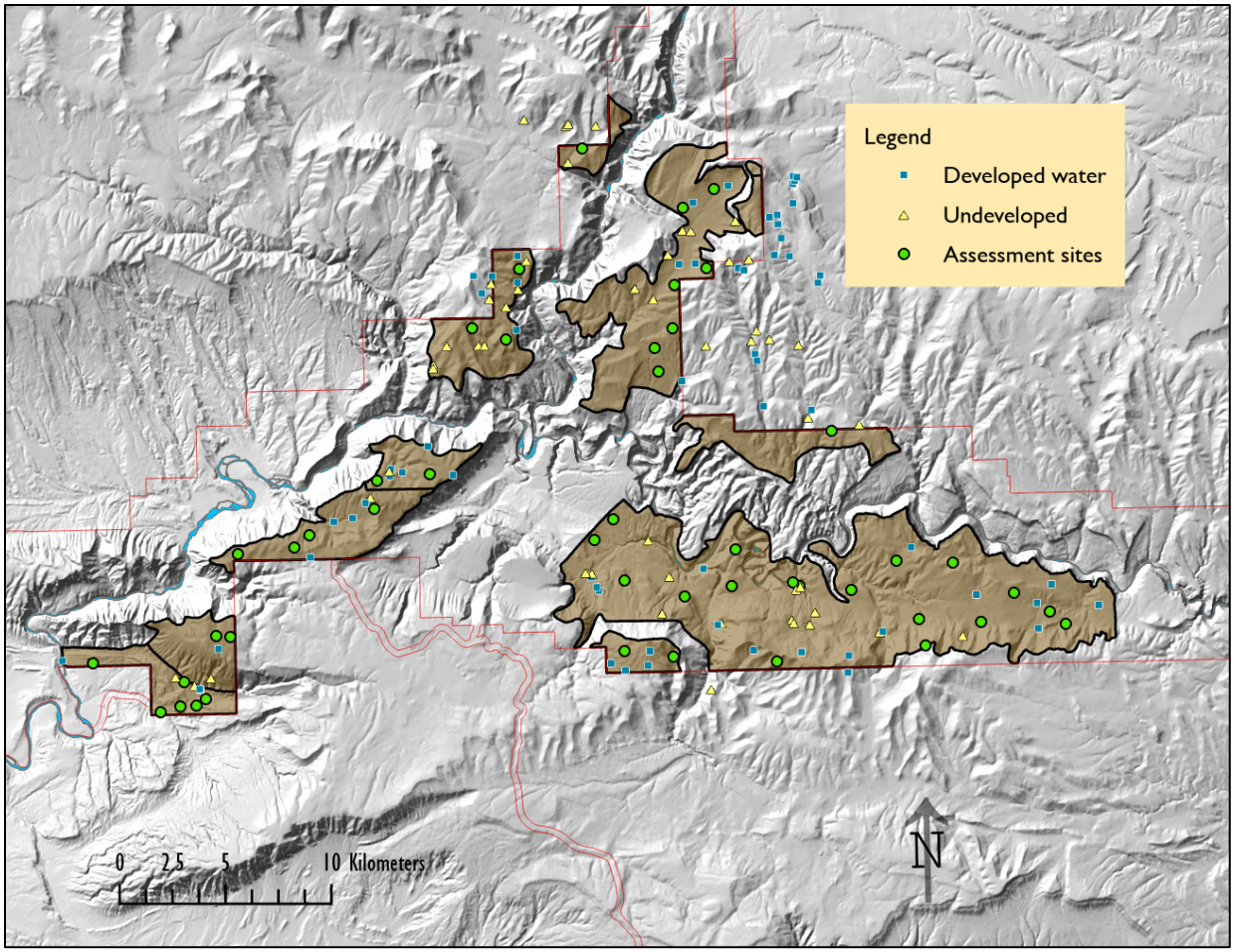

Figure 14. Developed and undeveloped water locations in Dinosaur National Monument, with assessment locations. Note that off-monument water locations that are believed to be accessible while cattle are grazing on the monument allotments are included.

Table 21. Mean attribute ratings as a function of distance from any usable water source for livestock. Qualitative ratings are converted to an ordinal scale, where none-to-slight equals one and extreme-to-total equals five.

Distance to water	Count	Soil and Site Stability	Hydrologic Function	Biotic Integrity
< 500 m	3	1.00	1.33	2.67
500 m ≤ 1000 m	15	1.13	1.27	2.53
1000 m ≤ 1500 m	14	1.07	1.43	2.50
1500 m ≤ 2000 m	10	1.20	1.30	2.60
≥ 2000 m	2	1.00	1.50	2.00

4. Summary and Recommendations

4.1. Summary

Overall, rangeland health is good on grazing allotments across the monument. While Soil and Site Stability and Hydrologic Function are consistently good to excellent, Biotic Integrity is moderately to severely compromised in many places. The main driver of this is alterations in plant community composition, including shifts in dominant functional/structural groups, reduced plant species diversity, and high populations of invasive species such as cheatgrass (*Bromus tectorum*) and alyssum (*Alyssum desertorum*). In many cases, shrub and tree overstories are intact while the grasses and forbs in the understory are diminished or missing. These shifts can lead to reduced system resilience and productive capacity, especially in the challenging and highly variable climate of Dinosaur National Monument.

It is important to note, however, that these findings should be interpreted within the context of individual assessment sites and integrate a firm understanding of the specifics of the ecological site. Ecological Site Descriptions are written to be valid across relatively wide regions but are often based on a handful of sampled reference locations. Thus, for example, the presence of a species at a site where the ESD indicates it should not be is not always indicative of compromised Biotic Integrity but may instead be simply a bioregional quirk. These quirks are ultimately rare among the assessed sites, and the qualitative nature of IIRH allows them to be accounted for in final attribute ratings, but care should nonetheless be taken in drawing management conclusions.

Also, we did not compare the grazing allotment sites to sites on the monument that are never grazed by livestock, as none were assessed. This makes it difficult or impossible to determine the extent to which livestock grazing has contributed to the finding of consistent departures from reference condition for Biotic Integrity or whether this finding is instead a result of broader ecological trends that are reflected across the monument. This approach is justified and consistent with the intended use of IIRH because the IIRH protocol is not intended to be used to "identify the cause(s) of resource problems" or to "independently make grazing and other management changes" (Pellant et al. 2018, p. 14). This is not to say that changes in livestock grazing management cannot contribute to improved conditions in areas identified as ecologically compromised. Indeed, altered livestock grazing management can be used as a tool to improve ecological health whether it initially caused the problem or not. IIRH is designed to assist managers in the identification of management opportunities and potential resource problems and to aid in the development of monitoring efforts to support management (Pellant et al. 2018).

In this discussion we will synthesize the IIRH findings for groups of sites with similar outcomes, offering suggestions for where and how to focus management and monitoring efforts. For this, we will offer both general recommendations across the group as well as specific suggestions for sites with unique situations or where the greatest departures from reference conditions were evident. It is important to reiterate that NPS chose the IIRH assessment sites and the authors of this report were not fully informed of the selection criteria. These criteria may dictate if and how the assessment applies to a broader area, so the discussion to follow is pertinent only to the sites assessed.

Extrapolation to larger areas (if appropriate) can only be carried out by the individuals who know the criteria used to select the sites.

In general, when managers are considering objectives to change species composition, whether suggested by IIRH assessments or for other reasons, there are common considerations that deserve attention at each location. Managers should specify which groups of plant species they would like to see increase in abundance; which groups they would like to see decline in abundance; and which groups they would like to see maintain roughly the same abundance. For each group of plants at each location, managers should be able to specify the reasoning for desired changes (or lack thereof) and relate those reasons to broader goals. Desired changes in species composition should be specified and consistent with the ecological dynamics described in the ecological site description for each site. Although IIRH can provide strong indications of needed changes in plant species composition, more detailed quantification of species composition may be required to better predict plant community responses to management changes and to provide baseline conditions for monitoring of progress toward objectives. For this, all existing and previously collected monitoring data and information should be considered.

For areas grazed by domestic livestock, managers (both NPS and permittees) familiar with the current and historic livestock grazing management may be able to determine whether opportunities exist to achieve plant community objectives by altering livestock grazing management. If so, livestock grazing management should ensure that the plant species that managers would like to see increase in abundance have an opportunity to grow or regrow in the absence of herbivory at some point during the growing season. Monitoring efforts then must be able to quantify changes in species composition and capture information about annual grazing management and other factors that influence plant growth. If herbivores other than domestic livestock are important at particular sites, monitoring should be conducted in a way that allows mangers to estimate the impacts of the various groups of herbivores.

Many areas on the monument are currently dominated by cheatgrass and alyssum and support lower relative abundances of native herbaceous perennials than expected. The dominance by invasive annuals and lack of many of the native perennial plants expected in the reference state are likely responsible for reduced annual production. Although challenging, opportunities may exist for managers to reduce the relative abundances of invasive annuals and increase the relative abundances of native perennials.

If managers decide to pursue such opportunities, the following recommendations are offered. First, any available monitoring, inventory and assessment data and information pertinent to the sites of interest should be located and reviewed. Any information that could help managers piece together the management and natural history of the sites will help inform future management and monitoring priorities. Additional monitoring may be needed to provide a reliable estimate of the relative abundances of remaining native perennials to provide an indication of the potential of a site to respond to future management. It is often suggested that 10–20% relative abundance of desirable native species should be sufficient to enable desirable responses to management changes. If desirable native species are absent or not sufficiently abundant to respond to management, seeding or other

restoration efforts will likely be required. However, a restoration plan is well beyond the scope of this project.

Although alyssum is also present, cheatgrass is most likely driving ecological dynamics of most sites where invasive species concerns were noted. For that reason, it is recommended that cheatgrass be targeted for vegetation management efforts in relevant sites. Selective herbicides, targeted grazing of cheatgrass, or a combination thereof are the approaches most likely to reduce cheatgrass abundance and increase the relative abundances of native perennials. Once it is labeled for use in areas grazed by domestic livestock, indaziflam is a promising new herbicide for invasive annual grass management on rangeland because of its effectiveness at reducing invasive annual grass abundance without negatively impacting established desirable plant (Sebastian et al. 2016). Other herbicides have been used for cheatgrass management with varying degrees of success (for examples, see James et al. 2015; Kessler et al. 2015; McIver et al. 2014; Munson et al. 2015; Pyke et al. 2014).

In areas where invasive annual grasses have invaded rangelands, much effort has concentrated on how domestic livestock grazing can be managed to favor desirable perennial species over the invasive annuals (Bailey et al. 2019). Schmelzer et al. (2014) provided a review of successful efforts using spring livestock grazing to reduce cheatgrass abundance and fuels and then reported success of their own approach using fall grazing to reduce fuel loads in areas dominated by cheatgrass. For extensive cheatgrass infestations, targeted grazing to reduce its abundance is an option, but would be management intensive. It may be more feasible to target strategic, smaller areas to serve as fuel breaks to reduce the chances of future fires and then use targeted grazing in those areas for fuel reduction.

4.2. Sites with Mature Pinyon-Juniper Overstory and Depleted Understory

Four IIRH assessment sites on the Blue Mountain/Yampa Bench Allotment (sites 31, 33, 38 and 39) and two sites on the Green River Allotment (sites 1 and 46) were identified as sites where the tree overstory was mature to very mature and the understory was lacking either native shrubs, native perennial herbaceous plants, or both. All six of these sites are classified as Pinyon-Juniper Sites although three different ecological sites are represented. Black sagebrush and alderleaf mountain mahogany were noted as greatly reduced or missing from five of the sites (1, 31, 38, 39, and 46). Sagebrush and other shrubs may serve as important “ladder fuels” to carry fire from the understory into the tree overstory. In systems where shrubs are important ladder fuels, their disappearance may have important implications for future fire dynamics in these systems. Native perennial grasses and forbs were also noted as greatly reduced or missing from three of these five sites (1, 31, and 38), while two sites (39 and 46) may have enough of these species to respond to management changes.

Of the six sites in this group, only one (33) appears to have enough black sagebrush and native perennial herbaceous species to respond to management changes. Cheatgrass was described as “present and unlikely to dominate” at one site (46) but was scattered to very abundant at the rest of the sites in this group, indicating much greater risk of cheatgrass invasion and spread. Juniper can be very effective at out-competing shrubs, grasses, and forbs that may be found in the understory of open stands of trees. Evidence of this is provided by widespread documentation of juniper invasion of sagebrush/grass communities reviewed by Miller et al. (1994). Once the tree overstory is mature,

understory species will likely continue to decline in abundance until the tree dominance is removed (fire, mechanical treatment, etc.). Declines in the abundances of the native understory species can be accelerated by droughts or management decisions, but it is important to note that poorly managed livestock grazing has not provided sufficient explanation of increases in juniper dominance.

Further, even if past livestock grazing management has contributed to juniper dominance, removal or even changes in livestock grazing management may do little or nothing to reverse the trend. That said, where native herbaceous perennial species still occur, livestock grazing should be managed to favor their growth, recognizing that their future their presence in the plant communities may decline as tree overstory increases, regardless of how well grazing is managed. In areas where cheatgrass is a major threat, opportunities may exist to use targeted grazing or herbicides to reduce its abundance and favor native plants. Where shrubs or other native species are missing, seeding may be necessary in combination with vegetation management treatments to reduce the tree overstory (see applicable Ecological Site Descriptions).

It is important to note that there are differing opinions, and even some controversy, surrounding the status of pinyon pine and, particularly, juniper. Clearly, a strength of the Ecological Site Description approach in this regard is in basing estimations of potential vegetation on soils, climate, and topography rather than what vegetation is present at a given point in time. Nevertheless, as noted by Floyd et al. (2017), juniper stands in Dinosaur National Monument exist within shifting mosaics driven by a highly complex fire history as well as recent management interventions. What may at first appear to be an "invasion" may instead be merely a recovery from fire or adaptation to altered conditions. Within the framework of IIRH, we feel that reliance on the ESD is of foremost importance, but we also encourage managers to carefully consider the implications of labelling juniper as "invasive", as well as any management interventions that this label might impel.

4.3. Site with Mature Pinyon-Juniper Overstory but Otherwise Little Departure from Reference

As noted in section 3.4.2., site 5 in the Docs Valley allotment was rated as a moderate departure from reference condition for Biotic Integrity, but there were concerns among the crew because this was largely based on the presence of juniper, which the reference sheet listed as an invasive species. The juniper and pinyon on the site appeared well established. We leave the decision of whether to act on this rating to NPS staff, but we note that the typical concern with juniper as an invasive is that it leads to reductions in plant diversity and abundance in the understory, among shrubs, grasses, and forbs. These issues were currently not of concern at site 5 and, given the apparent age of the tree species, appear unlikely to occur in the future, at least due to the presence of juniper. However, it may be useful to explore existing historical data for the area, and even to collect additional quantitative data on the understory plants, in order to provide further context for future management decisions.

4.4. Sagebrush Grasslands Dominated or Threatened by Cheatgrass

Six IIRH assessment sites across five different allotments were identified as sagebrush grasslands where cheatgrass is either currently dominant or likely to become dominant. Five of the six sites (9, 12, 15, 16 and 17) occur on one ecological site (R047XA430UT) with the sixth (site 28) on another

(R047XC320UT). Recommendations for these six sites are similar but, given the uniqueness of site 28, we will discuss it separately.

The five sites in this group that occur on the *Mountain Loam* ecological site (R047XA430UT) are distributed among four grazing allotments. Cheatgrass is present at all sites and ranges from scattered to dominant. In addition, alyssum is scattered to common at most of the sites. The IIRH assessment noted that sagebrush is reduced or missing from three sites (9, 15, and 17). Field notes suggest that evidence of fire was observed at two of these sites (9 and 15) which would explain the observed reductions in the abundance of sagebrush.

Although some species were noted as missing, the presence and abundances of native herbaceous perennials at these two sites should ensure favorable responses to management in the future, provided that these sites do not burn again in the near future. In fact, the field notes from site 15 indicated that native perennials were "doing well" despite there being an abundance of cheatgrass. No evidence of fire was noted at site 17, but there was a notable absence of sagebrush cover at the sampled IIRH site. That being said, the area immediately surrounding the sampled site supported a hearty stand of sagebrush and, although they were few, some apparently young sagebrush plants were present at the sampled site. Site 17 probably has enough native herbaceous perennials to respond.

Two sites in this group (12 and 16) were similar to the three described above except for that sagebrush was not reduced or missing. Both sites support a decent mix of native herbaceous perennials with potential to respond to management. The assessment at site 16 noted that antelope bitterbrush was less abundant than expected.

The one site in this group that occurred on the *Upland Shallow Loam* ecological site (R047XC320UT) was site 28 on the Blue Mountain / Yampa Bench Allotment. This site is similar to the other five sites in this group in terms of the reduced abundances of native herbaceous perennials (especially grasses) and the prevalence of cheatgrass and alyssum. As with those five sites, it also supported less sagebrush than expected. However, one important difference is that this site supports black sagebrush instead of big sagebrush. Another difference is that, at this site, dead sagebrush plants are present, and the assessment notes estimated that 95% of sagebrush is "standing dead". No obvious causes of sagebrush death were noted. In the absence of information about what might have killed the sagebrush at this site, one can only speculate. Herbicide treatment or insect outbreaks such as the aroga moth (*Aroga websteri* Clarke) could cause this.

Regardless of cause, shrub skeletons can still capture snow or provide other functions that do not rely on live shrubs. For site 28 especially, it would be important to look for and review information and data from previous monitoring efforts or management records to determine likely causes of the dead black sagebrush at this site. Any information that would help managers piece together the managerial and natural history of this site will help inform future management and monitoring priorities. For example, it is interesting to note that Trlica and Thorne (2001) reported significant reductions in shrub (mainly sagebrush) and native perennial grass abundances and a related increase in annual grass (mainly cheatgrass) abundance from 1996–2001 for sites on the Yampa Bench on the same or similar ecological sites. The authors did not mention fire as a primary cause of these shrub

reductions, and our IIRH assessment noted many dead sagebrush plants, so these changes may have been caused by other factors.

To the extent possible, managers should rely on existing data and information to assemble a comprehensive list of factors (growing conditions, insect outbreaks, wildlife dynamics, livestock grazing management, etc.) that may have contributed to the abundance of invasive annuals and relative lack of sagebrush and other native perennials. If there are established monitoring sites close to (or similar to) site 28, managers are encouraged to continue the trend analysis initiated by Trlica and Thorne (2001). For all sites in this group, it is advisable for managers to review records of management history, data, and information collected through previous monitoring efforts in order to identify factors most likely related to the declines in abundances of the native plants. Additional, more detailed quantification of species composition may be required to better predict plant community responses to management changes and to provide baseline conditions for monitoring of progress toward objectives. Where native herbaceous perennial species still occur, livestock grazing should be managed to maintain or increase their relative abundance in the plant communities. In areas where cheatgrass is a major threat, opportunities may exist to use targeted grazing or herbicides to reduce its abundance and favor native plants. Where shrubs or other native species are missing and unlikely to arrive, seeding may be necessary (see applicable Ecological Site Descriptions for appropriate species).

4.5. Sagebrush Grasslands Threatened by Cheatgrass and Juniper Invasion

Site 43, on the Blue Mountain / Yampa Bench Allotment, occurs on a *Semidesert Shallow Loam* Ecological Site (R034BY225UT) and is similar to those in the previous group in that native herbaceous perennials and sagebrush have been reduced, and cheatgrass is present and poses a threat of invasion. Although some species are missing, the diversity and abundance of native herbaceous perennials are likely sufficient to respond to management. In addition to, and different from the sites in the group above, many young and seedling junipers were noted at this site, but are not expected, suggesting early stages of juniper invasion of a sagebrush grassland ecological site. At locations similar to this IIRH site, managers are encouraged to consider vegetation management actions that will reverse juniper invasion before it progresses too far and while the major components of the sagebrush grassland plant communities are still present and sufficiently abundant to respond.

4.6. Sagebrush Grasslands with Depleted Herbaceous Understory and Mature Sagebrush Overstory

The IIRH assessments from three sites on three different allotments and three different ecological sites indicated that native herbaceous perennials were less abundant than expected, sagebrush was more abundant than expected, and cheatgrass was not a major concern. Alyssum was present at all three sites but was not highlighted as a major concern. One site (34) occurred on the Blue Mountain / Yampa Bench Allotment in a *Rolling Loam* Ecological site (R034XY298CO); one site (45) occurred on the Harpers Corner Allotment in a *Mountain Shallow Loam* Ecological Site (R047XC446UT); and one site (10) occurred on the Murray Allotment in a *Mountain Loam* Ecological Site (R047XA430UT). It is important to consider that the IIRH assessment and associated pictures taken at this site (10) reveal a super-dominance of arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh)

Nutt.) at the exact location of this assessment site. Adjacent surrounding areas appear to support much less arrowleaf balsamroot than the sampled site and would likely not be represented by conditions at this site (10).

Ecological site descriptions for all three of these sites suggest that efforts to increase the representation of native herbaceous perennials should also be accompanied by efforts to reduce sagebrush dominance. It is unlikely that native herbaceous perennials will increase unless the sagebrush dominance is reduced. Supplemental, more detailed quantification of species composition may be required to better predict plant community responses to management changes and to provide baseline conditions for monitoring of progress toward objectives. Where native herbaceous perennial species still occur, livestock grazing should be managed to maintain (no effort to reduce sagebrush dominance) or increase (sagebrush dominance reduced) their relative abundance in the plant communities.

4.7. Annual Invaded Shrubland / Grassland

Three sites were identified where invasive annual plants dominate the understory (or in one case, the entire plant community) and ecological dynamics of the site. Native herbaceous perennials were mostly or entirely lacking from these sites and two of the three still supported native shrubs in the overstory. All three of these sites occurred on the Green River Allotment. Two of the three sites (2 and 4) occurred on the *Alkali Flat* Ecological Site (R034BY006UT). These two sites supported at least one native shrub in the overstory, with an understory heavily dominated by cheatgrass and very few native species present. The assessment revealed significantly more litter than expected which was attributed to the abundance of cheatgrass. One site (0) occurred on a *Semidesert Sandy Loam* Ecological Site (R034BY216UT) that was dominated by cheatgrass and halogeton. Unlike the other two sites in this group, native shrubs were very infrequent at this site.

Efforts to change the plant species composition at these sites will require treatments to reduce the abundance of cheatgrass (and halogeton at site 0). Information about herbicides and targeted grazing of cheatgrass was presented above. Herbicide treatments are likely to be the only option for reducing halogeton abundance. Prior to the initiation of vegetation management efforts, managers are encouraged to invest the time and effort necessary to better quantify the relative abundances of native perennials on these sites in order to improve predictions about post treatment responses of the sites and the potential need for seeding desired species. Post-treatment monitoring of the plant community will be critical to determining the responses of both the targeted invasive annuals and the established/seeded native species.

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Appendix A. Indicator and Attribute Result Maps

Figures A1-A20 illustrate the IIRH assessment ratings for the 17 indicators and three attributes included in the study.

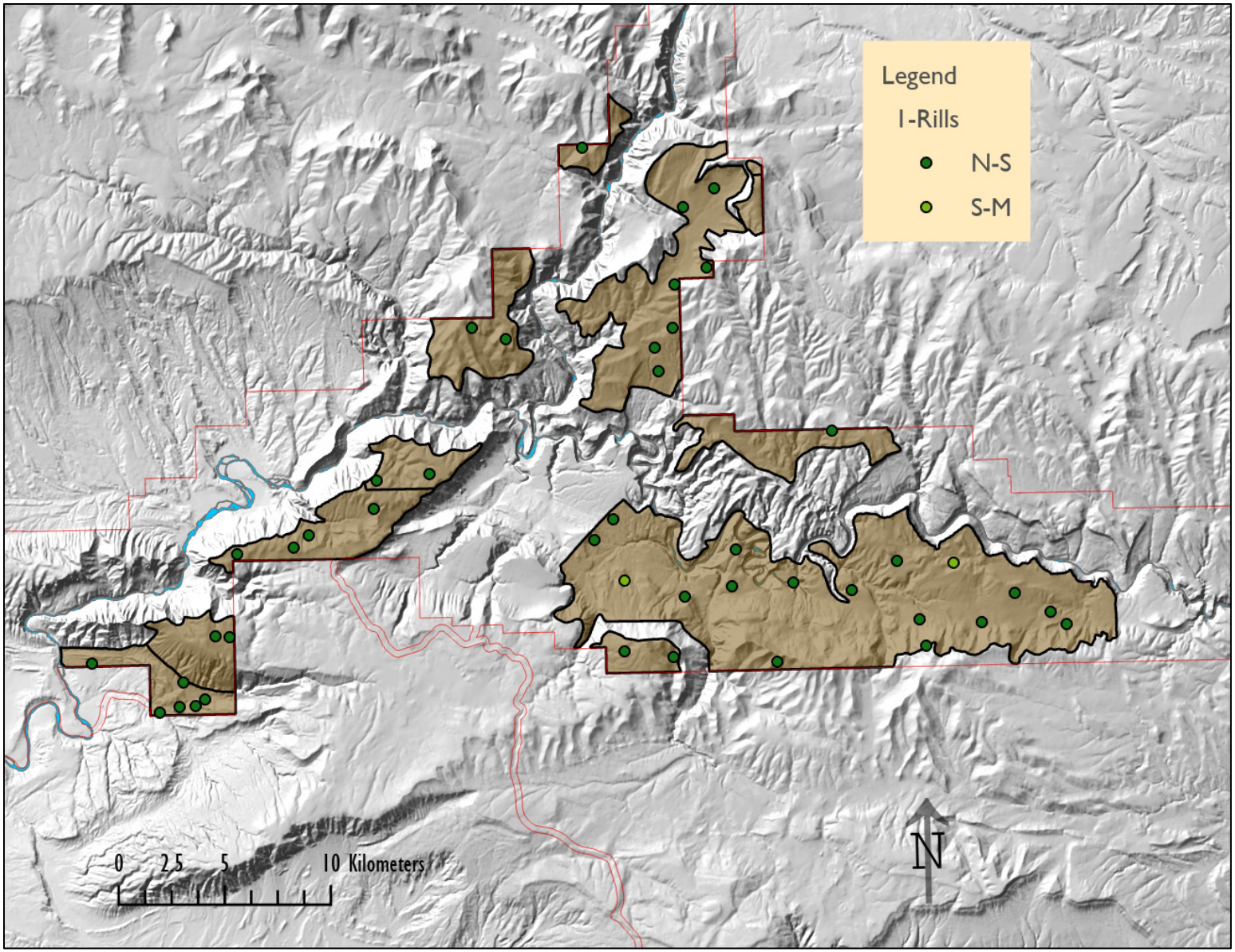

Figure A1. IIRH assessment ratings for indicator #1, rills.

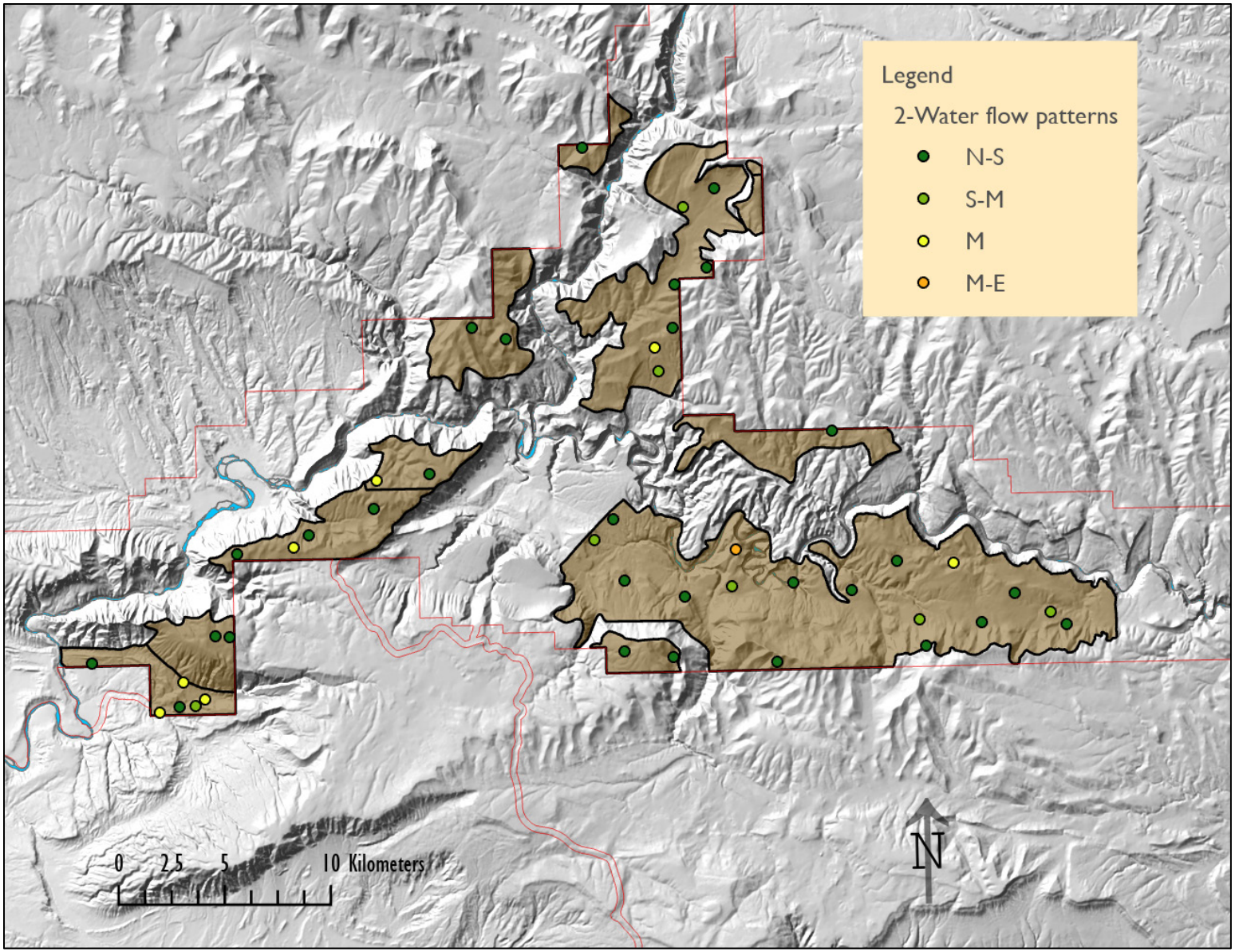

Figure A2. IIRH assessment ratings for indicator # 2, water flow patterns.

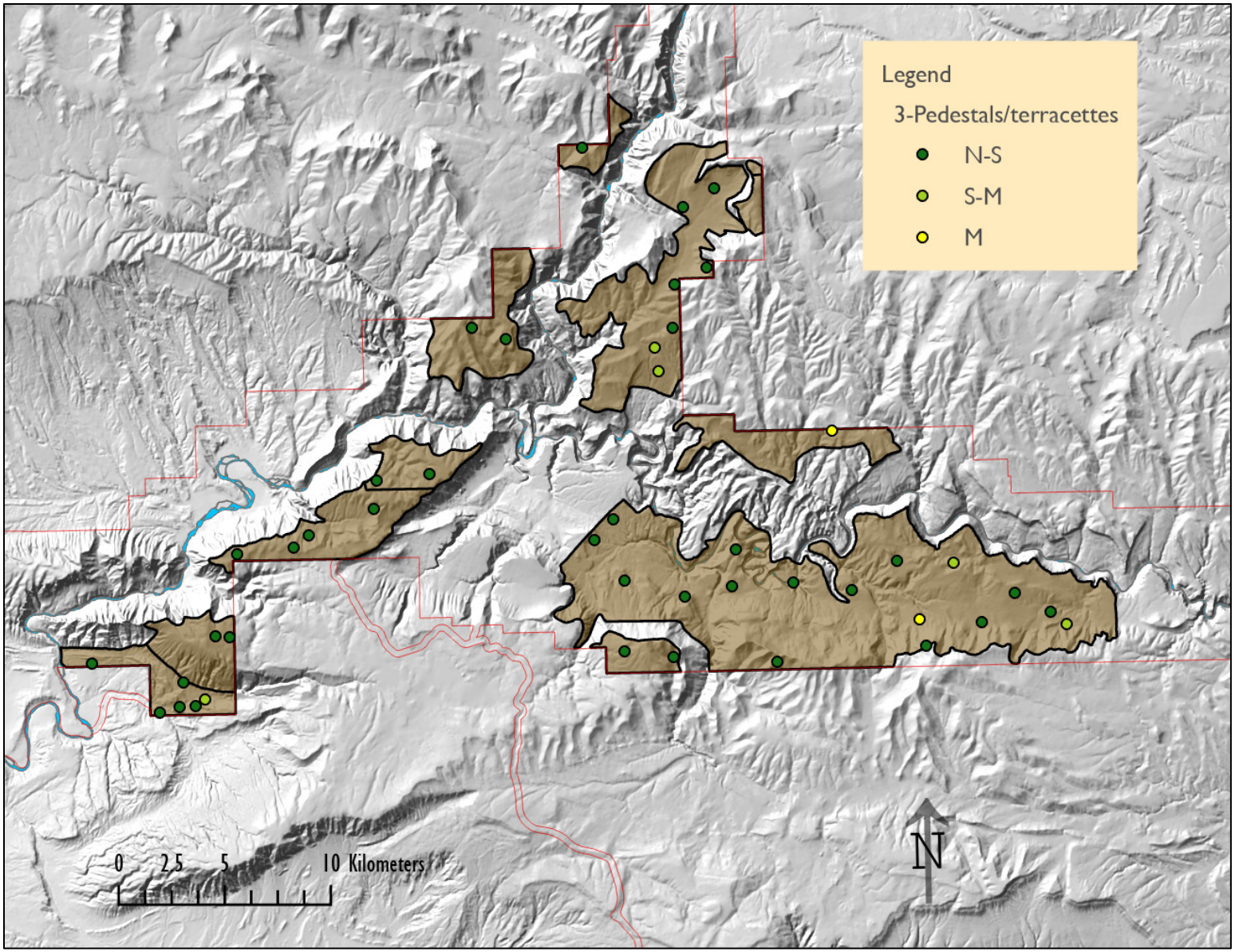

Figure A3. IIRH assessment ratings for indicator #3, pedestals and/or terracettes.

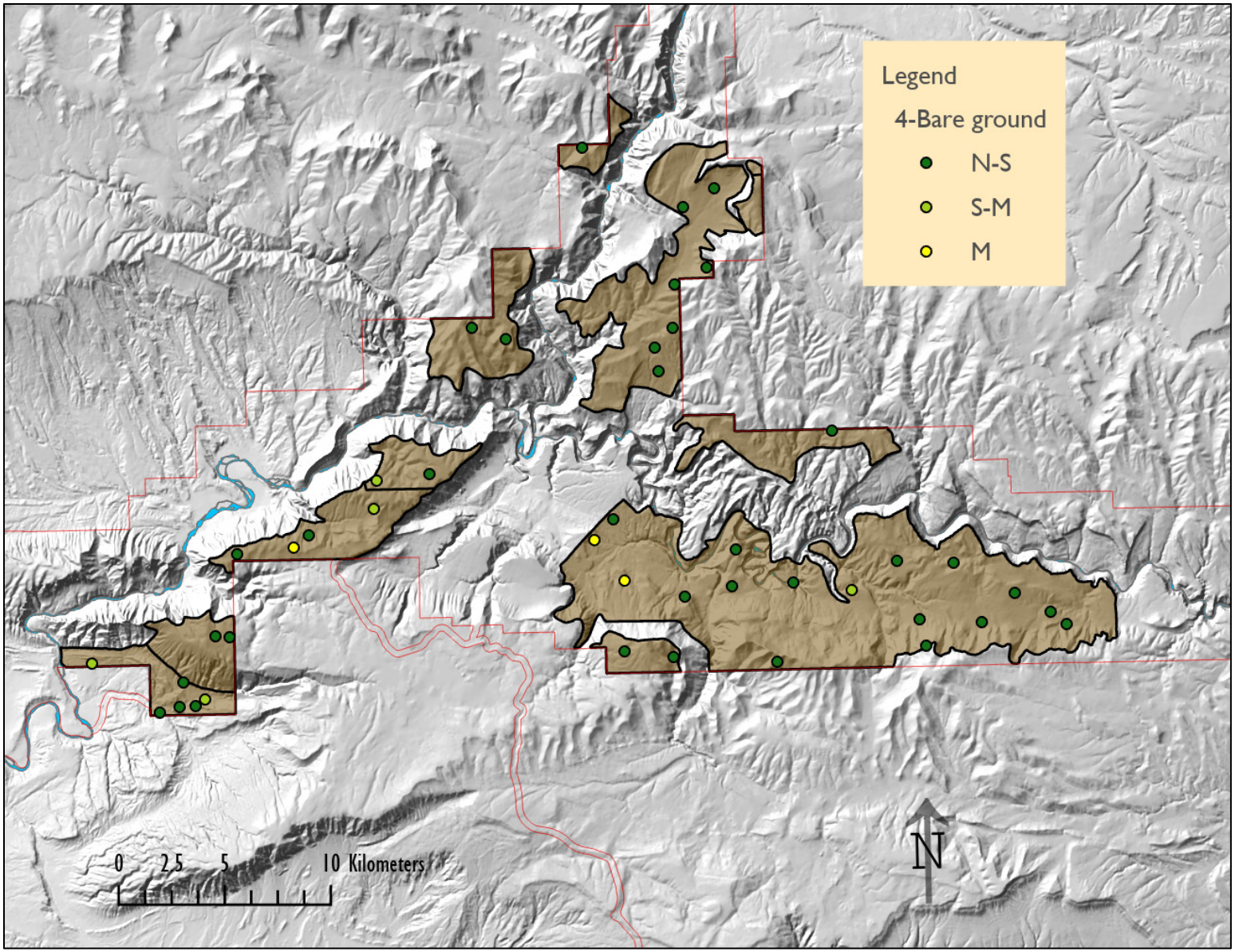

Figure A4. IIRH assessment ratings for indicator #4, bare ground.

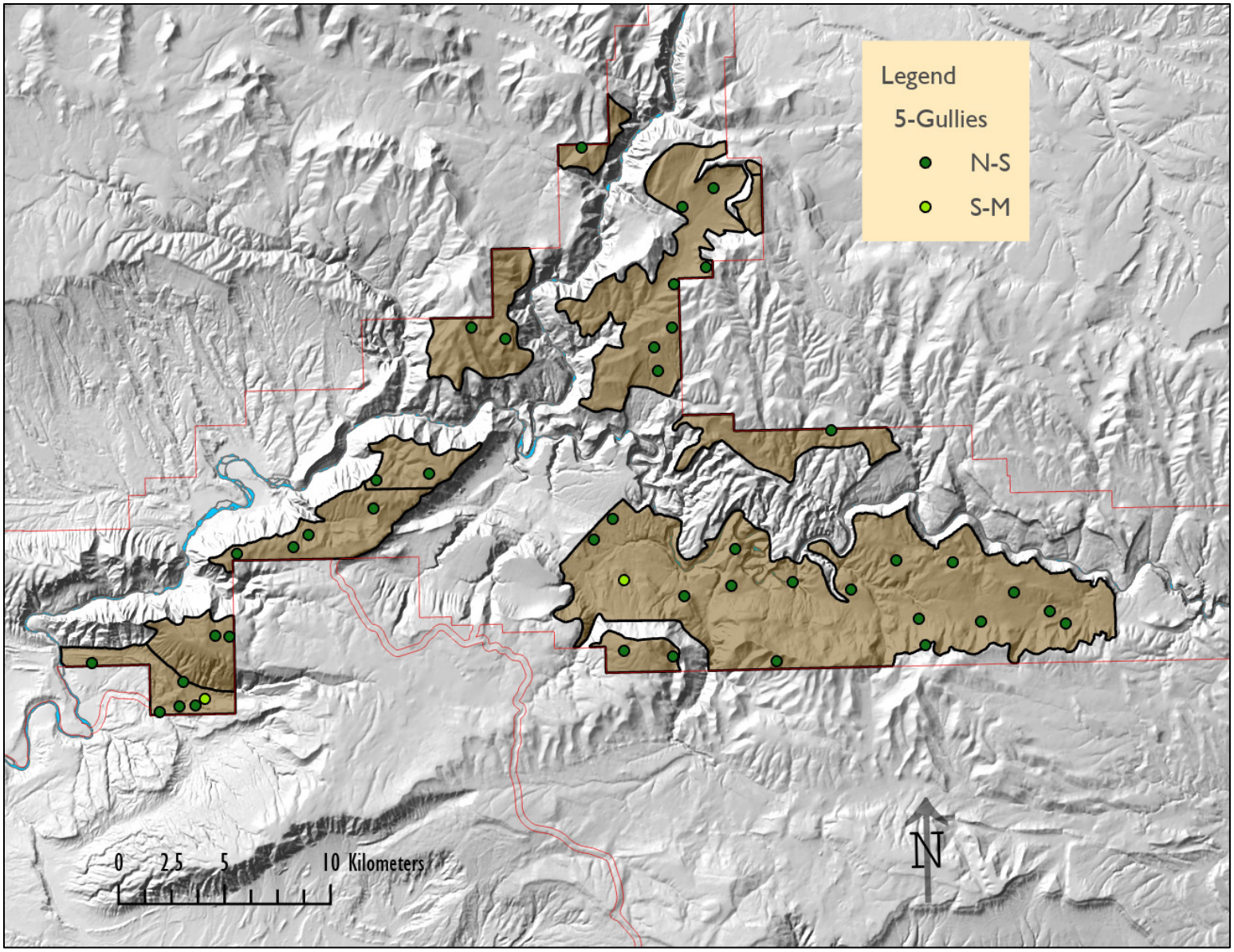

Figure A5. IIRH assessment ratings for indicator #5, gullies.

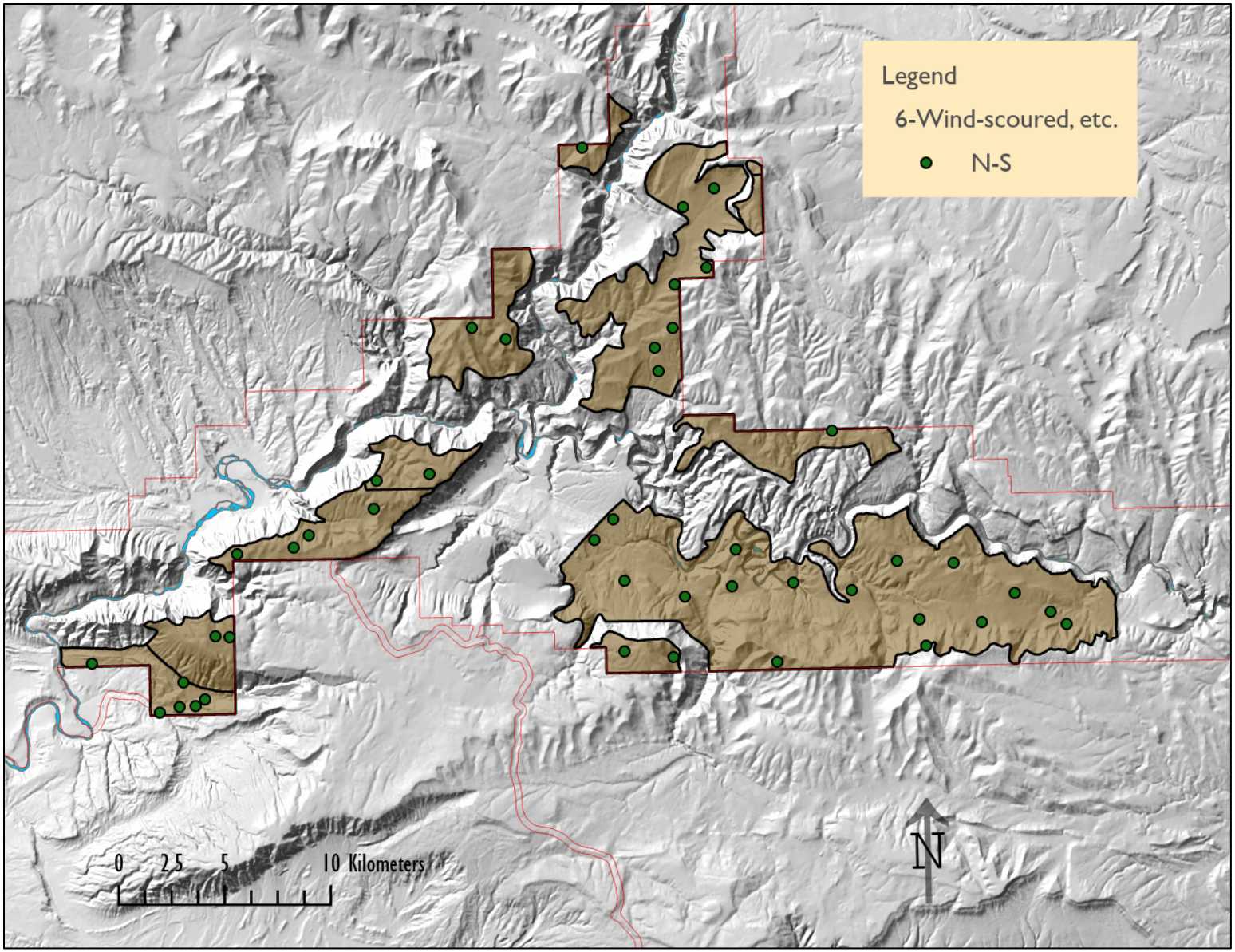

Figure A6. IIRH assessment ratings for indicator #6, wind-scoured areas, blowouts, and/or deposition areas

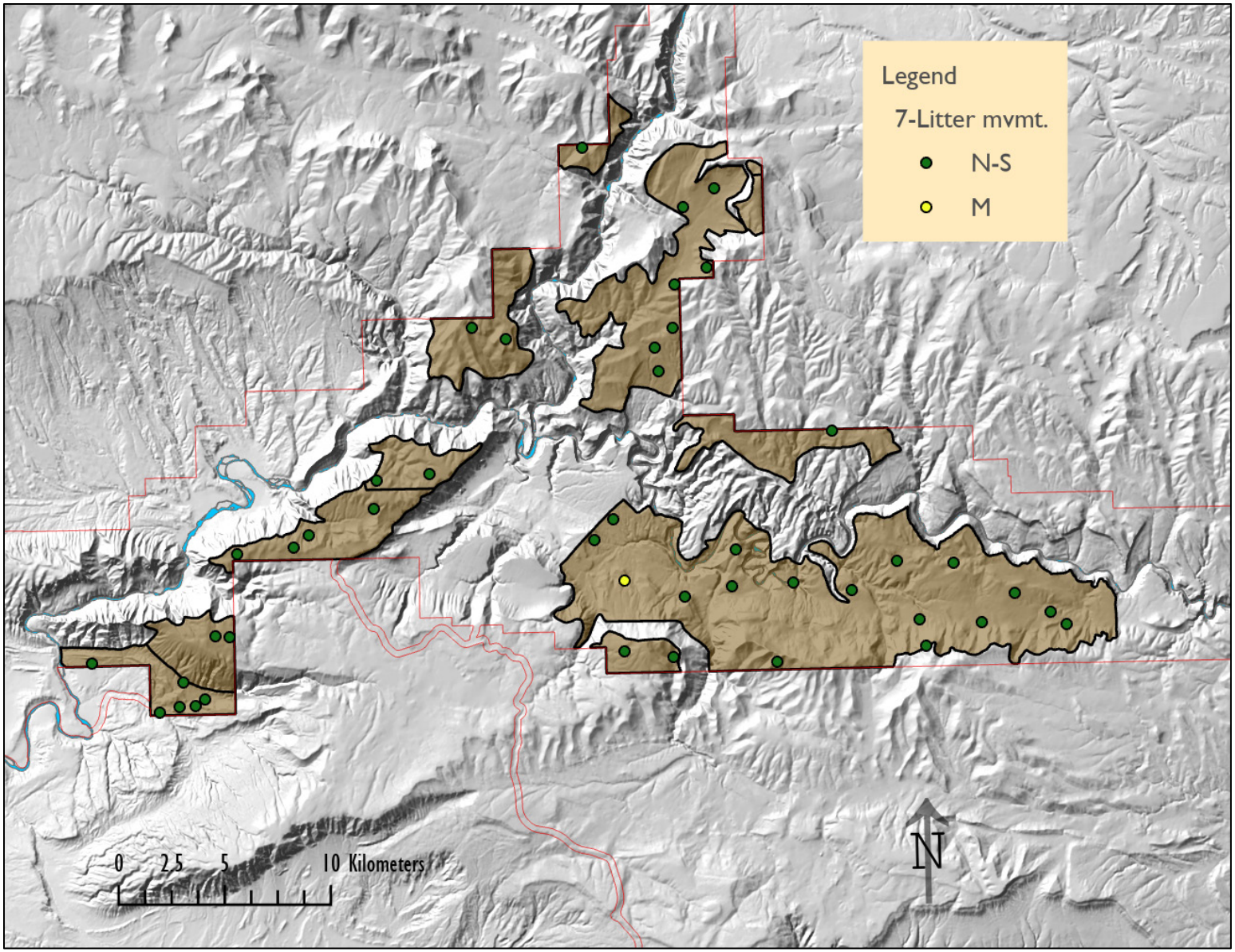

Figure A7. IIRH assessment ratings for indicator #7, litter movement.

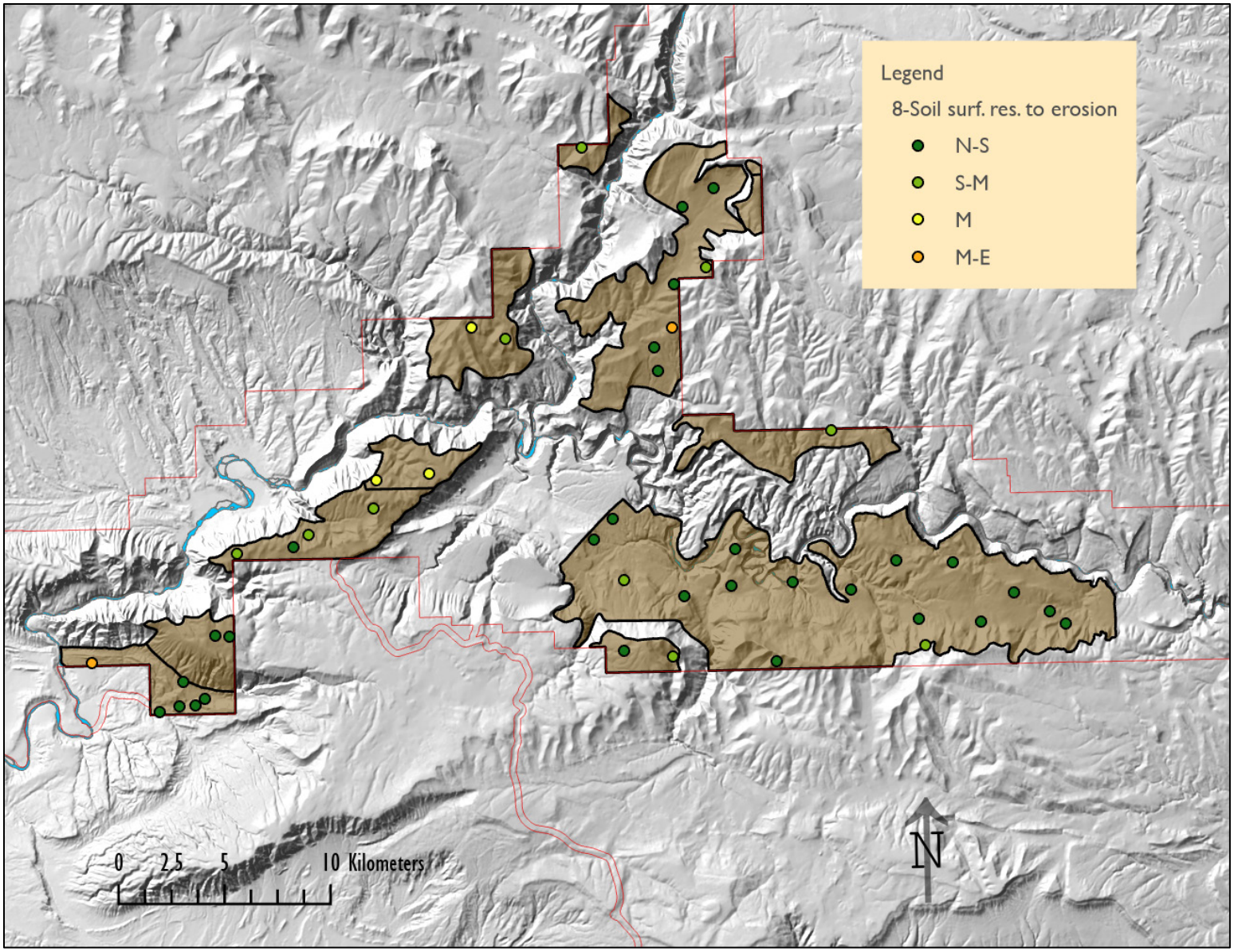

Figure A8. IIRH assessment ratings for indicator #8, soil surface resistance to erosion.

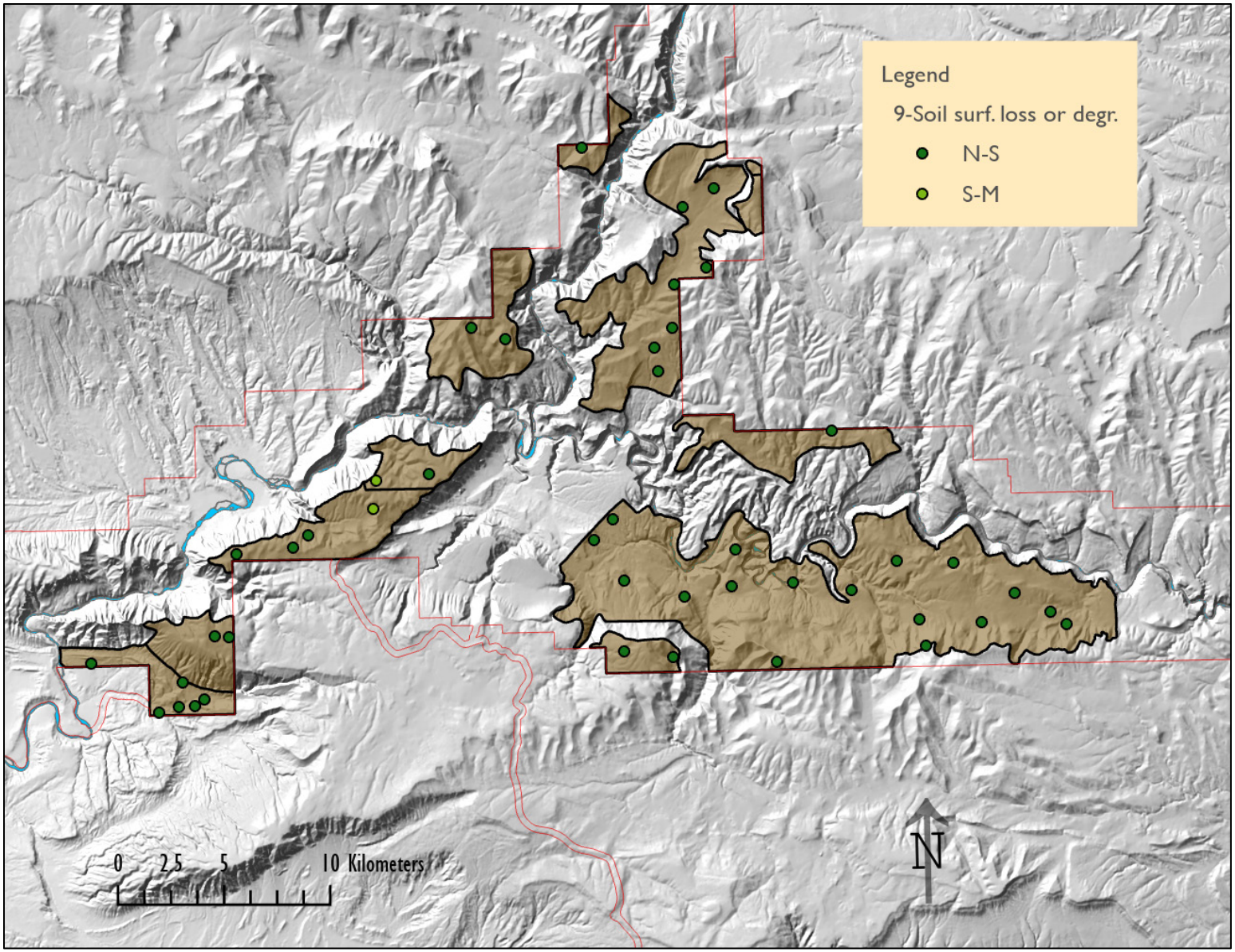

Figure A9. IIRH assessment ratings for indicator #9, soil surface loss or degradation.

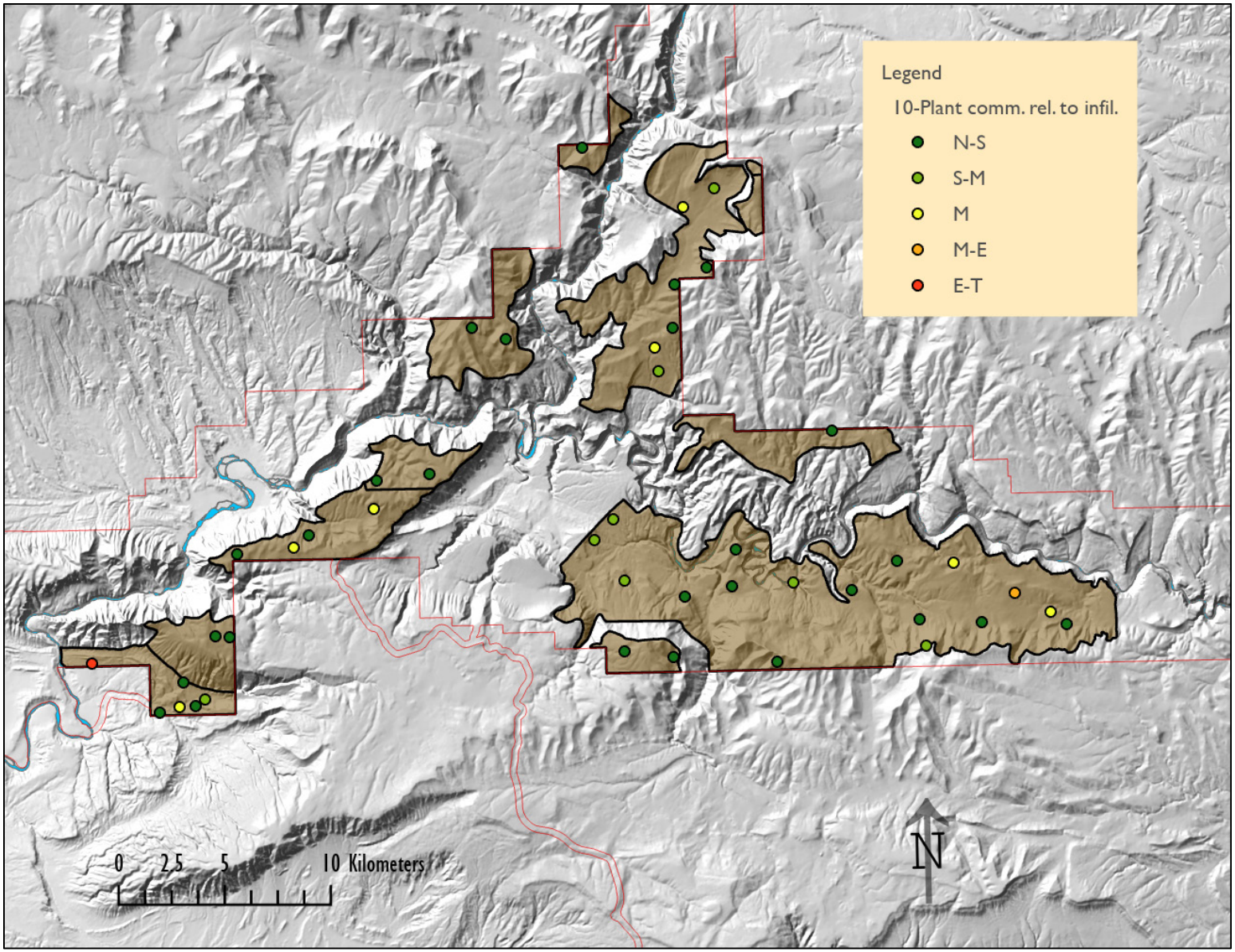

Figure A10. IIRH assessment ratings for indicator #10, plant community composition and distribution relative to infiltration and runoff.

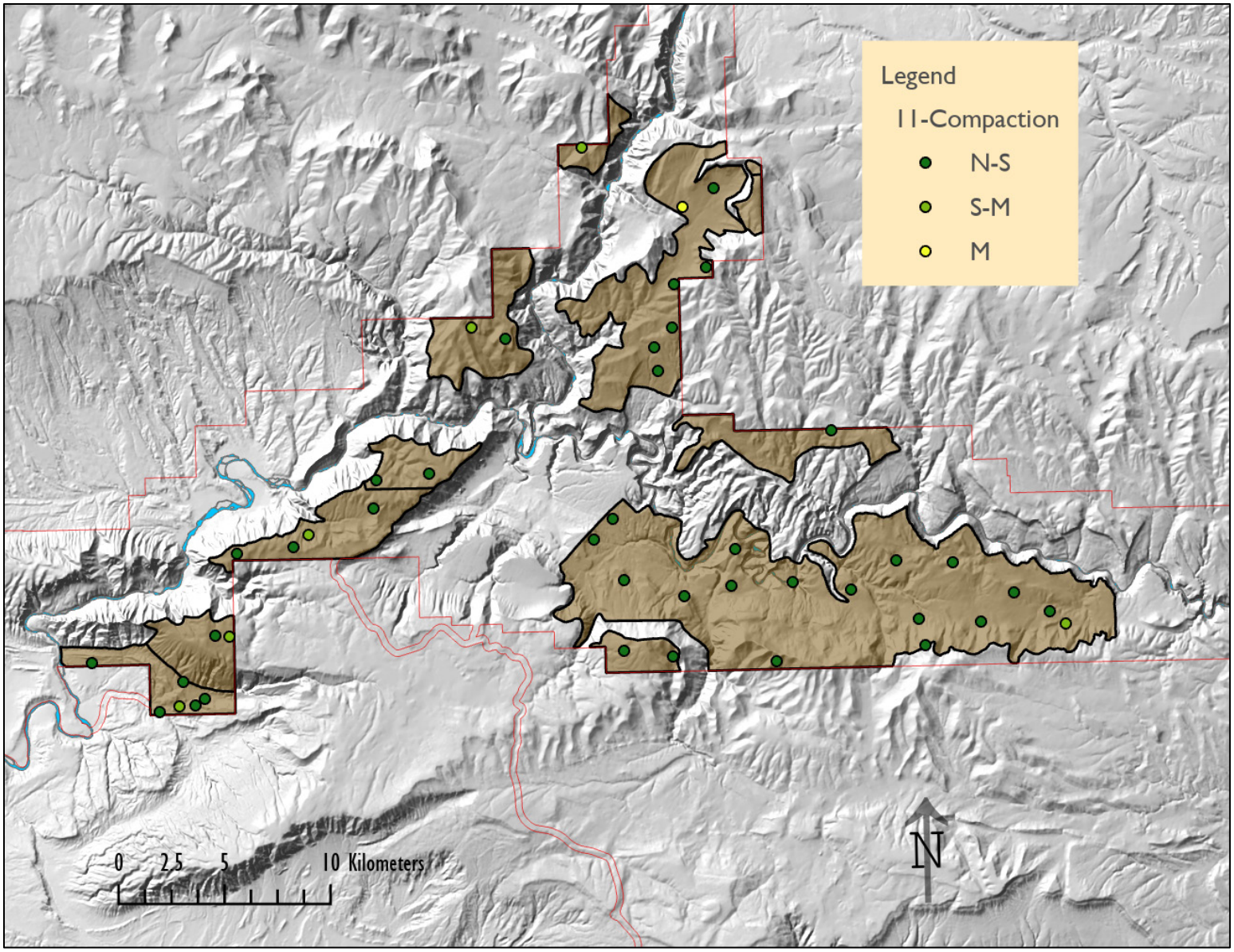

Figure A11. IIRH assessment ratings for indicator #11, compaction.

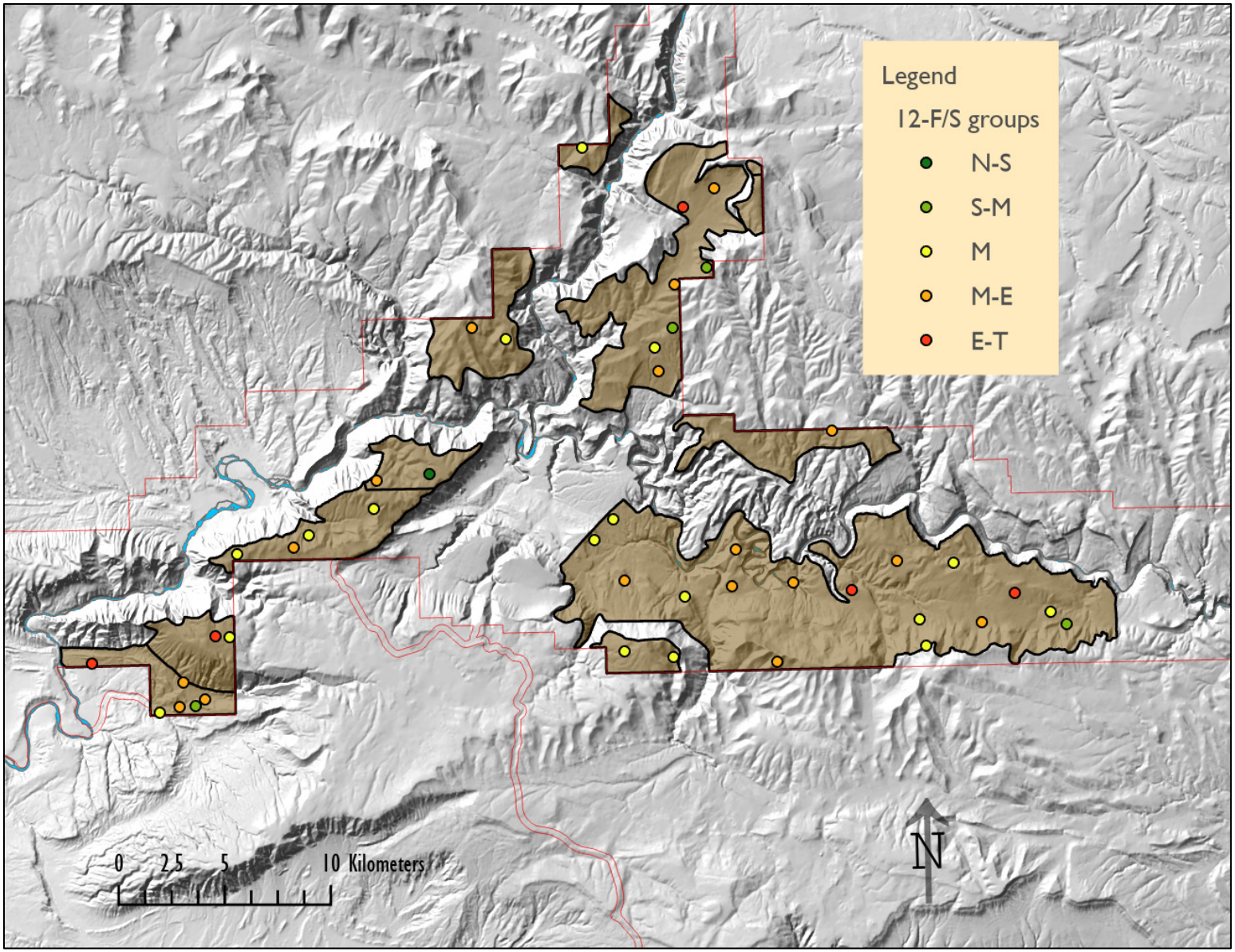

Figure A12. IIRH assessment ratings for indicator #12, functional/structural groups.

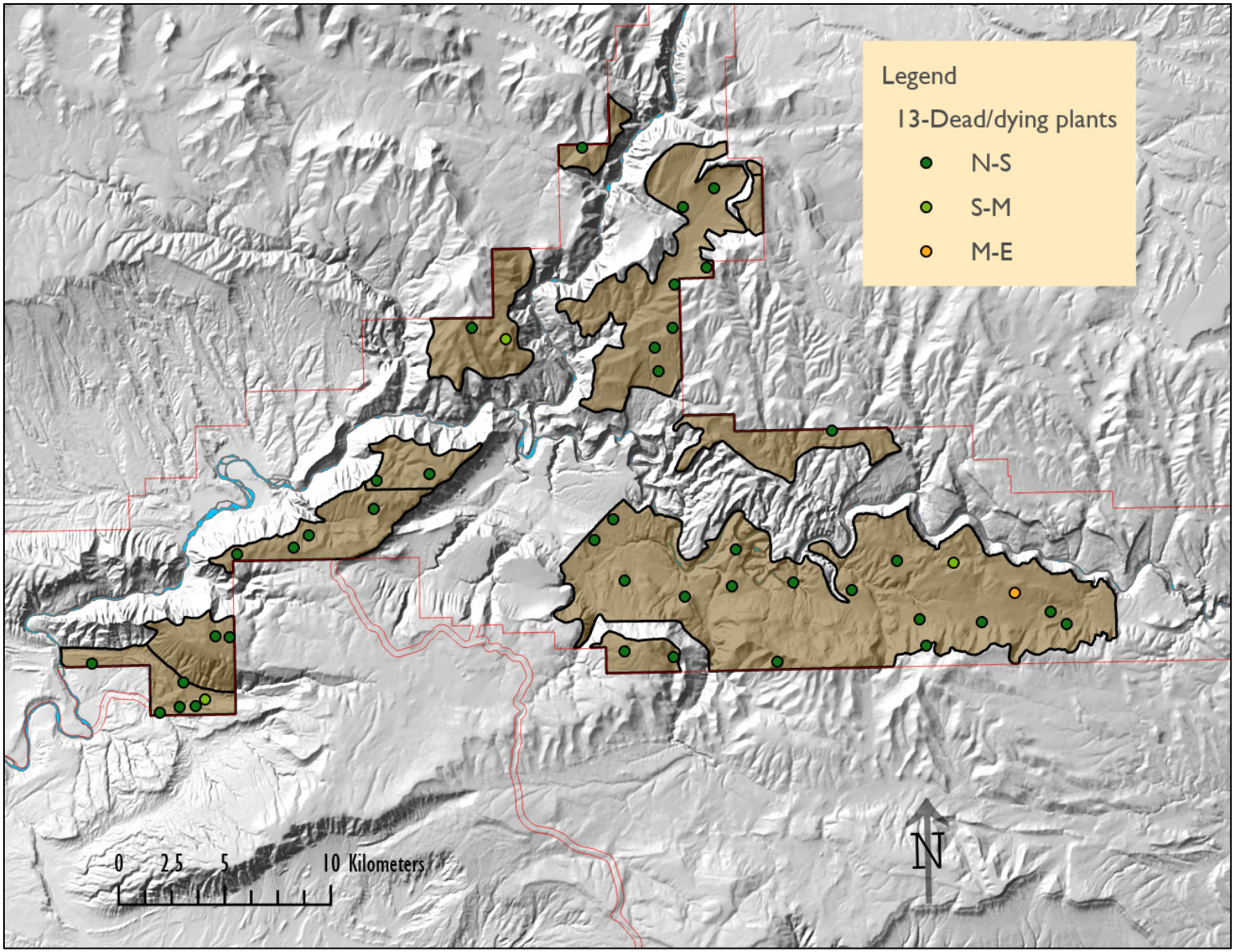

Figure A13. IIRH assessment ratings for indicator #13, dead or dying plants or plant parts.

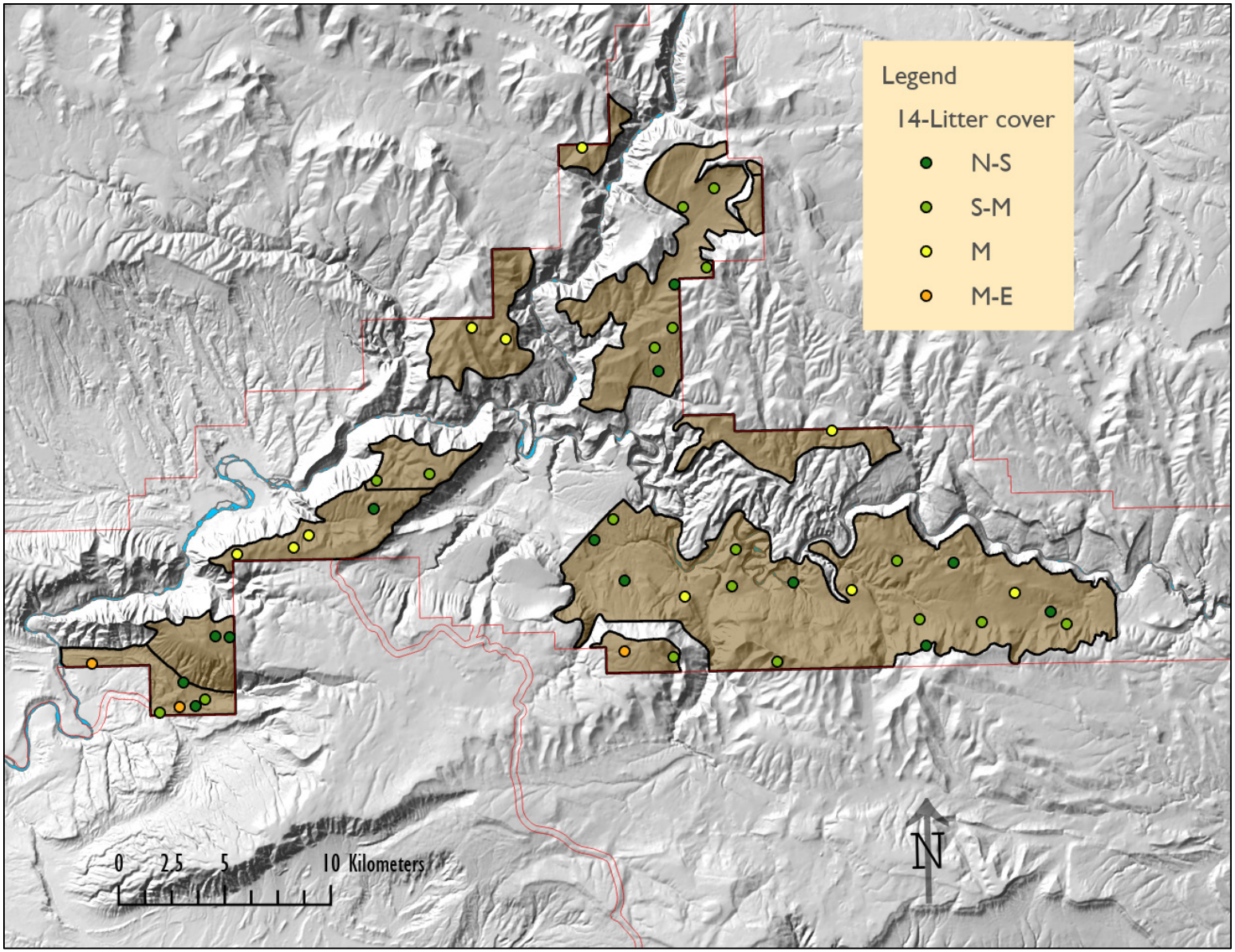

Figure A14. IIRH assessment ratings for indicator #14 – litter cover and depth.

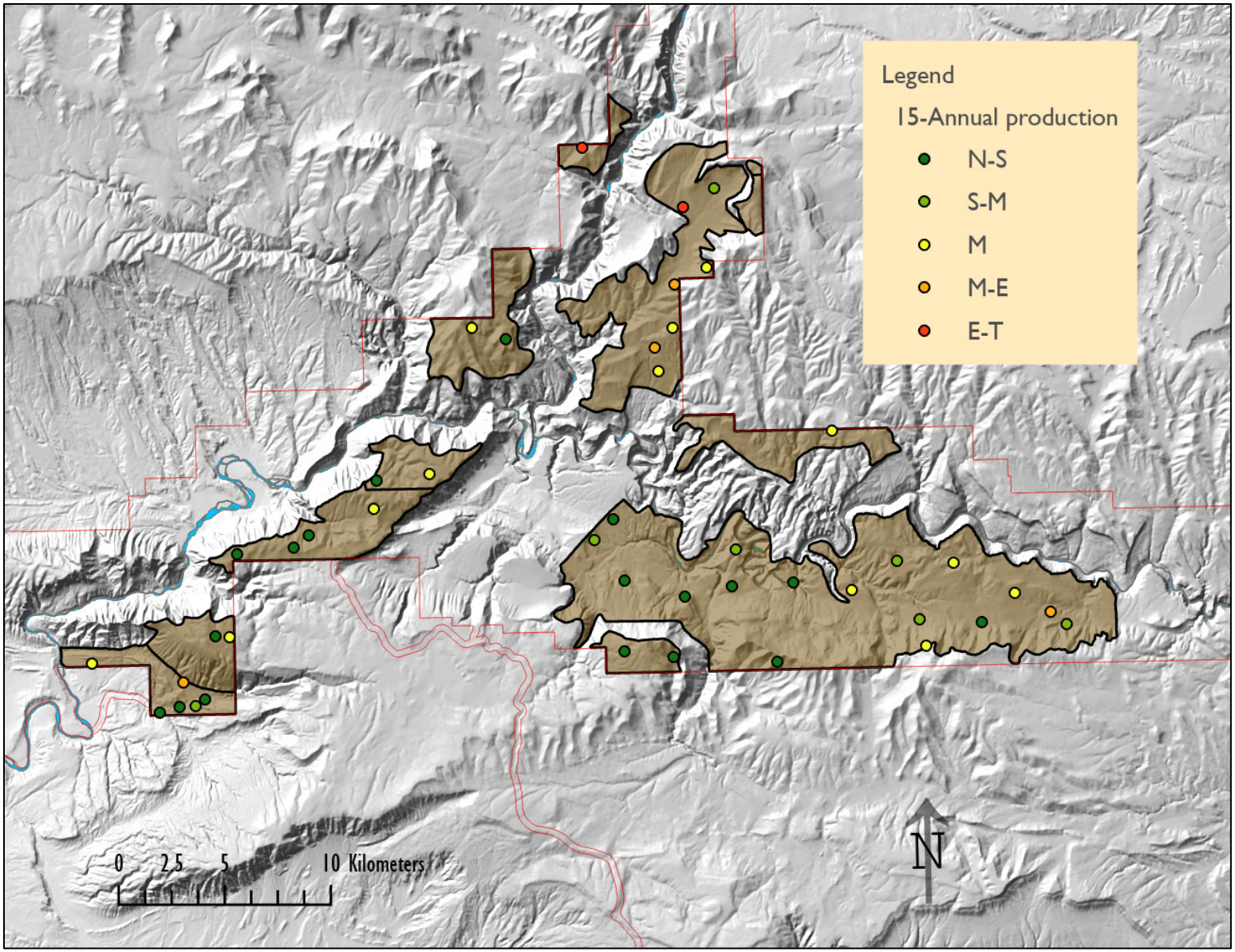

Figure A15. IIRH assessment ratings for indicator #15, annual production.

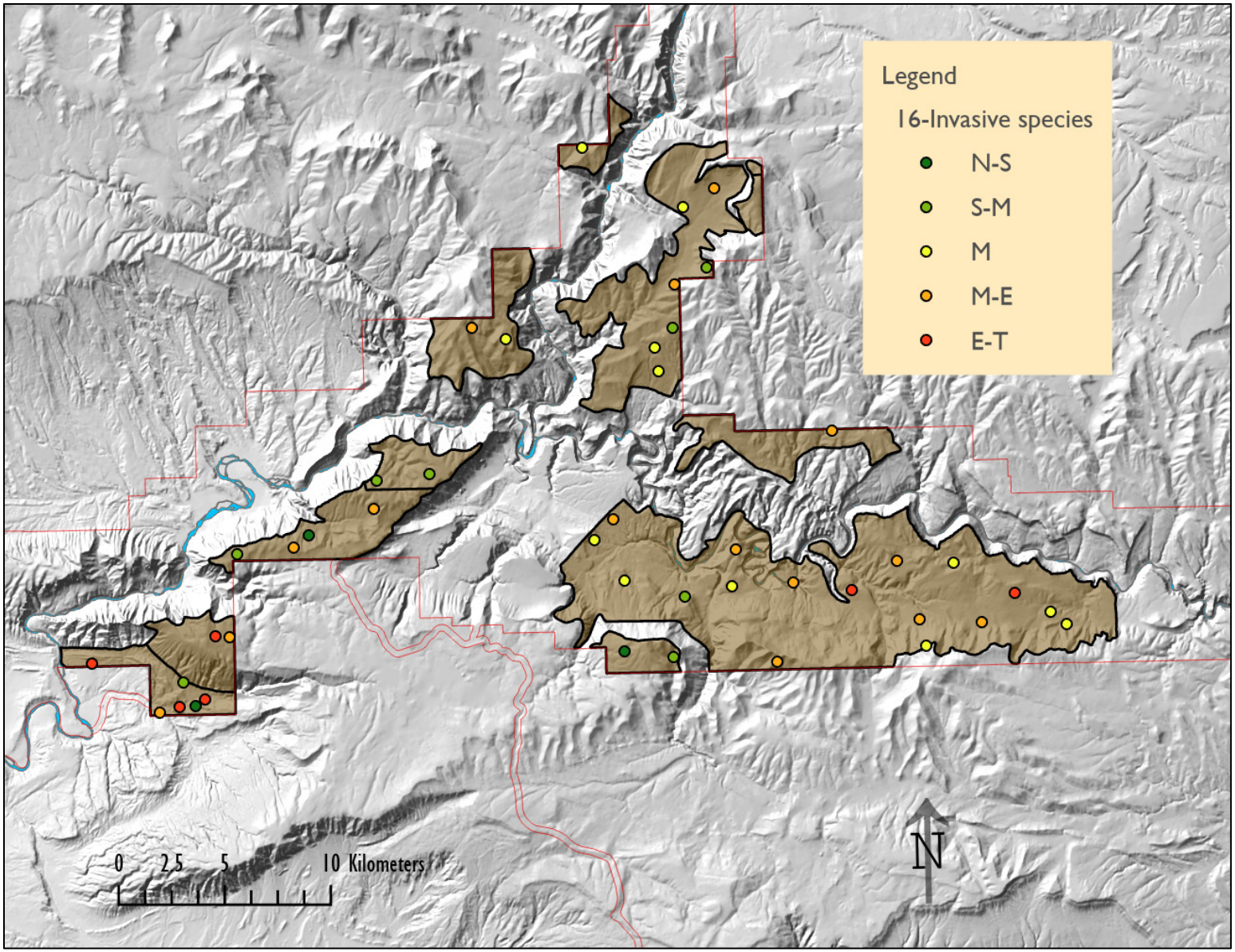

Figure A16. IIRH assessment ratings for indicator #16, invasive plants.

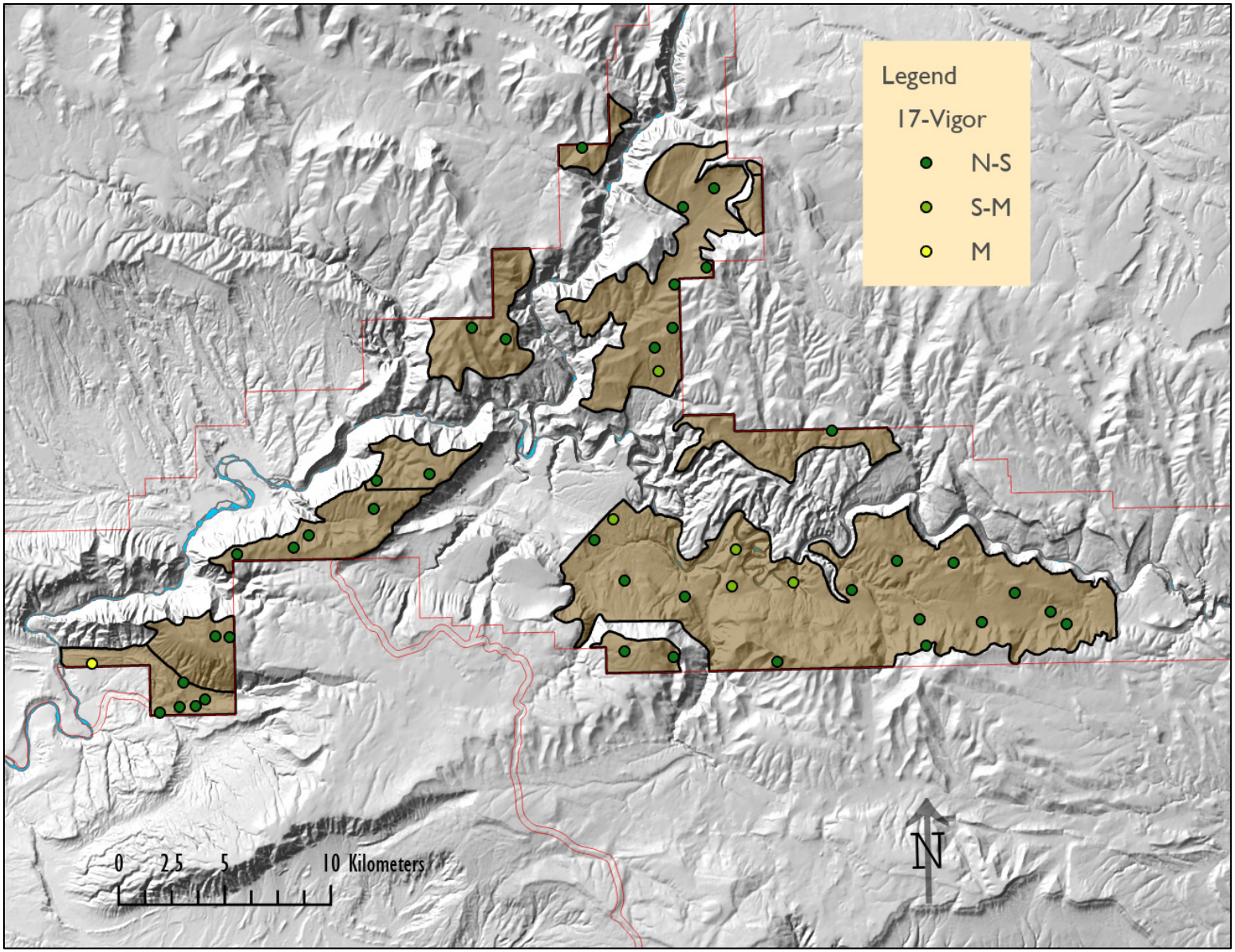

Figure A17. IIRH assessment ratings for indicator #17, vigor with an emphasis on reproductive capability of perennial plants.

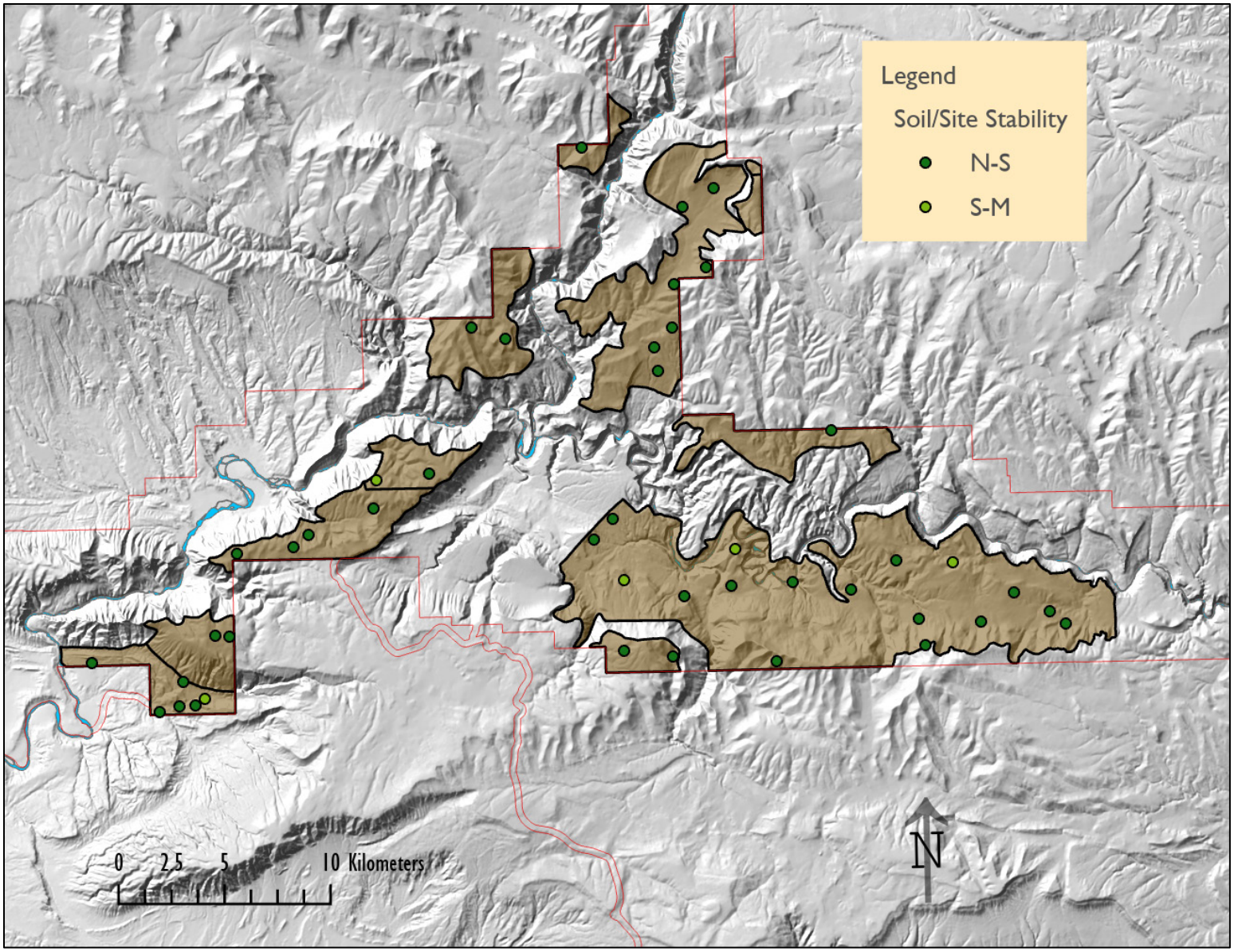

Figure A18. IIRH assessment ratings for the attribute Soil and Site Stability.

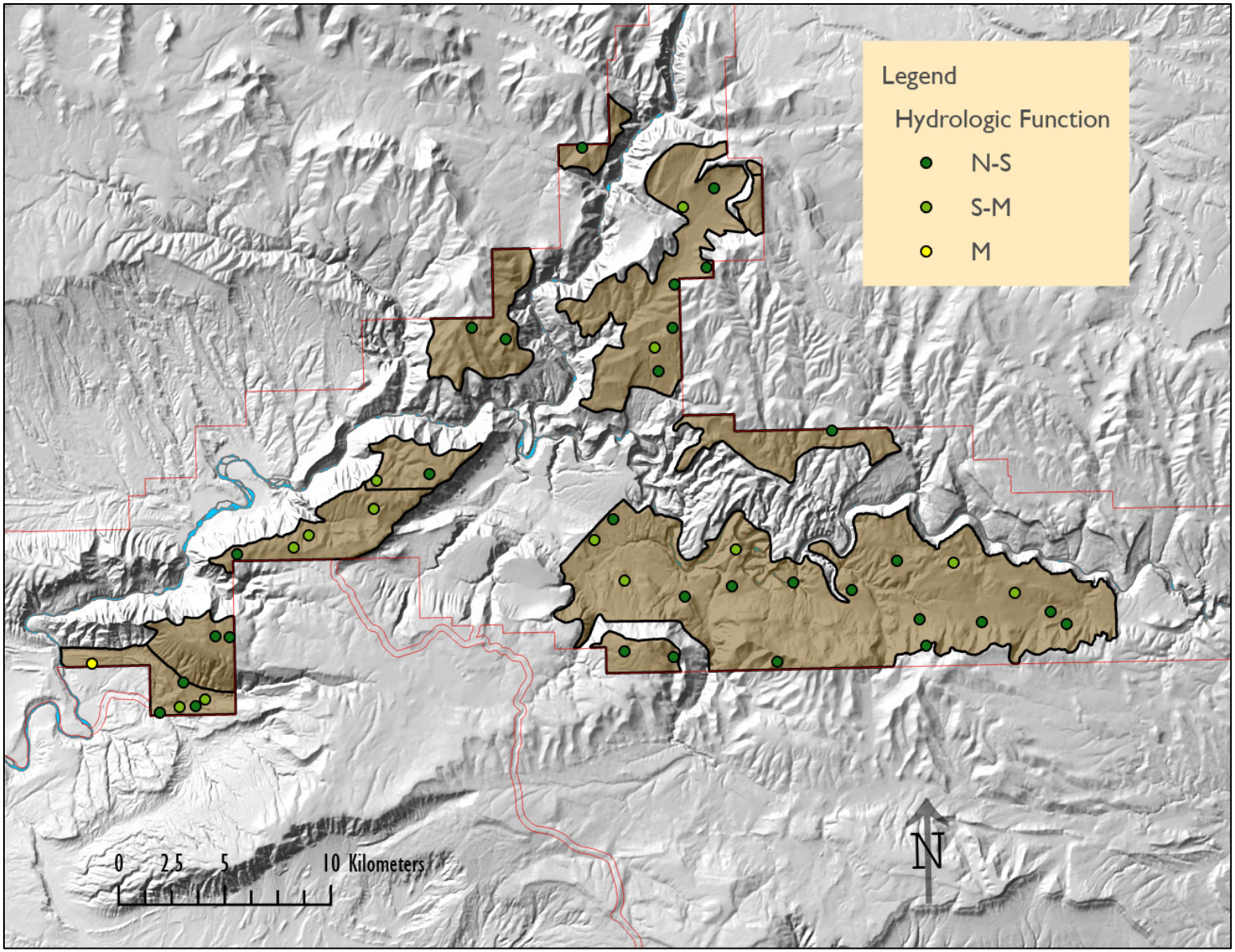

Figure A19. IIRH assessment ratings for the attribute Hydrologic Function.

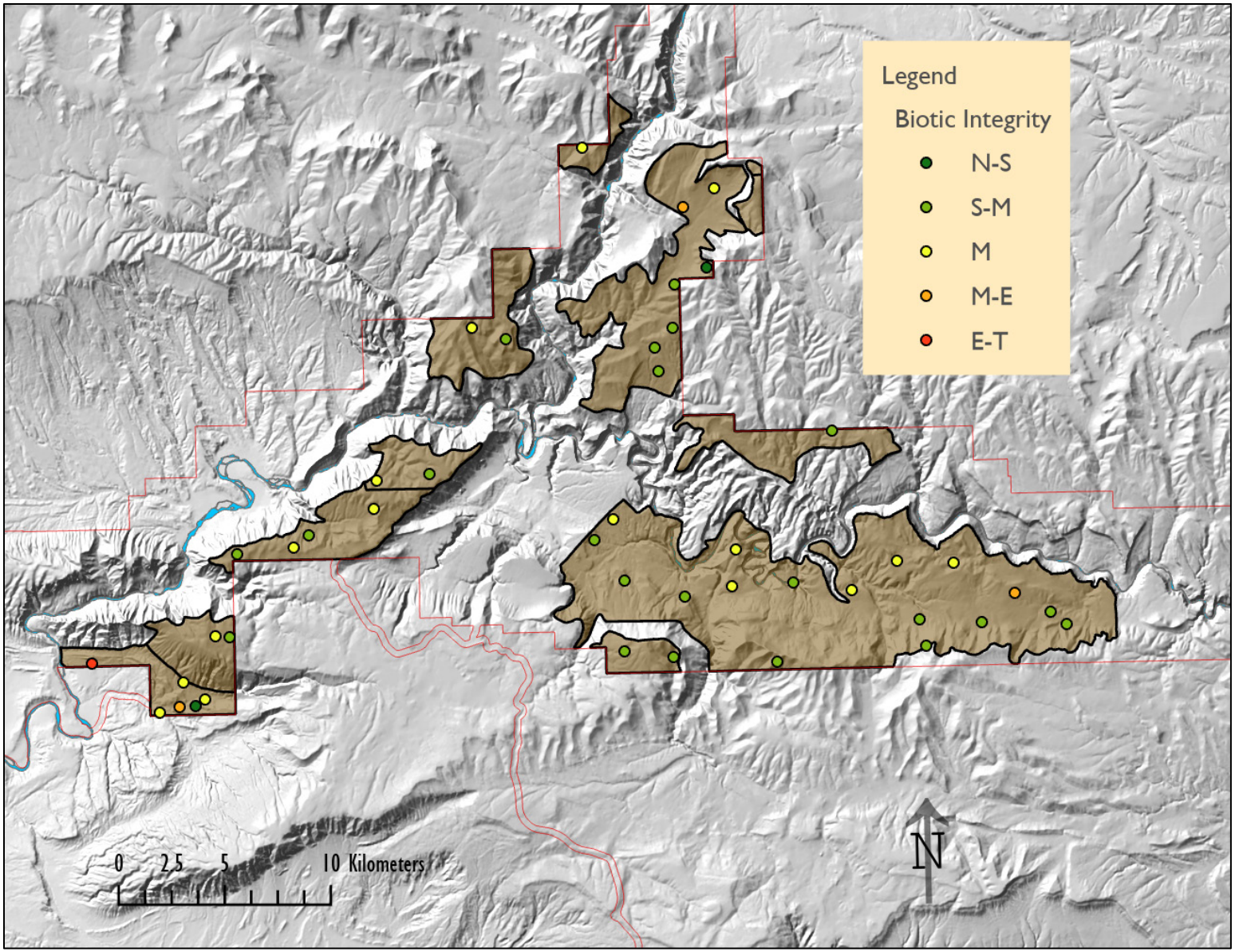

Figure A20. IIRH assessment ratings for the attribute Biotic Integrity.

Appendix B. Data

Tables B1–B4 include summary data sheets for the 17 indicators and three attributes for all sites included in the study.

Table B1. Metadata for assessment sites.

Site	Date	X	Y	Elev. (m)	Allotment	ESD code	Method
0	6/3/2019	649827	4477798	5042	Green River	R034BY216UT	IIRH
1	6/6/2019	653019	4475471	5223	Green River	R034BY239UT	IIRH
2	6/7/2019	653933	4475764	5190	Green River	R034BY006UT	IIRH
3	5/31/2019	654683	4475809	5480	Green River	R034BY239UT	IIRH
4	7/17/2019	655156	4476110	5300	Green River	R034BY006UT	IIRH
5	6/24/2019	655637	4479086	7650	Docs Valley	R047XC446UT	IIRH
6	6/24/2019	656316	4479054	7565	Docs Valley	R047XA430UT	IIRH
7	6/5/2019	656651	4482951	7928	Harpers Corner	R047XA430UT	IIRH
8	6/11/2019	660036	4483832	7476	Harpers Corner	R047XA430UT	IIRH
9	6/4/2019	663085	4485104	7709	Harpers Corner	R047XA430UT	IIRH
10	6/4/2019	663213	4486415	7972	Murray	R047XA430UT	IIRH
11	6/3/2019	665733	4486750	7655	Murray	R047XA430UT	IIRH
12	7/16/2019	667737	4493642	7730	Wild Mountain	R047XA430UT	IIRH
13	7/16/2019	669322	4493106	8075	Wild Mountain	R034BY334UT	IIRH
14	7/15/2019	669934	4496417	6935	Massey	–	DIRH
15	7/15/2019	672915	4502124	6768	Zenobia	R047XA430UT	IIRH
16	7/9/2019	679145	4500214	7193	Zenobia	R047XA430UT	IIRH
17	7/9/2019	677660	4499324	7025	Zenobia	R047XA430UT	IIRH
18	7/10/2019	678808	4496484	7930	Zenobia	R047XC460UT	IIRH
19	7/9/2019	677265	4495664	7600	Zenobia	R047XA461UT	IIRH
20	7/8/2019	677201	4493651	7500	Zenobia	R047XA430UT	IIRH
21	7/11/2019	676324	4492703	7270	Zenobia	R047XC326UT	IIRH
22	7/11/2019	676531	4491583	6900	Big Joe/ West Douglas	R047XC335UT	IIRH
23	7/10/2019	684690	4488775	6910	Round Top	R047XA430UT	IIRH
24	6/25/2019	674916	4478370	8100	Round Top	R047XA430UT	IIRH
25	6/25/2019	677219	4478132	7800	Yampa Bench	R047XA461UT	IIRH
26	6/14/2019	695746	4479668	6689	Yampa Bench	R047XA334UT	IIRH
27	6/22/2019	695032	4480228	6550	Yampa Bench	R047XA430UT	IIRH
28	6/15/2019	693310	4481120	6659	Yampa Bench	R047XC320UT	IIRH
29	6/15/2019	688852	4479903	6400	Yampa Bench	R047XC335UT	IIRH
30	6/15/2019	691773	4479780	6666	Yampa Bench	R034XY298CO	IIRH
31	6/27/2019	690419	4482541	6280	Yampa Bench	R047XC326UT	IIRH

Table B1 (continued). Metadata for assessment sites.

Site	Date	X	Y	Elev. (m)	Allotment	ESD code	Method
32	6/26/2019	689142	4478629	7950	Yampa Bench	R047XA461UT	IIRH
33	6/19/2019	685625	4481254	6050	Yampa Bench	R047XC326UT	IIRH
34	6/20/2019	687759	4482639	6270	Yampa Bench	R034XY298CO	IIRH
35	6/12/2019	683208	4481433	5315	Yampa Bench	–	DIRH
36	6/12/2019	682894	4481624	5227	Yampa Bench	R034BY212UT	IIRH
37	6/26/2019	682134	4477897	8120	Yampa Bench	R047XC335UT	IIRH
38	6/13/2019	680166	4483183	6142	Yampa Bench	R034BY239UT	IIRH
39	6/28/2019	679986	4481434	5700	Yampa Bench	R034BY233UT	IIRH
41	6/19/2019	677746	4480981	5760	Yampa Bench	R034BY259UT	IIRH
42	6/18/2019	674926	4481723	5801	Yampa Bench	R047XB312UT	IIRH
43	6/17/2019	674386	4484611	5742	Harpers Corner	R034BY225UT	IIRH
44	6/18/2019	673507	4483636	5702	Green River	R034BY212UT	IIRH
45	6/5/2019	659315	4483293	7694	Harpers Corner	R047XC446UT	IIRH
46	5/29/2018	654108	4476895	5483	Green River	R034BY233UT	IIRH

Table B2. IIRH attribute ratings for sites.

	Attribute[1,2]		
Site	S	H	B
0	N-S	M	E-T
1	N-S	N-S	M
2	N-S	S-M	M-E
3	N-S	N-S	N-S
4	S-M	S-M	M
5	N-S	N-S	M
6	N-S	N-S	S-M
7	N-S	N-S	S-M
8	N-S	S-M	S-M
9	N-S	S-M	M
10	S-M	S-M	M
11	N-S	N-S	S-M
12	N-S	N-S	M
13	N-S	N-S	S-M
15	N-S	N-S	M

[1] Attributes: S = Soil/site stability; H = Hydrologic function; B = Biotic integrity.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B2 (continued). IIRH attribute ratings for sites.

Site	Attribute[1,2]		
	S	H	B
16	N-S	N-S	M
17	N-S	S-M	M-E
18	N-S	N-S	N-S
19	N-S	N-S	S-M
20	N-S	N-S	S-M
21	N-S	S-M	S-M
22	N-S	N-S	S-M
23	N-S	N-S	S-M
24	N-S	N-S	S-M
25	N-S	N-S	S-M
26	N-S	N-S	S-M
27	N-S	N-S	S-M
28	N-S	S-M	M-E
29	N-S	N-S	S-M
30	N-S	N-S	S-M
31	S-M	S-M	M
32	N-S	N-S	S-M
33	N-S	N-S	M
34	N-S	N-S	M
36	N-S	N-S	S-M
37	N-S	N-S	S-M
38	S-M	S-M	M
39	N-S	N-S	M
41	N-S	N-S	S-M
42	S-M	S-M	S-M
43	N-S	N-S	M
44	N-S	S-M	S-M
45	N-S	S-M	M
46	N-S	N-S	M

[1] Attributes: S = Soil/site stability; H = Hydrologic function; B = Biotic integrity.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B3. IIRH indicator (#1–9) ratings for assessment sites.

Site	Indicator[1,2]								
	1	2	3	4	5	6	7	8	9
0	N-S	N-S	N-S	S-M	N-S	N-S	N-S	M-E	N-S
1	N-S	M	N-S	N-S	N-S	N-S	N-S	N-S	N-S
2	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
3	N-S	S-M	N-S	N-S	N-S	N-S	N-S	N-S	N-S
4	N-S	M	S-M	S-M	S-M	N-S	N-S	N-S	N-S
5	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
6	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
7	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
8	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
9	N-S	N-S	N-S	S-M	N-S	N-S	N-S	S-M	S-M
10	N-S	M	N-S	S-M	N-S	N-S	N-S	M	S-M
11	N-S	N-S	N-S	N-S	N-S	N-S	N-S	M	N-S
12	N-S	N-S	N-S	N-S	N-S	N-S	N-S	M	N-S
13	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
15	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
16	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
17	N-S	S-M	N-S	N-S	N-S	N-S	N-S	N-S	N-S
18	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
19	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
20	N-S	N-S	N-S	N-S	N-S	N-S	N-S	M-E	N-S
21	N-S	M	S-M	N-S	N-S	N-S	N-S	N-S	N-S
22	N-S	S-M	S-M	N-S	N-S	N-S	N-S	N-S	N-S
23	N-S	N-S	M	N-S	N-S	N-S	N-S	S-M	N-S
24	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
25	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
26	N-S	N-S	S-M	N-S	N-S	N-S	N-S	N-S	N-S
27	N-S	S-M	N-S	N-S	N-S	N-S	N-S	N-S	N-S
28	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
29	N-S	S-M	M	N-S	N-S	N-S	N-S	N-S	N-S
30	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
31	S-M	M	S-M	N-S	N-S	N-S	N-S	N-S	N-S
32	N-S	N-S	N-S	N-S	N-S	N-S	N-S	S-M	N-S
33	N-S	N-S	N-S	S-M	N-S	N-S	N-S	N-S	N-S

[1] See Table 1 for indicator names.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B3 (continued). IIRH indicator (#1–9) ratings for assessment sites.

Site	Indicator[1,2]								
	1	2	3	4	5	6	7	8	9
34	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
36	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
37	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
38	N-S	M-E	N-S	N-S	N-S	N-S	N-S	N-S	N-S
39	N-S	S-M	N-S	N-S	N-S	N-S	N-S	N-S	N-S
41	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
42	S-M	N-S	N-S	M	S-M	N-S	M	S-M	N-S
43	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S	N-S
44	N-S	S-M	N-S	M	N-S	N-S	N-S	N-S	N-S
45	N-S	M	N-S	M	N-S	N-S	N-S	N-S	N-S
46	N-S	M	N-S	N-S	N-S	N-S	N-S	N-S	N-S

[1] See Table 1 for indicator names.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B4. IIRH indicator (#10–17) ratings for sites.

Site	Indicator[1,2]							
	10	11	12	13	14	15	16	17
0	E-T	N-S	E-T	N-S	M-E	M	E-T	M
1	N-S	N-S	M	N-S	S-M	N-S	M-E	N-S
2	M	S-M	M-E	N-S	M-E	N-S	E-T	N-S
3	N-S	N-S	S-M	N-S	N-S	S-M	N-S	N-S
4	S-M	N-S	M-E	S-M	S-M	N-S	E-T	N-S
5	N-S	N-S	E-T	N-S	N-S	N-S	E-T	N-S
6	N-S	S-M	M	N-S	N-S	M	M-E	N-S
7	N-S	N-S	M	N-S	M	N-S	S-M	N-S
8	N-S	S-M	M	N-S	M	N-S	N-S	N-S
9	M	N-S	M	N-S	N-S	M	M-E	N-S
10	N-S	N-S	M-E	N-S	S-M	N-S	S-M	N-S
11	N-S	N-S	N-S	N-S	S-M	M	S-M	N-S
12	N-S	S-M	M-E	N-S	M	M	M-E	N-S
13	N-S	N-S	M	S-M	M	N-S	M	N-S
15	N-S	S-M	M	N-S	M	E-T	M	N-S
16	S-M	N-S	M-E	N-S	S-M	S-M	M-E	N-S

[1] See Table 1 for indicator names.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Table B4 (continued). IIRH indicator (#10–17) ratings for sites.

Site	Indicator[1,2]							
	10	**11**	**12**	**13**	**14**	**15**	**16**	**17**
17	M	M	E-T	N-S	S-M	E-T	M	N-S
18	N-S	N-S	S-M	N-S	S-M	M	S-M	N-S
19	N-S	N-S	M-E	N-S	N-S	M-E	M-E	N-S
20	N-S	N-S	S-M	N-S	S-M	M	S-M	N-S
21	M	N-S	M	N-S	S-M	M-E	M	N-S
22	S-M	N-S	M-E	N-S	N-S	M	M	S-M
23	N-S	N-S	M-E	N-S	M	M	M-E	N-S
24	N-S	N-S	M	N-S	M-E	N-S	N-S	N-S
25	N-S	N-S	M	N-S	S-M	N-S	S-M	N-S
26	N-S	S-M	S-M	N-S	S-M	S-M	M	N-S
27	M	N-S	M	N-S	N-S	M-E	M	N-S
28	M-E	N-S	E-T	M-E	M	M	E-T	N-S
29	N-S	N-S	M	N-S	S-M	S-M	M-E	N-S
30	N-S	N-S	M-E	N-S	S-M	N-S	M-E	N-S
31	M	N-S	M	S-M	N-S	M	M	N-S
32	S-M	N-S	M	N-S	N-S	M	M	N-S
33	N-S	N-S	E-T	N-S	M	M	E-T	N-S
34	N-S	N-S	M-E	N-S	S-M	S-M	M-E	N-S
36	S-M	N-S	M-E	N-S	N-S	N-S	M-E	S-M
37	N-S	N-S	M-E	N-S	S-M	N-S	M-E	N-S
38	N-S	N-S	M-E	N-S	S-M	S-M	M-E	S-M
39	N-S	N-S	M-E	N-S	S-M	N-S	M	S-M
41	N-S	N-S	M	N-S	M	N-S	S-M	N-S
42	S-M	N-S	M-E	N-S	N-S	N-S	M	N-S
43	S-M	N-S	M	N-S	S-M	N-S	M-E	S-M
44	S-M	N-S	M	N-S	N-S	S-M	M	N-S
45	M	N-S	M-E	N-S	M	N-S	M-E	N-S
46	N-S	N-S	M-E	N-S	N-S	M-E	S-M	N-S

[1] See Table 1 for indicator names.

[2] Ratings: N-S = None to slight; S-M = Slight to moderate; M = Moderate; M-E = Moderate to extreme; E-T = Extreme to total.

Appendix C. Ecological Site Descriptions

The ecological site descriptions used in this study are shown in Table C1.

Table C1. The ESDs used in the IIRH assessments.

ESD Code	ESD Name
R034BY006UT	Alkali Flat (Greasewood)
R034BY212UT	Semidesert Loam (Wyoming Big Sagebrush)
R034BY216UT	Semidesert Sandy Loam
R034BY225UT	Semidesert Shallow Loam (Wyoming Big Sagebrush)
R034BY233UT	Semidesert Shallow Loam (Utah Juniper-Pinyon)
R034BY239UT	Semidesert Shallow Sandy Loam (Utah Juniper/Two-Needle Pinyon)
R034BY259UT	Semidesert Very Steep Shallow Loam (Pinyon-Juniper)
R034BY334UT	Upland Stony Loam (Wyoming Big Sagebrush)
R034XY298CO	Rolling Loam
R047XA430UT	Mountain Loam (Mountain Big Sagebrush)
R047XA461UT	Mountain Stony Loam
R047XB312UT	Upland Shallow Clay (Pinyon-Utah Juniper)
R047XC320UT	Upland Shallow Loam (Black Sagebrush)
R047XC326UT	Upland Shallow Loam (Pinyon-Juniper)
R047XC335UT	Upland Stony Loam (Pinyon – Utah Juniper)
R047XC446UT	Mountain Shallow Loam (Mountain Big Sagebrush)
R047XC460UT	Mountain Stony Loam (Shrub)

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