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A geographic strategy for cross-jurisdictional, proactive management of invasive annual grasses in Oregon

By Megan K. Creutzburg, Andrew C. Olsen, Molly A. Anthony, Jeremy D. Maestas, Jacqueline B. Cupples, Nicholas R. Vora and Brady W. Allred

On the Ground

- Invasive annual grasses pose a widespread threat to western rangelands, and a strategic and proactive approach is needed to tackle this problem.
- Oregon partners used new spatial data to develop a geographic strategy for management of invasive annual grasses at landscape scales across jurisdictional boundaries. The geographic strategy considers annual and perennial herbaceous cover along with site resilience and resistance in categorizing areas into intact core, transitioning, and degraded areas.
- The geographic strategy provides 1) a conceptual framework for proactive management, building upon similar work recently begun across the Great Basin, and 2) multi-scale spatial products for both policymakers and local managers to identify strategic areas for investment of limited resources.
- These spatial products can be used by Oregon partners to generate a shared vision of success, facilitate proactive management to "defend and grow the core," and collaboratively develop meaningful and realistic goals and strategies for management of annual grasses at landscape scales.

Keywords: Defend and grow the core, Invasive annual grass, Spatial strategy, Vegetation map.

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Invasive annual grasses: an old problem in need of a new approach

In the early 1900s, Aldo Leopold observed the widespread invasion of cheatgrass (*Bromus tectorum*) in Oregon and Utah. He noted societal attitudes toward this invader in the chapter "Cheat Takes Over" in his seminal book *A Sand County Almanac*, observing "I listened carefully for clues whether the West has accepted cheat as a necessary evil, to be lived with until kingdom come, or whether it regards cheat as a challenge to rectify its past errors in land-use. I found the hopeless attitude almost universal."[1] Over the last century, invasive annual grasses - including cheatgrass, medusahead (*Taeniatherum caput-medusae*), ventenata (*Ventenata dubia*), and others - have continued to spread, and hope has continued to fade. During this time science has also deepened our understanding of the negative impact of these invasive species on the health, productivity, and resilience of western rangelands,[2-6] and communities have been challenged to cope with these novel ecosystems (see Boyd et al., this issue).[7]

Many land treatments have been implemented to reduce invasive annual grasses over the years, but our collective efforts have not met the desired outcome of stopping the conversion of native rangelands. Anecdotal evidence suggests that management is too often done at small scales relative to the scale of the problem, without sufficient cross-jurisdictional coordination, and in locations where invasive species are already dominant or where wildfires have already altered the landscape. Attempts to rehabilitate invaded lands have high failure rates due to the arid climate, unpredictable weather, persistent annual grass seedbank, depleted perennial vegetation, and other factors.[8-10] Furthermore, lessons learned from these land treatments are rarely shared broadly among practitioners, limiting our collective ability to improve management outcomes at scale (see Schroeder et al., this issue).[11] The scale of the problem is immense; southeastern Oregon alone contains about 7.3 million hectares (18 million acres) of sagebrush

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steppe rangelands, with an estimated 1.7 million hectares (4.1 million acres) heavily impacted by invasive grasses and 3.0 million hectares (7.5 million acres) more at risk.[12]

Concern over the accelerating loss of sagebrush rangelands and the hundreds of sagebrush dependent species, along with the potential for a listing of the greater sage-grouse (*Centrocercus urophasianus*) under the Endangered Species Act, sharpened our focus on sagebrush rangelands and catalyzed conservation actions over the last ten years. As a result, western state partners have been coming together to develop and implement new approaches for proactive and coordinated management of invasive annual grasses through state-based efforts like Idaho's Cheatgrass Challenge[13] and regional efforts through the Western Association of Fish and Wildlife Agencies[14] and Western Governors Association.[15] These efforts address the need to refocus around a shared vision of conserving healthy and resilient sagebrush plant communities and working together across boundaries to address invasive annual grasses at the scale and scope needed to slow and reverse the loss of healthy and functioning rangelands. This will require greater investment, coordination, communication, and a shared vision of success across large, multi-ownership landscapes - and a reframing of solutions in proactive terms to counterbalance the fatalistic view over the last century that was observed by Leopold.

In Oregon, the SageCon Partnership – a collaborative group coordinating actions to reduce threats to sagebrush and sage-grouse in the state – recently launched its own Invasives Initiative to spur more effective action on invasive annual grasses. Inspired by the roadmap in Idaho and elsewhere in the West, SageCon developed a geographic strategy for proactively managing invasive annual grasses at landscape scales across jurisdictions throughout eastern Oregon. The purpose of this strategy is to facilitate coordination and communication about shared goals and strategies to achieve those goals, with an emphasis on proactive management. We describe key concepts underpinning Oregon's geographic strategy, how it was created, and how it can be operationalized to support locally-led collaboration.

An emerging vision for proactive management

The old adage "an ounce of prevention is worth a pound of cure" is particularly salient in weed management, where invasive species control is much more effective and cost-efficient when done early before infestations become widespread. Landscape ecology also teaches us that context matters too, and management options and outcomes on any particular piece of land are inextricably affected by the surrounding area (see Maestas et al, this issue).[16-17] Applying these lessons to invasive annual grasses suggests conducting proactive, preventive management in relatively uninvaded areas is more likely to be effective in the long run than reactive, emergency management in highly invaded areas (Fig. 1).[18] This foundational premise lies at the heart of the emerging vision for tackling invasive annuals that is currently being adopted by partners across the West.[13–15,18]

This geographic strategy lays out an approach that emphasizes proactive management, while acknowledging that all parts of the landscape may need some level of intervention. Leveraging new remote sensing-derived vegetation data,[19] this conceptual model can be depicted geographically at multiple scales, providing landscape context across large and complex geographic areas. Importantly, large and relatively intact "cores" that have low annual grass invasion and robust perennial grasses can be identified for proactive management opportunities (Maestas et al., this issue).[17] These cores serve as anchor points for conservation of sagebrush rangelands, allowing local management to be more successful in the long term because of the favorable landscape context. Conversely, heavily invaded areas already in a degraded state can also be mapped; in these areas management may focus on crisis mitigation, such as minimizing fire risk to life and property. Transitioning areas between these extremes show where aggressive restoration may be needed to halt further loss of intact rangelands. This has given rise to a unified proactive strategy for tackling invasive annuals across ownerships: "Defend the Core, Grow the Core, Mitigate Impacts":[13,15]

1. **Defend the Core:** Prevent annual grass encroachment and promote a healthy perennial ecosystem in "core" areas where the problem is currently minimal. Defending cores from annual grass invasion is a top priority for management.
2. **Grow the Core:** Work adjacent to the core areas into the transition zone, containing intermediate levels of annual grass invasion, to strategically increase the amount of core across the landscape. Sustained and aggressive management will be needed in transitioning areas to halt spread into cores.
3. **Mitigate Impacts:** In addition to the more proactive approaches of defending and growing the core, ongoing management in the highly invaded degraded areas will also be required to mitigate the most severe impacts of annual grasses and wildfire.

Laying out a geographic strategy for Oregon

We describe the approach and spatial datasets used to support the SageCon Invasives Initiative geographic strategy mapping. These maps were developed by an interagency group of stakeholders and are designed to be used in concert with existing planning efforts, such as the Natural Resources Conservation Service (NRCS) Working Lands for Wildlife[18] and the Bureau of Land Management (BLM) Integrated Program of Work. The mapping effort built on the principles of "Defend the Core, Grow the Core, Mitigate Impacts" outlined above, but differed in a couple of unique ways to increase utility for Oregon partners.

A synthesis of herbaceous composition and site potential

In contrast to similar mapping efforts that focused solely on the cover of invasive annual grasses,[13,15] we mapped cur-

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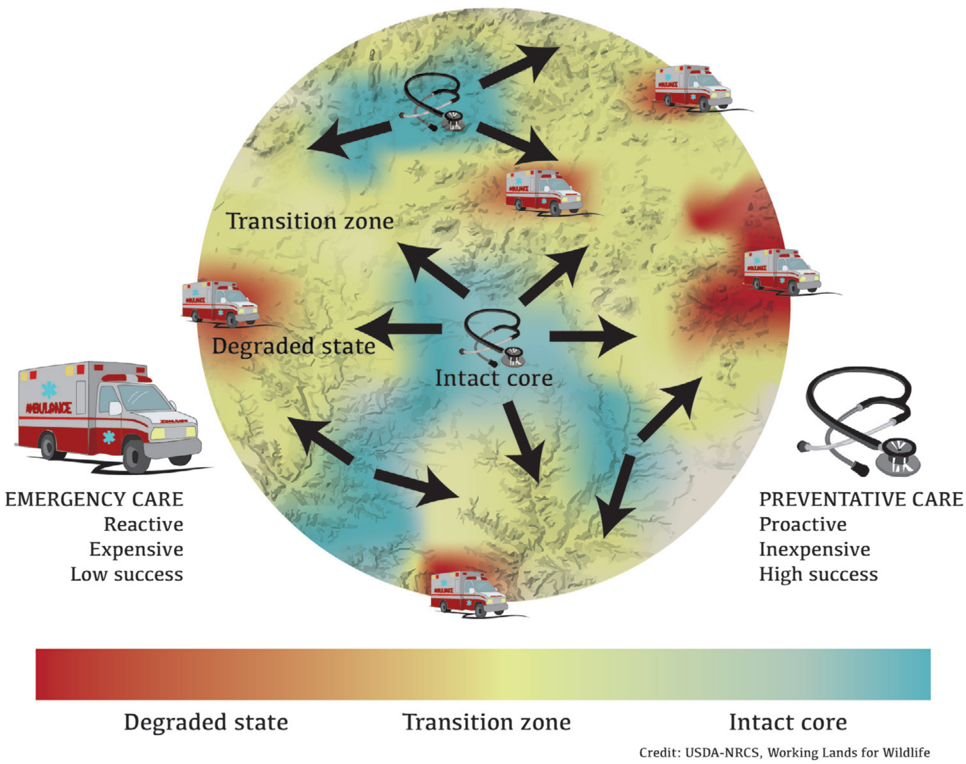

Figure 1. Concepts behind a geographic strategy for addressing rangeland threats that emphasize proactive conservation of intact areas ("cores") as a top priority for management. Credit: USDA-NRCS Working Lands for Wildlife.[15]

rent herbaceous composition of both annuals and perennials as well as site potential for recovery. Herbaceous composition was characterized by both annual (undesirable) and perennial (desirable) herbaceous cover, emphasizing not only the amount of invasive annuals but importantly the key role of perennial grasses in stabilizing sites (see Johnson et al., this issue).[20] To capture site potential and further inform the level of restoration intervention that may be needed, we used resilience and resistance (R&R) maps, which identify broad soil types and climatic conditions that influence recovery potential after disturbance.[21-22] An updated R&R map for Oregon was provided by the NRCS West National Technology Support Center in August 2020, which included the most recent soil surveys for Oregon (draft SSURGO data were used for parts of Crook, Grant, Malheur, and Wheeler Counties).[23-24] Accounting for both biotic and abiotic factors allows for some nuance in setting realistic expectations about appropriate management interventions and their likelihood of success. The following paragraphs outline how spatial datasets were constructed and combined into categories to guide management.

Oregon's strategy is enabled by recent advances in remote sensing that have increased the accuracy and spatiotemporal scale of data available to support rangeland management. To estimate invasive annual grass cover we used the Rangeland Analysis Platform version 2 (RAP)[19] annual forb & grass (AFG) cover, and perennial grass cover was estimated from RAP perennial forb & grass (PFG) cover. Cover values of AFG and PFG were averaged over a 5-year time frame from 2015-2019 to account for the variability in herbaceous cover due to annual variation in weather conditions,[25-26] and the ratio of AFG:PFG was calculated from these 5-year averages of absolute cover. We used this ratio to approximate the relative dominance by annual or perennial herbaceous functional groups and account for some of the variability in site potential and herbaceous production across eastern Oregon. For intermediate AFG:PFG ratios, an additional cover threshold of 20% PFG was used to distinguish sites with relatively robust remaining perennial grasses from areas with few perennials, based on communication with Oregon BLM Districts. The herbaceous composition classes were defined as follows:

- High – AFG:PFG ratio $\leq$0.33 (perennials highly dominant over annuals by at least a 3:1 ratio; similar to a ratio that captured relatively intact sagebrush and perennial grass communities in a Great Basin-wide analysis).[27]
- Moderate – AFG:PFG ratio between 0.33 and 1.0 and PFG cover $\geq$20% (perennials dominant with robust perennial cover, but presence of invasive annuals may be higher than desired).
- Fair – AFG:PFG ratio between 0.33 and 1.0 and PFG cover <20% (perennials dominant, but presence of annuals may be higher than desired and existing perennial cover may be inadequate to suppress further establishment of annuals).
- Low – AFG:PFG ratio >1.0 (annuals dominant over perennials)

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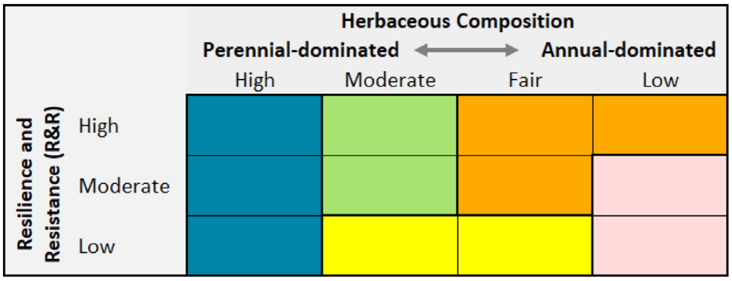

Core	Core	Communities with healthy bunchgrasses, limited annual invasion, and potential for low cost interventions to keep weeds out. Large blocks of core can serve as an anchor to grow areas with minimal invasion across the landscape into the adjacent transition zone.
Transitioning	Transitioning - high restoration potential	Areas with moderate invasion but adequate perennial bunchgrasses and relatively high site resilience. These areas require relatively minimal management intervention and include some of the most cost-effective areas for growing the core.
	Transitioning - low resilience	Areas with moderate invasion and low resilience. These sites are difficult to restore, require more intensive management intervention, and treatments are less likely to succeed.
	Transitioning - low perennials	Areas with moderate invasion and low perennial grass cover, but with higher site resilience. These areas require management intervention to restore perennial grass cover and reduce invasive annual grasses, and risk replacing one weed species with another.
Degraded	Degraded	Invasive annual grasses are dominant and site resilience is relatively low. Management for restoration is unlikely to succeed, and these areas will likely need continual maintenance.

Figure 2. The geographic strategy combines herbaceous composition and resilience and resistance in a 12-cell matrix, shown at top. Colors show management groupings as described in the table. For the Generalized Strategy Map, all three "transitioning" categories (green, yellow, orange colors) are grouped as shown in the lower left. Note that the two combinations in the upper right cells of the matrix (high R&R with fair or low herbaceous composition) are uncommon, representing a combined 3% of the landscape in southeastern Oregon.

The four herbaceous composition classes and three R&R classes were combined to form a 12-cell matrix of biotic and abiotic conditions, subsequently grouped into five management categories (Fig. 2). These categories were discussed extensively by the interagency working group, and informal external review was solicited from several experts. The group determined that these inputs and threshold values were useful in binning conditions to facilitate communication and guide management goals at landscape scales, while acknowledging that hard thresholds rarely occur in nature. It is important to keep in mind that all thresholds applied in this analysis are intended to classify continuous and highly variable conditions into simple and meaningful classes using just a few input datasets, and this categorization will not work well on every site. Local data and knowledge will always be critical to make use of this geographic strategy in management planning (see Putting the geographic strategy into practice).

Multiple map products for a diverse audience

Management planning in rangelands is conducted by a broad range of partners at multiple spatial scales. In many cases, state and federal agencies must first determine broad priorities and allocate funding across different geographic areas (states, counties, districts, etc), then local staff determine how to prioritize use of those resources across the areas they manage. A geographic strategy can be informative at both levels, but the purpose and audience are different. We developed a multi-scale geographic strategy consisting of two maps, aimed at these different planning stages, purposes, and audiences:

- **The Generalized Strategy Map** (Fig. 3A) is a simple tool to communicate the concepts of the geographic strategy for a broad and general audience. This map draws the eye to large blocks of core in blue to reinforce the concept of "Defend the Core, Grow the Core" and highlights the broad-scale distribution of core, transitioning, and degraded areas.
- **The Management Strategy Map** (Fig. 3B) provides finer-scale and more detailed information to help guide cross-jurisdictional collaborative work at the scale of counties, watersheds, districts, or large properties. This map is intended to help set landscape-scale goals, identify shared priorities, and facilitate discussion of desired - but also realistic - management outcomes. In particular, this map provides more detail on limiting factors that may reduce restoration success or increase cost within the "transitioning" zone.

The Management Strategy Map was built first as described above at the scale of 30m pixels. From the original 5-category map, the Generalized Strategy Map was built by combining the three "transitioning" categories and using focal statistics within a 30-cell circular radius to spatially generalize patterns. The two maps are based on the same datasets and concepts, but one is simplified for communication with a broad audience and the other contains more detail to guide

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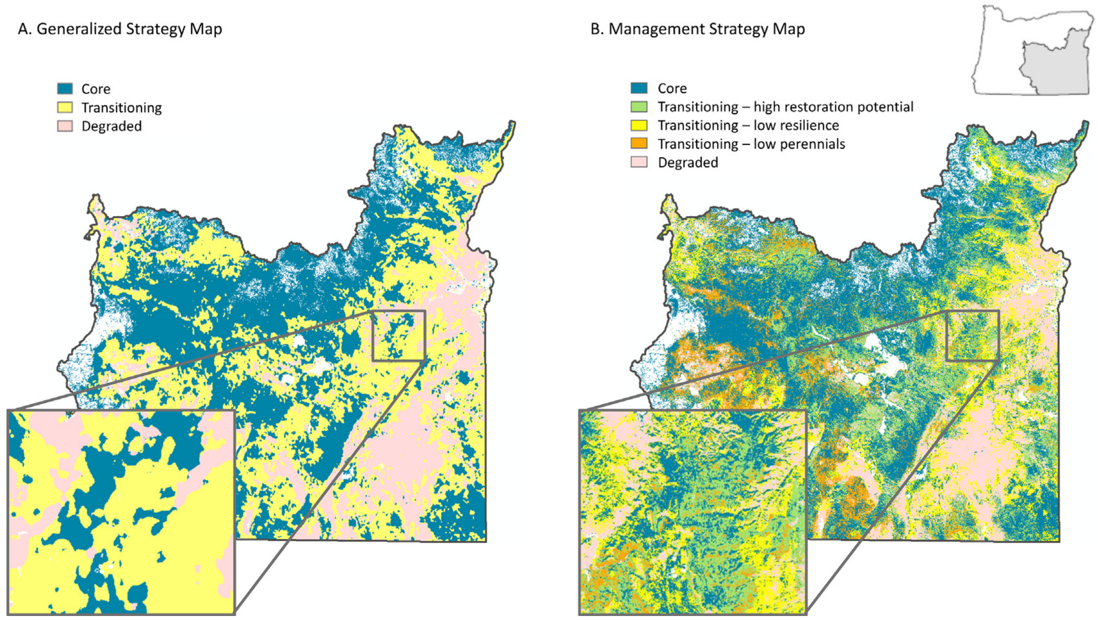

Figure 3. The Invasives Initiative geographic strategy consists of two map products, based on the same underlying data layers and concepts but visualized differently for different audiences. The Generalized Strategy Map (left) provides a broad-scale view to easily identify blocks of core (blue) to defend and grow. The Management Strategy Map (right) provides more nuance at a finer scale and differentiates between transitioning areas with different limiting factors and potential for restoration (green, yellow, and orange).

Table 1
Potential roles for the geographic strategy at multiple planning stages, following the guiding principles for using satellite-derived maps in decision-making outlined in Allred et al.[29]

Key Questions	Planning Step	Potential Role of the Geographic Strategy
Where are we now?	Inventory and assessment	Maps quantify the scale of invasion across large, heterogeneous landscapes, depict remaining cores, and highlight proactive management opportunities for where to invest time and resources for the greatest chance of successful outcomes. For example, the Generalized Strategy Map can help stakeholders and policymakers understand the urgency of the invasive annual grass problem and need for a landscape approach.
Where do we want to be?	Developing shared goals	The geographic strategy provides a common language of "Defend the Core, Grow the Core, Mitigate Impacts" and can facilitate discussion of foundational questions such as: 1) What are our shared goals for this landscape? 2) Are these goals realistic given the current level of invasion and potential for restoration? 3) Are there areas where it will be critical to work across ownership boundaries to achieve these goals?
How do we get there?	Strategy and prioritization	The geographic strategy provides spatial context needed to prioritize actions and set appropriate expectations. The Management Strategy Map can help identify areas that will be key to achieving landscape-scale goals with the greatest likelihood of success, or identify potential factors limiting restoration potential. Partners can use maps to help assess risks and prioritize where to work first.
What needs to change and when?	Setting objectives	Treatment-level objectives will be determined based on site-specific information, but the Management Strategy Map may help in setting measurable and achievable objectives across broader project areas based on the degree of invasion, site potential, and context of the surrounding landscape, informing expectations about the degree of difficulty involved in taking a particular management action.
What are we going to do?	Implementation	Maps do not tell us *how* to accomplish our management goals and are largely set aside in the implementation phase. Site- and project-specific characteristics determine the specific management tactics to apply, and barriers related to knowledge, technology, or management constraints will heavily influence the ability to work on the ground.
How will we know when we get there?	Monitoring and adaptive management	Maps can help track outcomes at scales from individual projects to broader planning units. Future updates to these maps, along with other datasets such as monitoring plots or photo points, may allow the geographic strategy to be used to highlight both successes and ongoing management needs. Maps are critical tools in assessing the effectiveness of conservation actions in maintaining healthy sagebrush rangelands over time.

local management. The geographic strategy maps are downloadable from the web[28] and also include vegetation functional group maps from RAP[19] to supplement the information provided in the strategy maps. In addition to the spatial datasets, supporting materials including a short overview document, management guide, technical documentation, and other related resources are provided to users.

Putting the geographic strategy into practice

Rangelands in Oregon cover a patchwork of federal, state, tribal, and private land ownerships, and a primary goal of the SageCon Invasives Initiative is to coordinate efforts across boundaries to achieve desired landscape-scale outcomes. This strategy can be used throughout the decision-making

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Core area (blue): Perennial grasses are highly dominant over annuals.

- Potential *management goals*: Maintain condition; Restore patches of lower condition sites within areas of predominantly core; Prevent disturbance where resilience is lower.
- Potential *strategies*: Implement early detection and rapid response by aggressive surveys and spot treatments; Implement grazing management plans to promote perennial dominance; Use strategic fuel breaks to prevent large wildfires.

Transition zone (green, yellow, orange): Some annual invasion with limited opportunities for restoration to prevent conversion to degraded condition.

- Potential *management goals*: Increase perennial grass cover and vigor, especially adjacent to core; Prevent disturbance; Reduce invasive annual grass cover.
- Potential *strategies*: Grazing management to promote perennials and reduce fine fuels; Herbicide to release existing perennials from competition with annuals; Herbicide followed by seeding where existing perennials are depleted.

Degraded area (pink): Invasive annual grasses dominate and site resilience is relatively low.

- Potential *management goals*: Mitigate fire risk; Containment to prevent spread of annuals.
- Potential *strategies*: Livestock grazing for fuels management; Strategic fuel breaks to prevent fire spread and protect adjacent areas.

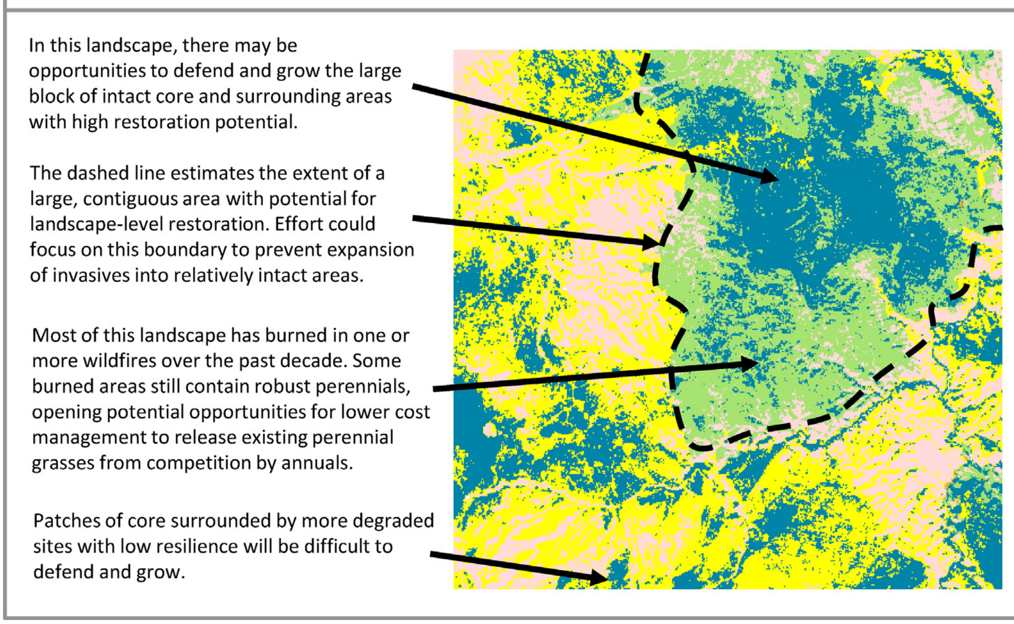

Figure 4. Example of applying the geographic strategy in an ecologically diverse landscape covering roughly 80,000 ha (200,000 ac). Some potential management goals and strategies for core, transitioning and degraded areas are listed at the top, and the map highlights patterns across the landscape and areas where different management goals and strategies may apply.

process of planning, implementation, monitoring, and adaptive management (Table 1). At local scales, the maps may facilitate the discussion of shared management goals across multi-jurisdictional landscapes and strategies to achieve those goals (Fig. 4). The geographic strategy itself does not provide answers or make difficult choices, but rather provides a conceptual framework along with a spatial depiction of the challenges and opportunities to inform and facilitate collaboration.

We reiterate that the geographic strategy maps are a tool and not an endpoint or management decision in and of themselves. These maps are intended to facilitate coordination and communication about shared goals and strategies to achieve those goals, with an emphasis on proactive management. Other datasets along with expert knowledge can and should be used to support planning efforts. Our stakeholder group considered including shrub or tree cover, wildfire probability, sage-grouse habitat, and climate resilience. Instead, we elected to keep the map relatively simple by focusing on biotic and abiotic factors that determine potential management strategies for invasive annuals at broad scales. We recommend overlaying the geographic strategy maps with other data sources that support identified objectives and values to make informed and holistic decisions about strategic areas for investment in long-term positive outcomes.

It is also important to remember that the maps contain known and unknown errors and should not be expected to accurately characterize every pixel across the landscape. For instance, R&R map categories can help approximate recovery potential after disturbance based on broad soil characteristics and climate, but don't capture site-specific characteristics such as landform, aspect, and finer-scale soil characteristics

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that will be critical in project design and restoration success. There are many other considerations in restoration planning and project design that cannot be represented in a map (funding, capacity, and planning processes, to name just a few) but maps present a crucial opportunity to inform landscape-scale planning.

Rising to the challenge: a call to action

Answering Leopold's call from over 70 years ago, conservation partners across the sagebrush biome are rallying to halt the conversion of western rangelands to invasive annual grasses. While the problem is daunting and outcomes uncertain, our rangeland ecosystems are too important to avoid rising to the challenge. New technology is giving us a better understanding of the spatial patterns of invasion and opportunities to protect relatively uninvaded lands. The geographic strategy outlined here, when combined with decades of knowledge of invasive species management and development of new tools and techniques,[30-31] can help us work strategically across large landscapes to put the right practices in the right places and move the needle on sagebrush conservation.

Oregon's geographic strategy provides a path forward for partners to shift from reactive crisis management of invasive annual grasses to a proactive approach to keep healthy rangelands intact. However, local land managers must be provided not just with tools and maps but also with the latitude to try new techniques and sustained resources for building the adaptive capacity of communities to cope with invasives long term (see Boyd et al, Maestas et al, Cahill, and Smith et al, this issue).[7,17,32-33] The strategy's ultimate success relies heavily on community-based partnerships coming together to coordinate actions, develop local prescriptions, and leverage resources to achieve our shared goal of conserving healthy and productive rangelands for people and wildlife. All stakeholders have a role to play in this 'all hands, all lands' effort, from field practitioners and ranchers to policy-makers and agency leaders.

Declaration of Competing Interest

The content of sponsored issues of *Rangelands* is handled with the same editorial independence and single-blind peer review as that of regular issues.

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