USER GUIDE

Invasion Severity Index

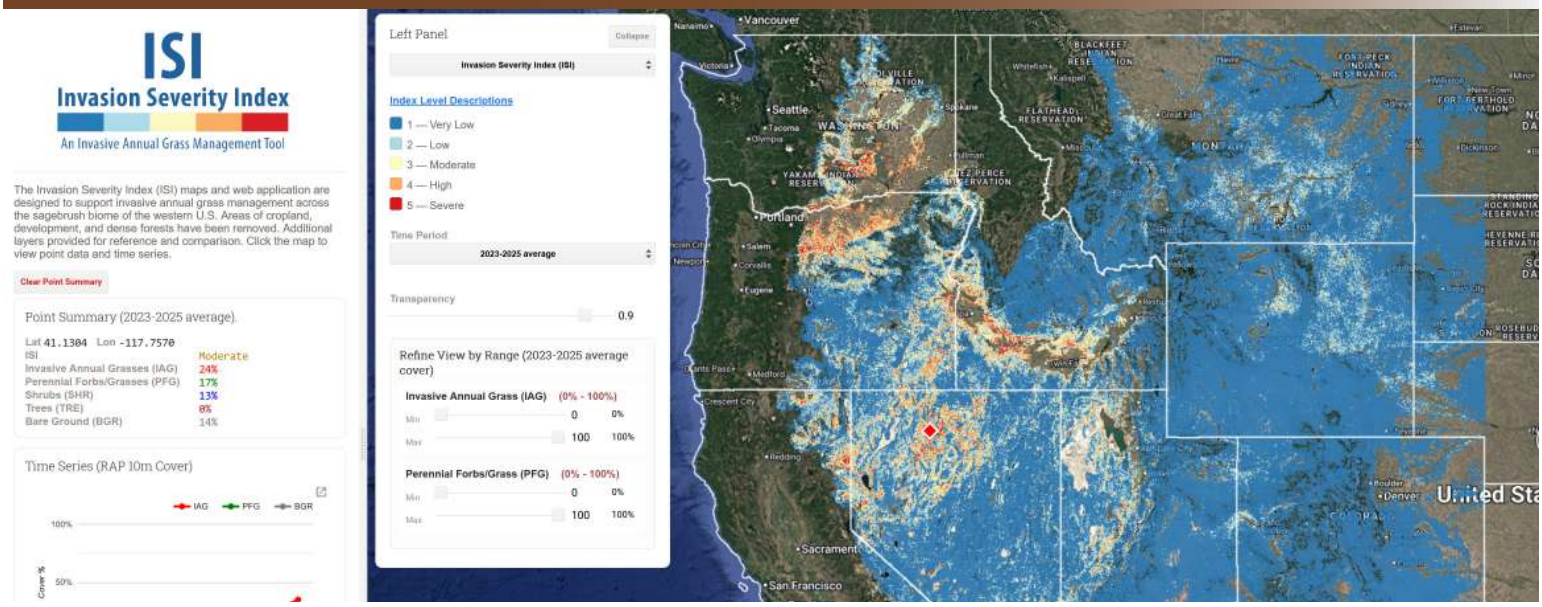
Maps and Web App to Support Strategic Annual Grass Management

Prototype Version 1.0 | March 2026

ISI
Invasion Severity Index

UNIVERSITY OF MONTANA

WORKING LANDS FOR WILDLIFE



Purpose

Invasive annual grasses (IAG) pose one of the most significant and rapidly expanding threats to rangeland health across the western United States. These exotic grasses include cheatgrass, medusahead, and ventenata, and when they overtake rangelands, they alter fire regimes, reduce habitat quality, and diminish long-term productivity. Developing effective management strategies and treatment prescriptions requires an understanding of the degree of invasion in an ecological context, including site potential, competitive balance with perennial grasses and forbs, and overall productivity.

The Invasion Severity Index (ISI) maps and web app provides a simple, interactive platform to help conservation planners and land managers prioritize and plan invasive annual grass treatments across the sagebrush biome.

Using cutting-edge Rangeland Analysis Platform (RAP) 10-meter resolution data, ISI maps depict five invasion levels linked to specific management strategies and actions. The ISI assesses the severity of annual grass invasion relative to perennial forb and grass cover and bare ground, providing an ecologically grounded framework for prioritizing management and aligning treatment techniques with site resilience and recovery potential. Other reference layers and features allow users to understand landscape context, consider trends through time, visualize specific vegetative thresholds, and generate time series charts.

This release represents a prototype designed to support conservation planners and land managers in making more informed, landscape-scale decisions. Ongoing refinement is anticipated, and user feedback is encouraged to improve future versions and ensure the tool remains scientifically sound, practical, and responsive to management needs.

Authors

Derek Tilley[1], Jeremy Maestas[2], Joe Smith[1], Kristopher Mueller[1], Scott Morford[1] David Naugle[1]
[1]Working Lands for Wildlife, University of Montana, Missoula, MT
[2]USDA Natural Resources Conservation Service, Bend, OR

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Introduction

Effective, long-term weed management doesn't just require managing against something; it also requires managing for something. Percent cover of invasive species is a useful metric for describing the extent of annual grass presence (Mealor et al., 2013; Pellant et al., 2020); however, it does not provide sufficient information to make specific management decisions. Equally important is the balance between invasive annual grasses and desired perennial grasses (Sheley and Smith, 2012, Mealor et al., 2013; Creutzberg et al., 2025) because perennial grasses play a critical ecological role by capturing soil moisture, nutrients, light, and belowground space that invasive annual grasses require to re-establish each year. Sites with abundant perennial grasses are more resistant to invasion following disturbance and more likely to respond favorably to management or restoration treatments (Chambers et al., 2007; Anthony et al., 2023; Smith et al., 2021).

Recent advances in remote sensing—specifically the availability of the Rangeland Analysis Platform (RAP) 10-meter resolution data—provide new opportunities to visualize and assess the relationship between various plant functional groups at management-relevant scales (Allred et al., 2025). For the first time, RAP 10-m provides an invasive annual grass (IAG) functional group layer that estimates the percent cover of the ten most common invasive annual grass species in the western U.S. This allows invasive annual grass cover specifically to be compared to desired perennials and other indicators to depict invasion severity and recovery potential at relatively fine scales through time.

The Invasion Severity Index (ISI) maps and web app leverages this new spatial data and provides a suite of products to support invasive annual grass project planning and decision-making across the sagebrush biome. Depicted in five invasion levels linked to specific management strategies and actions, the ISI provides an ecologically grounded framework for prioritizing management and aligning treatment techniques with site resilience and recovery potential.

The maps and web app are not intended to serve as a one-stop solution, but rather as one tool among many available to conservation planners and partners. They are most effective when used in conjunction with complementary planning frameworks such as the Sagebrush Conservation Design, Threat-Based Strategic Conservation, and when informed by local expertise and relevant datasets. The University of Wyoming's IMAGINE partnership provides in-depth training and resources that can help users increase their knowledge of how to plan effective treatments, and this web app is designed to be used with their guiding principles in mind.

Principles of Effective IAG Management

Effective management of invasive annual grasses requires a strategic, ecologically based approach. The five guiding principles outlined below help planners and land managers move beyond reactive treatments and toward proactive, landscape-scale strategies that protect healthy rangelands, slow invasion, and maintain ecosystem services (Fig 1). Together, they highlight the importance of acting before thresholds are crossed, leveraging ecological processes, considering landscape context, working collaboratively across boundaries, and staying engaged over the long term to achieve durable management outcomes.

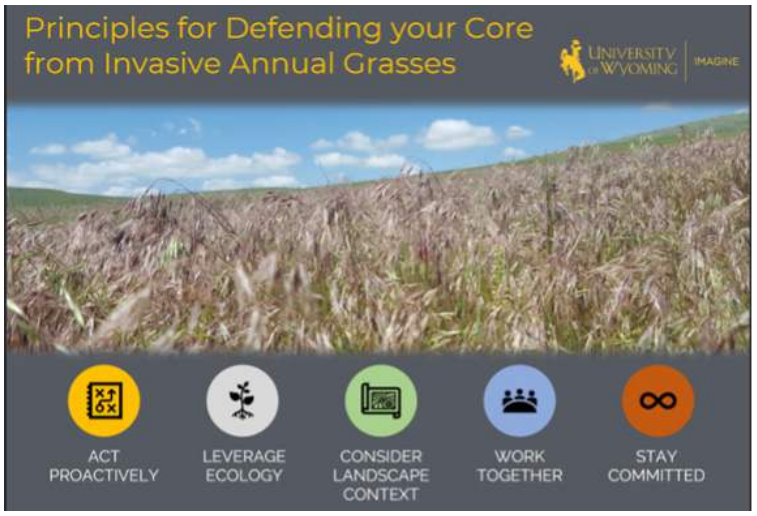


Figure 1. Follow the five principles of effective invasive annual grass management: act proactively, leverage ecology, consider landscape context, work together, and stay committed. Credit: UW IMAGINE

Act Proactively: Act early and decisively. Do not accept the idea that invasive annual grasses cannot be managed. Proactive action means targeting leverage points—places where modest, timely effort can slow or reverse invasion and protect ecosystem services, even in already invaded areas. Priorities include preventing spread into intact core areas, rapidly controlling new infestations through early detection and rapid response, and reducing seed sources. Most importantly, act before annual grasses cross ecological thresholds and become ecosystem "drivers," when control becomes far more costly and less effective.

Leverage Ecology: Understanding how invasive annual grasses grow, reproduce, and interact with their environment allows managers to target vulnerable life stages and apply strategies suited to specific conditions. Long-term control depends on breaking the seed-production cycle, limiting new inputs to the seed bank, and reducing viable seeds in the soil while simultaneously maintaining or enhancing desired vegetation to build site resilience. Connecting invasion processes and plant ecology at a landscape scale helps identify risks and opportunities for proactive management that can prevent lasting ecosystem change.

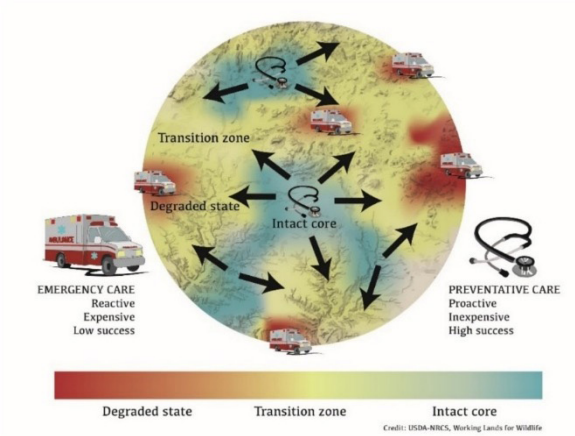


Figure 2. Defend and grow your core by managing and protecting high-quality rangelands before they become degraded by invasion. Zoom out to see the larger landscape context before implementing treatment actions.

Consider Landscape Context: Understanding the landscape surrounding your management unit helps managers mitigate risks from adjacent lands, better manage expectations for long-term outcomes, and prioritize efforts to maintain high-quality rangelands. Rather than focusing only on heavily impacted areas, a "defend and grow your core" approach emphasizes conserving areas of high value before they have been invaded (Fig. 2). Examining the surrounding areas allows managers to evaluate how their actions fit within the larger landscape.

Work Together: Effective invasive species management depends on teamwork because invasions are contagious, crossing ownership and jurisdictional boundaries. Addressing them requires shared information, coordinated planning, and a landscape-level perspective beyond any single ranch or management unit. Collaboration brings diverse knowledge, ideas, and resources, enabling stronger strategies. While individual ranch teams can manage their own lands well, large-scale invasions demand diverse partnerships among landowners, agencies, scientists, and others to succeed.

Stay Committed: Invasive annual grass management is a long-term effort, not a one-time fix. While early enthusiasm in collaborative efforts may be high, sustained success requires intentional planning and engagement—such as a clear mission, written strategy, celebration of successes, and inclusion of new members. Because teams and conditions change over time and annual grasses can rapidly rebound, regularly updated plans are essential to maintain momentum and prevent reinvasion after short-term gains.

Introducing the Invasion Severity Index

The Invasion Severity Index (ISI) was created to assess the severity of annual grass invasion relative to site recovery potential. ISI maps provide a lens for understanding invasive annual grass dynamics and impacts relative to other key rangeland functional groups through space and time, at a management-relevant scale, while accounting for variations in site productivity across the sagebrush biome. The maps are intended to help practitioners put the principles of effective invasive annual grass management into practice by:

- Creating a rapid baseline inventory of herbaceous conditions to inform treatment prioritization, delineation, and prescriptions (as a starting point to verify in the field),
- Providing a tool to facilitate communication with landowners and managers about conditions, goals, alternative treatments, and management expectations,
- Enabling remote monitoring to assess treatment efficacy and the need for follow-up management.

Below is a description of the ISI inputs and formula so users can better understand what's 'under the hood.'

RAP 10-m Cover Data Inputs

The RAP 10-m cover data provide estimates of rangeland functional group indicators at a 10-m x 10-m pixel scale (about half a tennis court) from 2018 to present (Allred et al., 2025). This allows remotely sensed vegetation data to capture meaningful within-project variability, producing maps that align with how, where, and when management decisions are made. RAP 10-m also generates new indicators designed to capture specific groups of species, including invasive annual grass, sagebrush, and pinyon-juniper species. RAP 10-m cover data use satellite data from the European Space Agency Sentinel-2 missions, instead of Landsat, which reduces errors found in RAP 30-m products.

We use three RAP 10-m functional groups to generate the ISI: invasive annual grass, perennial forbs and grass, and bare ground.

Invasive Annual Grass Cover

Percent cover of invasive annual grasses is one of the most important metrics for developing an effective management plan because it directly reflects both current site condition, impacts, and management strategies and actions. Percent cover also serves as a practical indicator of fuel continuity and fire risk, particularly in sagebrush and mixed-grass systems where annual grasses can shorten fire return intervals. Low cover levels may signal an opportunity for rapid intervention and recovery with relatively light inputs, while high cover levels often indicate a need for more intensive, multi-year strategies and realistic expectations about restoration outcomes.

However, percent cover alone is not enough to guide management decisions. It must be evaluated in the context of site recovery potential (biotic and abiotic).

Perennial Forbs and Grass Cover

Percent cover of perennial grasses and forbs is an important consideration because it reflects the competitive strength and biotic recovery potential after invasive grasses are removed. Perennial grasses in particular provide biological resistance that limits invasive annual grass establishment by occupying space (above and below ground), capturing soil moisture, and stabilizing nutrient cycles. Higher perennial cover generally signals greater resilience to disturbance, reduced likelihood of dominance by invasive annuals, and a stronger foundation for long-term ecosystem function. Conversely, low perennial cover often indicates diminished competition, reduced seed sources, and a narrower margin for successful recovery without additional revegetation. When paired with invasive annual grass cover, perennial cover helps managers assess not just how invaded a site is, but how capable it is of responding to treatment and sustaining desired conditions over time.

Bare Ground Cover

One significant challenge in mapping the relationship of invasive annuals to perennials across a vast and diverse biome is the variation in precipitation patterns, temperatures, and soil conditions that drive inherent site potential and risks. Site productivity, plant density, and expected cover vary substantially across the landscape making it impractical to use a rule-of-thumb or threshold for assessing invasion impacts. For example, in southern Nevada, where annual precipitation may range from 5 to 8 inches, productivity is naturally low and total vegetative cover is limited. In contrast, rhizomatous grass–dominated systems in eastern Wyoming receive higher precipitation and can approach full vegetative cover under favorable conditions.

Because of this variability, the balance of invasive annual grasses and perennial functional groups alone is not a reliable predictor of invasion impacts or appropriate management strategies and actions. Abiotic factors must also be considered (Urza et al., 2024). To better account for differences in inherent productivity and site invasibility, we incorporate bare ground into the ISI, allowing

management recommendations to be interpreted within the ecological capacity of each site. Bare ground is an under-appreciated, but critically important, part of determining rangeland dynamics especially as it relates to invasive annuals that affect fuel continuity and fire frequency.

Calculating the ISI

We use the natural log-transformed ratio of invasive annual grass cover (IAG) to the sum of perennial forb and grass (PFG) and bare ground (BGR) cover as a continuous metric of the severity of invasion to create an Invasion Severity Index (ISI) following the equation.

$$\mathrm{ISI} = \ln\left(\frac{\mathrm{IAG} + \varepsilon}{\mathrm{PFG} + \mathrm{BGR} + \varepsilon}\right)$$

The numerator, IAG, is the total cover of invasive annual grasses. The denominators, PFG and BGR, are the desired functional groups. A small constant (ε = 0.1) is added to the numerator and denominator to avoid mathematical errors when cover values are zero. The natural log-transformation normalizes this ratio and simplifies choosing breaks between categories. This index is designed to highlight areas where invasive annual grasses make up a large fraction of the understory while at the same time de-emphasizing areas where total herbaceous cover is very low. Index values above zero indicate cover of invasive annual grasses exceeds cover of bare ground and perennials, and vice-versa. We categorized ISI into five levels by using evenly spaced breaks of width 0.75, centered around zero. Figure 4 provides a random sample of data pixel values by category.

The Five ISI Levels: Linking Invasion Severity to Management

ISI maps are presented in five levels linked directly to typical management strategies and actions (Table 1). These categories simplify complex environmental conditions into meaningful levels designed to help practitioners with treatment delineation, selecting appropriate actions, setting site-appropriate goals and expectations, and tracking change through time.

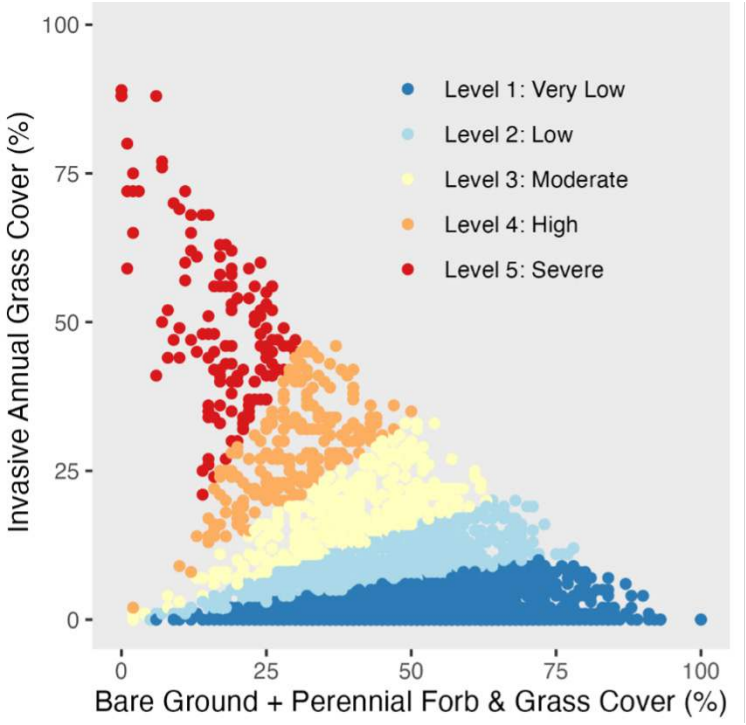


Figure 4. Invasion states show a ratio of percent cover of invasive annual grasses to perennial forbs and grasses plus bare ground cover. Each pixel indicates the cover ratio value of an actual site. Data points were derived from 3,145 random pixels of natural vegetation where tree cover was <20%.

The category breaks do not represent fixed ecological thresholds; rather, they are intentionally simplified divisions that help managers interpret patterns on the landscape and prioritize actions in a consistent, transparent way. Accordingly, the associated management strategies and actions are intended as suggestions, not rigid prescriptions, and should be adapted to site-specific conditions, management objectives, and available resources. Use the maps with best professional expertise and field observations to adjust as needed.

Because the levels depict invasion severity as it relates to management strategies, some areas may be categorized differently than one might expect. For example, a site may have >30% IAG cover but still be categorized as a moderate ISI provided it also has a relatively high (~50%) perennial forb and grass cover. In this case, the exact cover of invasive annuals is less important than the proportion of perennials in determining what management action would likely be applied on the ground. Again, conservation planners and land managers should always use local expertise and knowledge to help inform actual prescriptions.

Below is a description of the typical scenario represented by each ISI level.

	1 - Very Low	2 - Low	3 - Moderate	4 - High	5 - Severe
Typical Management Strategy & Actions	**MAINTAIN** Prevention, EDRR, eradicate early invasions, spray-and -release perennials (spot)		**IMPROVE** Spray-and-release perennials (broadcast), repeated treatments to deplete IAG seed bank, localized seeding as needed		**REVEGETATE OR CONTAIN** Site prep and seeding more likely, fuel breaks, grazing to reduce fine fuels
Description	**IAG absent or cover is very low relative to PFG+BGR**	**IAG cover low relative to PFG + BGR Cover**	**Moderate IAG Cover relative to PFG+BGR cover**	**High IAG cover relative to PFG+BGR cover**	**IAG cover dominant relative to PFG+BGR cover**
Impacts	**Limited impacts on site function**	**Minor impacts on site function, fire risk increasing**	**Moderate impacts on site functions, fire risk elevated**	**Major impacts on site function, fire risk greatly elevated**	**Site function extremely impacted, fire risk greatly elevated**
Invasion Severity Index (ISI)	**ISI < -1.875**	**-1.875 < ISI < -1.125**	**-1.125 < ISI < -0.375**	**-0.375 < ISI < 0.375**	**ISI > 0.375**

* ISI=ln (IAG+ ε/PFG+BGR+ ε)

Table 1. Breakdown of five Invasion Severity Index (ISI) levels with associated management strategies, descriptions and mathematical range of each. Strategies are suggestions and may differ based on conditions, values, and resources available.

Level 1 – Very Low

Sites are characterized by strong dominance of perennial grasses and forbs and/or bare ground, with invasive annual grasses absent, occurring as isolated individuals, or in very low amounts within the remote-sensing modeling error (~ +3%). Ecological processes such as soil stability, nutrient cycling, and resistance to invasion remain largely intact. Invasions likely have limited impacts on site function. These areas have the highest recovery potential and lowest treatment input costs.

Management strategy emphasizes maintenance of perennials and prevention of invasions. Typical actions include maintaining grazing regimes that support perennial vigor, minimizing excessive soil disturbance, and implementing early detection and rapid response (EDRR) techniques to monitor and address any new invasive annual grass seed sources before they alter competitive relationships.

Level 2 – Low

These areas remain dominated by perennial grasses and forbs and/or bare ground but contain a measurable presence of invasive annual grasses that are beginning to establish and reproduce. Although perennials still control most site resources, resistance to invasion is reduced, and these areas represent critical transition zones with high potential for either recovery or degradation. Invasion impacts remain relatively minor on the site function, but fire risk is increased due to invasive fine fuels.

Management strategies can focus on maintenance and improvement by reversing invasion trajectories through targeted interventions. Typical actions include pre-emergent and/or early post-emergent herbicide applications to suppress invasive annual grass recruitment and eliminate the seedbank, grazing management to promote perennial grasses, and limited spot seeding where perennial cover is locally reduced. Timely intervention in these areas can often shift the ratio back toward perennial dominance with relatively low investment.

Level 3 – Moderate

These areas are defined by co-dominance of invasive annual grasses and perennial grasses and forbs and/or bare ground, resulting in an unstable ecological condition with diminished resistance and resilience. Invasive annual grasses contribute substantially to biomass and seed production, increasing competition with perennials and greatly elevating fire risk.

Management strategy focuses on improvement that typically requires a multi-year, integrated approach aimed at stabilizing the system and preventing further transition toward invasive dominance. Typical actions may include repeated pre-emergent herbicide applications to reduce

invasive annual grass establishment and seedbank, grazing management designed to reduce annuals and promote perennials (e.g., dormant season grazing), and restoration seeding where desired perennials are depleted or unlikely to recover without assistance.

Level 4 – High

These areas are dominated by invasive annual grasses most years, with perennial grasses and forbs persisting in lower-than-expected amounts for the site. Ecological processes such as fire regimes and competitive interactions are strongly altered. Recovery potential in these areas is variable and treatment outcomes less predictable.

Management strategies range from improvement and rehabilitation where site potential is high (i.e., wetter, productive sites) to containment and impact reduction, particularly to prevent spreading into adjacent areas with lower invasion levels. Typical actions include aggressive, repeated pre-emergent herbicide programs to suppress seed production, grazing management designed to reduce annual grass biomass while promoting perennials (e.g., dormant season and/or targeted grazing), and highly targeted restoration seeding in locations where site conditions and management objectives support potential perennial re-establishment.

Level 5 – Severe

These areas represent a converted condition in which invasive annual grasses overwhelmingly dominate site productivity and perennial grasses and forbs are greatly reduced compared to what is expected for the site. Ecosystem processes are fundamentally altered, and resistance and resilience are very low. Management options in these areas are constrained, and large-scale removal of invasives is questionable without sustained, intensive intervention.

Management strategy focuses primarily on containment or revegetation to reduce fine fuels and protect adjacent higher-value areas. Typical actions include grazing management designed to reduce annual grass biomass and fine fuels (e.g., dormant season and/or targeted grazing), establishment of strategic fuel breaks and greenstrips, and rehabilitation seeding to establish competitive (often introduced) perennial grasses.

Assumptions and Limitations

As with any product derived from remotely sensed satellite data, there are important assumptions and limitations that should be considered when using ISI maps to inform management decisions. Here are a few key issues to be aware of:

- Estimates of vegetative cover at the pixel level reflect modeled outputs with known inaccuracies and margins of error, particularly in heterogeneous areas, during atypical growing seasons, or where vegetation structure is complex.
- RAP invasive annual grass cover represents a combined group and cannot distinguish between individual species such as cheatgrass, medusahead, or ventenata. If land managers require species-specific information, additional inventory is required.
- RAP perennial forb and grass cover does not consider species origin. Therefore, stands of introduced or even invasive perennial plants may be represented. Landowner knowledge and field inspection can help verify what perennials occur on site. Additional planning and treatment prescriptions may be required to address perennial invasive species.
- ISI levels are not separated by sharp ecological thresholds; conditions transition gradually across the landscape, and pixels near category breaks may reasonably fall on either side depending on local conditions or year-to-year variability. For these reasons, the maps are best used as a screening and planning tool, complemented by local knowledge and field verification rather than as a stand-alone, prescriptive depiction of site conditions.
- A high-density invasive grass overstory can hide desirable perennial forbs and grasses such as Sandberg's bluegrass from remote sensing tools. Close examination may reveal a greater presence of PFGs than indicated on the maps.

An Example of How to Use the ISI

The ISI maps and web app are intended to be applied as a decision-support tool, best used in combination with other relevant information and datasets rather than in isolation. They provide a useful starting point for inventory and assessment, helping users identify

meaningful patterns and areas of interest that can then be refined through field observations, local knowledge, and site-specific data. When used this way, the maps can support realistic conversations about management costs and expectations—highlighting where proactive defense is most likely to succeed, where recovery may require sustained effort, and where re-treatment or long-term maintenance should be anticipated. By grounding planning discussions in both spatial data and on-the-ground context, the invasion levels map helps align management strategies with ecological potential.

In this section, we present a fictional scenario to highlight a possible step-by-step planning and decision-making process. Local, real-world priorities may differ. We recommend going through this exercise proactively, rather than waiting until after a fire or until funding becomes available.

Hypothetical Conservation Scenario:

- Area size: Approximately 1 section, 640 acres
- Ecological characteristics: Big sagebrush with perennial bunchgrass understory, 12 to 16-inch precipitation zone
- Goals: Improve rangeland productivity for livestock grazing and enhance habitat for sagebrush dependent wildlife

Step 1. Assess landscape context

The Sagebrush Conservation Design (SCD) helps place a potential invasive annual grass treatment site within its broader ecological context across the sagebrush biome. Rather than focusing narrowly on whether a site falls inside or outside a specific Core Sagebrush Area (CSA) or Growth Opportunity Area (GOA) boundary, managers should zoom

out to understand how the site functions within the surrounding landscape or watershed. In this example, the site is well connected to nearby CSA and GOA habitats, increasing its ecological value and strategic importance. Viewed at this broader scale, the area represents a high-value opportunity for proactive invasive annual grass management because effective treatment can help protect and reinforce intact, connected sagebrush systems. The condition of neighboring lands indicates the project area will face less pressure from invasion impacts happening outside its boundaries, resulting in a higher likelihood of long-term success.

Step 2. Assess local invasion levels

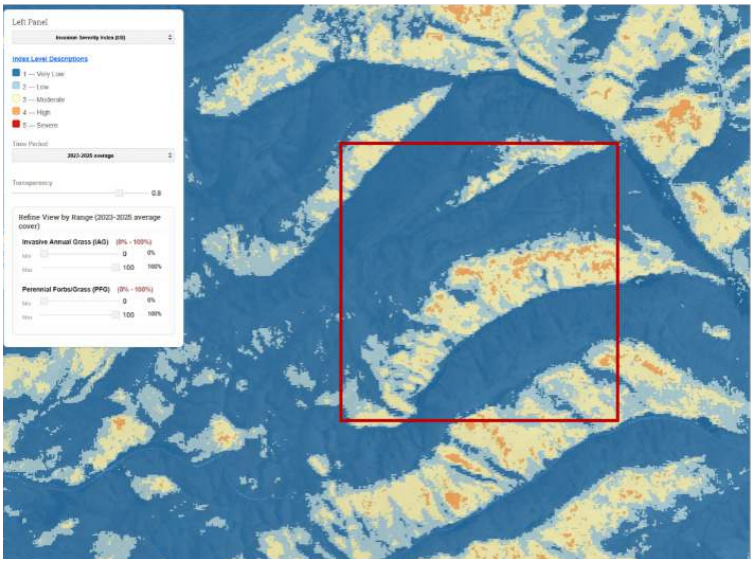
Use the ISI maps (latest 3-year average) to characterize current conditions within the planning area and establish a baseline for management decisions. Use the pixel analysis tool in multiple locations and levels to better understand functional group dynamics and relative cover. Randomly placed pixel analysis in the different ISI levels shows the following:

- Very low: PFG 55%, IAG 0%, BGR 5%
- Low: PFG 31%, IAG 9%, BGR 13%
- Moderate: PFG 21%, IAG 25%, BGR 14%
- High: PFG 23%, IAG 37%, BGR 8%
- Severe: none

Single-year snapshots can be misleading because environmental conditions, especially precipitation, can significantly change IAG cover from year to year. We recommend using the 3-year average maps for assessing 'current' conditions to more

effectively capture this variability. However, it can be useful to look at individual years to see recent flushes of IAG productivity. For example, yearly ISI analysis for this site indicates localized areas of severe invasion in 2018, 2020, 2022, and 2023 with 2022 being especially high.

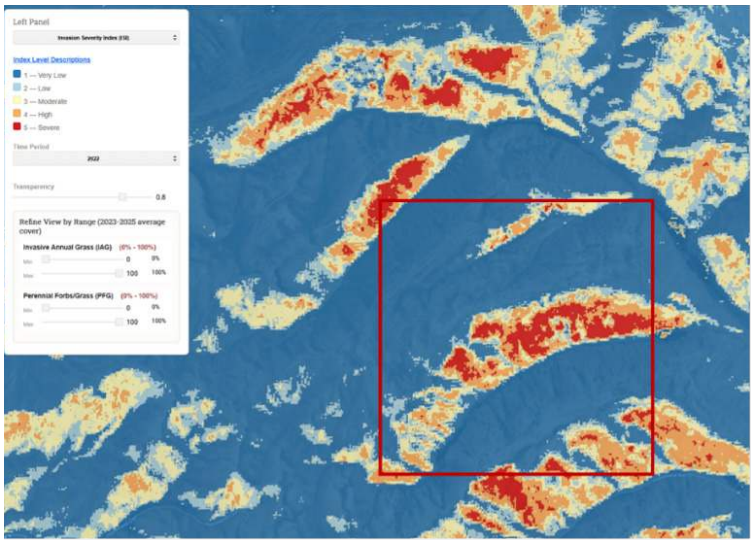
Adjusting the minimum threshold for PFGs to 20% reveals some areas not meeting the threshold on invaded south-facing slopes. This may indicate a significant degradation of the plant community, or it may be an indicator of low productivity due to abiotic factors, (south facing and shallow soils). This information is critical to decision making regarding the need for revegetation. A site visit or checking Web Soil Survey can answer these questions.



Step 3. Divide the area into management subunits

Treatment areas are designated by grouping the landscape into management-sized units that reflect operational scale, access, and feasible treatment implementation rather than attempting to isolate individual ISI levels at the pixel level. As a result, many units contain a mixture of ISI levels, which is both expected and appropriate for planning purposes.

The size and relative homogeneity of these units depend largely on management capacity, treatment objectives, and available resources; smaller operations or those with greater flexibility

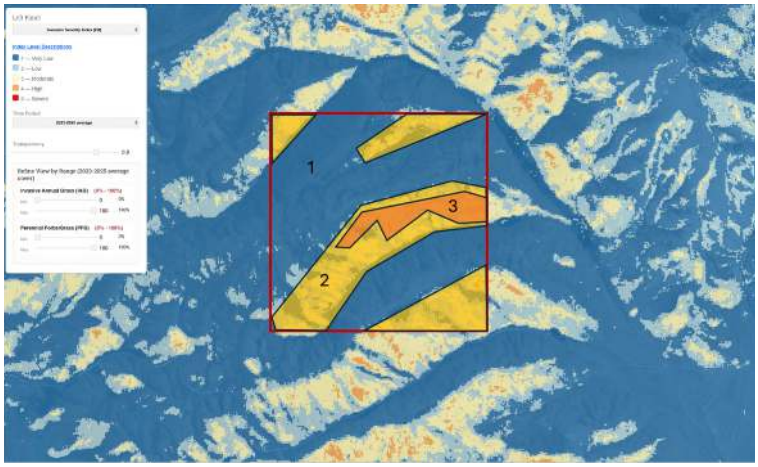


may be able to delineate more finely resolved units, while larger projects often require broader groupings. Importantly, attempting to plan treatments at overly fine spatial scales can be misleading and counterproductive, as it may obscure broader patterns and create unrealistic expectations for precision. Instead, effective planning balances spatial detail with operational practicality, using invasion levels to inform priorities and strategies at a scale that supports implementation and adaptive management. Refine management subunits based on field observation and local knowledge whenever possible.

Step 4. Determine appropriate management actions and objectives

Management objectives should be set with a clear understanding that treatments are intended to shift areas to a more favorable ISI level, not necessarily to restore them to an intact, reference condition. Because ISI levels reflect underlying changes in competitive balance, seed banks, and ecosystem processes, large level jumps are rarely realistic within a single treatment cycle.

For example, areas dominated by invasive annual grasses (Level 5) are very unlikely to transition directly to perennial dominance (Level 1), and even moving from mixed dominance (Level 3) to Level 1 typically requires multiple years of sustained management and favorable conditions. More realistic objectives often involve incremental

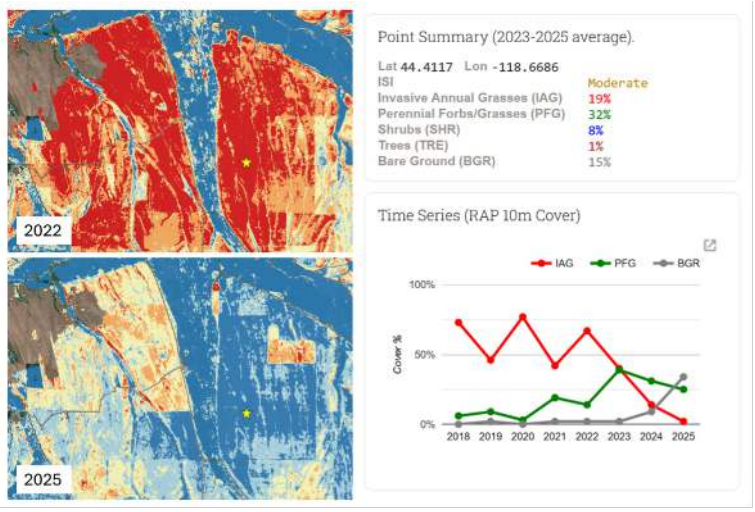


improvements—such as moving a site from Level 5 to Level 4, or from Level 3 to Level 2—where invasive pressure is reduced and perennial function is stabilized.

Setting goals around achievable level transitions helps align management actions, timelines, and budgets with ecological reality, and provides a clearer basis for evaluating treatment success.

Step 5. Implement and evaluate treatments

The ISI maps and web app provide a practical tool for monitoring and evaluating the effectiveness of invasive annual grass treatments over time. By comparing pre- and post-treatment ISI level classifications, managers can assess whether treatments are producing the intended shift toward more favorable levels, such as reduced invasive annual dominance or stabilized perennial cover. The RAP 10-m spatial resolution substantially improves the ability to detect treatment responses and boundary changes within treated areas, making it far more suitable for before-and-after comparisons than the earlier RAP 30-m products. This increased spatial accuracy allows managers to more confidently link observed changes to specific treatments, determine if objectives are being met, and assess when re-treatment might be appropriate.



Treatment Unit	Current ISI Level	Desired Future ISI Level	Strategy	Possible Treatment RX
1	Level 1	Level 1	Maintain	Prevention, EDRR, spray-and-release perennials (spot/broadcast) where needed
2	Level 2-3	Level 1	Improve	Spray-and-release perennials (broadcast) with pre-emergent chemical
3	Level 4-5	Level 3	Improve, Revegetate	Spray-and-release perennials (broadcast) with pre-emergent chemical; revetation

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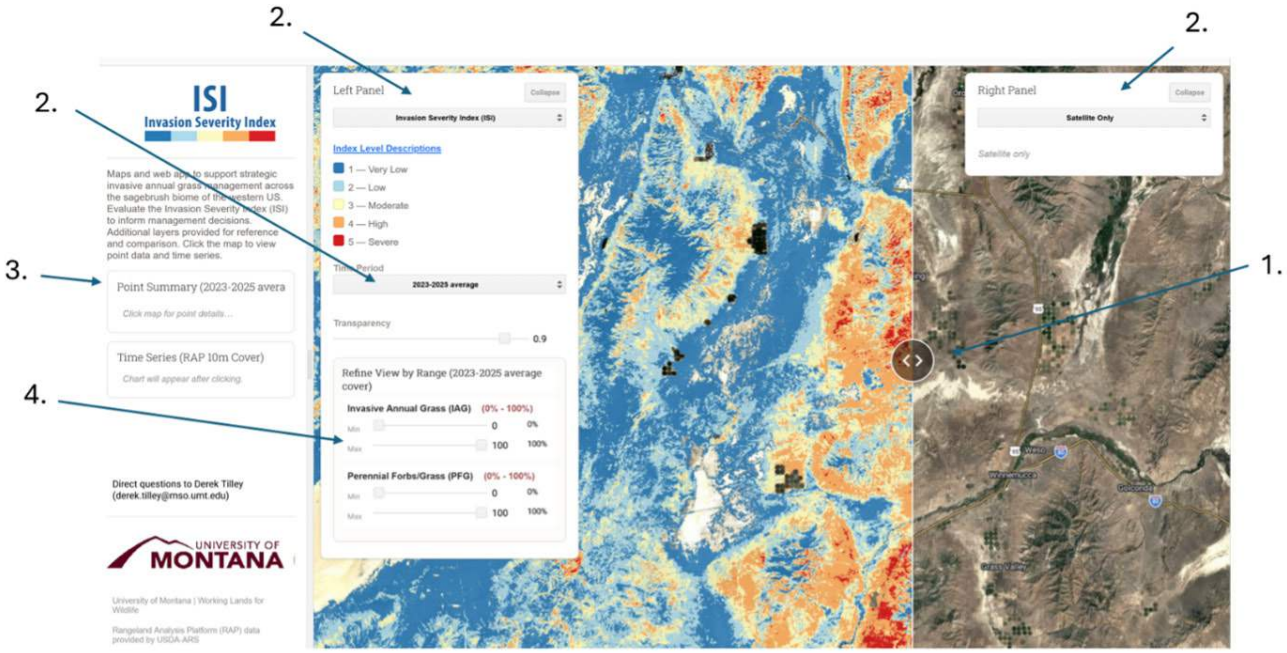
Appendix

Navigating the web app

This Google Earth Engine web app version is a prototype offering basic features and functions to help with invasive grass management planning.

Scroll: Press and hold the left-click button on the mouse to scroll around the screen.

Zoom: Zoom in and out using the mouse roller wheel or by pressing Ctrl + or Ctrl – on the keyboard. You can also zoom using the +|- button on the top left of the map window.

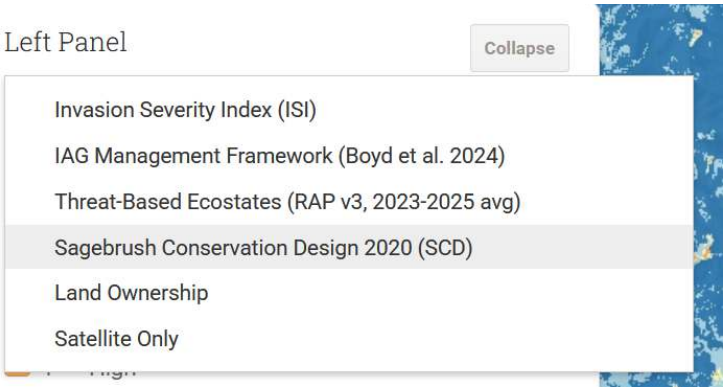


Panels

The screen is divided into two panels to allow the user to toggle between layers simultaneously. A slider bar **(1)** can be moved side to side while left clicking on the mouse.

Layers

An expandable box of available layers is located within the Left and Right Panel boxes **(2)**. These include the ISI, Interpreting Indicators of Rangeland Health (IIRH) (Pellant et al., 2020), derived from 10-m RAP, invasive annual grass and perennial forb and grass trends (2018-2025), the Invasive Annual Grass Management Framework (Boyd et al., 2024), the Sagebrush Conservation Design (Doherty et al., 2022), as well as land ownership, and satellite view. Layers are static with non-selectable features. All layers except the satellite only layer contain an adjustable transparency slider.



Invasion Severity Index: The ISI layer has several features to enhance functionality.

- **Index Level Descriptions:** A hyperlink is available to send the user to a table that provides ISI level descriptions, ecological impacts, and management strategies.
- **Time Period:** ISI can be viewed as an average spanning 2023-2025, or by individual years.
- **ISI Range:** IAG and PFG cover ranges can be adjusted using Min/Max slider bars located in the appropriate Panel box **(4)**.

IAG Management Framework: Boyd et al. (2024) divides rangelands into three strategic IAG priorities (Maintain, Improve, and Contain) by combining three inputs, 1) current annual herbaceous cover, 2) invasion risk, and 3) potential loss of ecological integrity.

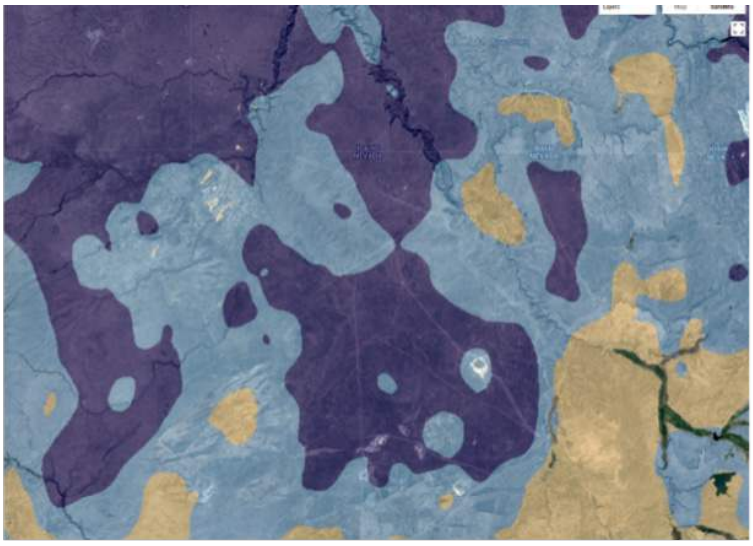
Threat-Based Ecostates: Threat-based ecostate maps (Creutzberg et al. 2025) offer a comprehensive assessment of sagebrush rangeland condition and trends across the sagebrush biome, applying the principles of Threat-Based Land Management. Ecostates classify vegetation into broad condition categories based on dominant ecosystem threats, including invasive annual grasses, conifer expansion, and wildfire.

Sagebrush Conservation Design (SCD): Doherty et al. (2022) rated sagebrush ecological integrity (SEI) to identify Core Sagebrush Areas (CSAs), Growth Opportunity Areas (GOAs), and Other Rangeland Areas (ORAs). High integrity areas were those with abundant sagebrush and perennial grass/forb cover and with low levels of annual grass/forb cover, minimal conifers, and minimal human modification.

The SCD measures the level of sagebrush habitat intactness, considering multiple factors. This is a helpful first step for those trying to improve habitat, but it is not necessarily specific to IAG management decisions. Local managers should use higher resolution remote sensing products to develop landscape-level plans for each acre of land under their purview.

Land Ownership: The land ownership layer is divided into eight categories of state, federal, tribal, and private ownership.

Satellite Only: A satellite only option is available to facilitate navigation and visualize terrain.



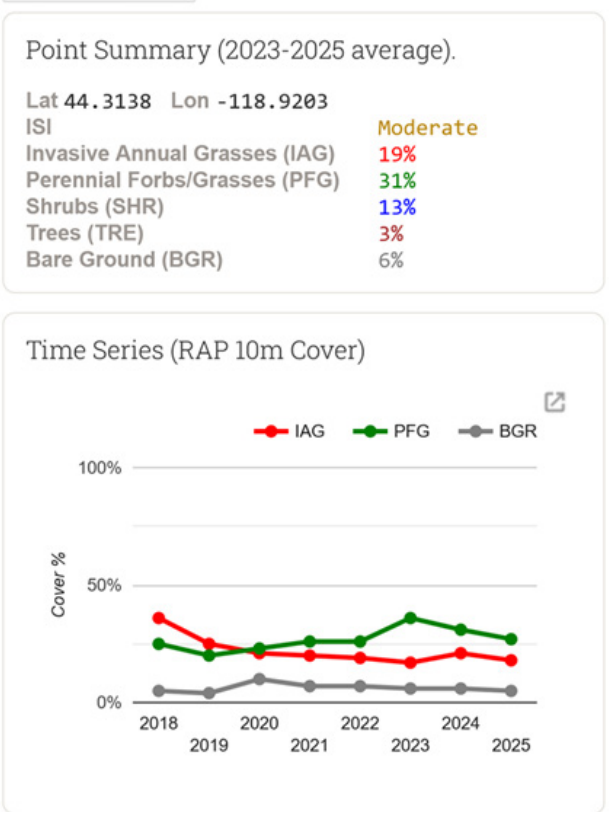
Analysis

Point Summary: Left click on any point of the map for a percent cover analysis from 10-m RAP **(3)**. The summary includes the coordinates of the point, ISI level, and percent cover values for IAG, PFG, SHR, TRE, and BGR.

Plant Functional Group Cover Time Series: Displayed below the point summary is a time series chart for IAG, PFG, and BGR from 2018 to the current year.

To remove a selected point for analysis, click the Clear Point Summary tab.

Larger, print-friendly graphics can be generated by selecting the expand button to the top right of each graph. This opens a new browser window. From this window, one can download CSV, SVG, and PNG files.



Feedback is Welcome

The ISI maps and web app is a prototype version with limited field testing. Questions, comments, or other feedback should be directed to Derek Tilley, Technology Transfer Specialist, University of Montana at derek.tilley@mso.umt.edu.

Find more practical, science-backed and solutions-focused resources for invasive annual grasses in sagebrush rangelands at www.WLFW.org