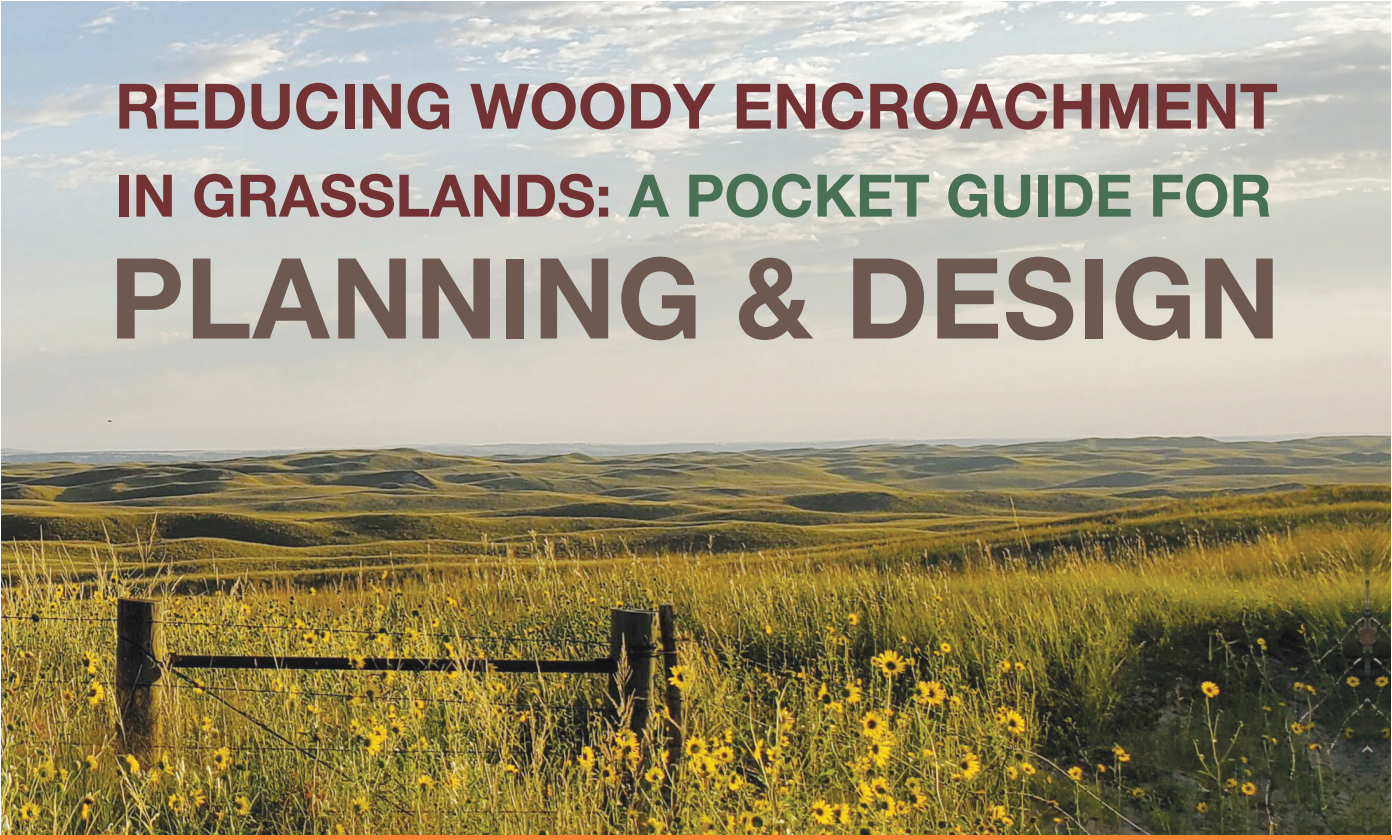
REDUCING WOODY ENCROACHMENT IN GRASSLANDS: A POCKET GUIDE FOR PLANNING & DESIGN



GREAT PLAINS
Grasslands Extension Partnership

EC3076PG

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Purpose

This pocket guide provides an improved planning process to design grassland ecosystems that are less vulnerable to the threat of woody encroachment. This pocket guide builds on the ***Reducing Woody Encroachment in Grasslands: A Guide for Understanding Risk and Vulnerability***, produced by Dr. Dirac Twidwell, and integrates new guidelines for reducing woody encroachment with a formal planning process used to deliver conservation investments on grasslands. The goals of the pocket guide are to:

1. Provide a field-based resource for understanding grassland risk and vulnerability to woody encroachment,
2. Detail key steps in the planning process from inventory to decision support and implementation, and
3. Provide a suite of management scenarios and options that can be used to reduce grassland risk and vulnerability to woody encroachment.

Who Benefits?

This pocket guide was developed at the request of rangeland planners who wanted new guidelines for reducing woody encroachment in the grassland conservation training and planning processes. More than 20,000 copies of Twidwell's "Vulnerability Guide" were requested in the first two years following publication, and the guidelines have been incorporated into multiple state and national Great Plains grassland conservation initiatives. This pocket guide provides an important resource that further incorporates the latest, science-backed approaches for reducing woody encroachment into the conservation business model.

Key Principles for Reducing Woody Encroachment in Grasslands

Principle 1: Grasslands do not have trees.

Principle 2: Grasslands are so widespread, they form a biome.

Principle 3: Grasslands are more vulnerable to woody encroachment today than in the past.

Principle 4: Proximity to seed sources (exposure) is the most important predictor of where encroachment occurs.

Principle 5: Management efforts should target all three stages of woody encroachment.

Principle 6: Develop a plan for every acre and track progress over time.

Principle 7: Reducing grassland vulnerability is the cheapest way to manage woody encroachment.

Principle 8: Anchor to intact grasslands and scale up collaboration.

Grassland *(noun)*

large-scale treeless ecosystems dominated by herbaceous vegetation (grasses and broadleaf plants)

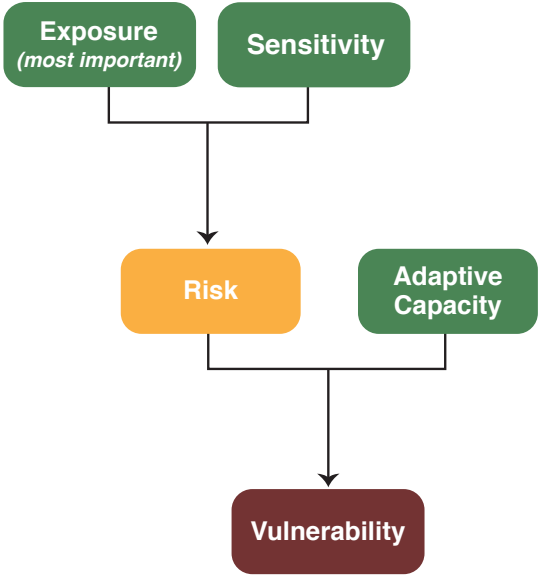
Biome *(noun)*

a region dominated by uninterrupted, similar vegetation and lifeforms; biomes are the largest unit of vegetation classification (e.g., desert, grassland, forest, etc.)

Grassland Biome *(noun)*
regions of uninterrupted vegetation dominated by grasses and broadleaf plants (patches of trees occur but are rare)

Biome Collapse *(verb)*
the act of a biome abruptly shrinking and transitioning to an alternative biome type

Grasslands are More Vulnerable to Woody Encroachment Today Than in the Past



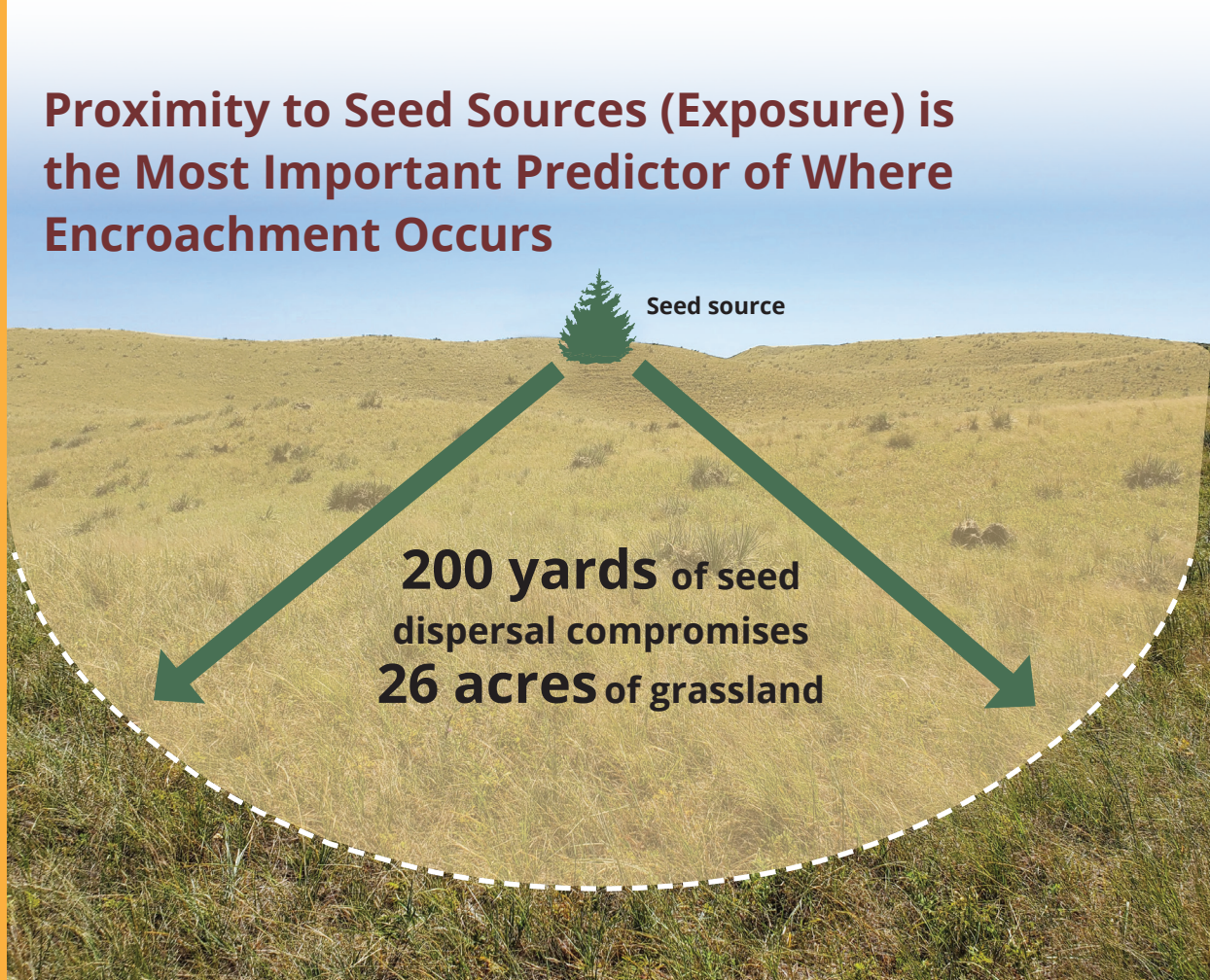
Exposure is driven by proximity to seed sources, which contaminate nearby areas. Exposure is the most important consideration for successful planning.

Sensitivity is the relative ease that woody plants establish and the speed at which they spread in grasslands.

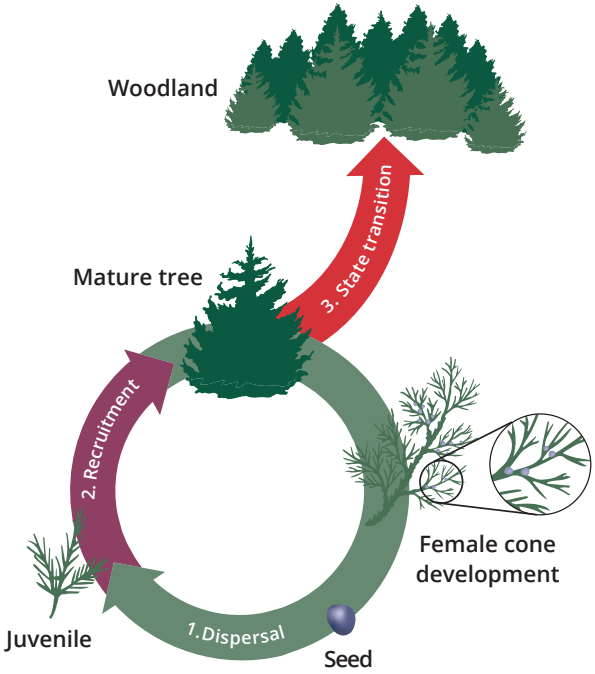
Adaptive capacity is the ability to increase collaborative partnerships and resources to reduce the risk of woody encroachment.

What is vulnerability?
The degree to which a grassland is susceptible to, or unable to cope with, the risk of woody encroachment. All grasslands are vulnerable to encroachment. More arid and sandier sites are less sensitive than other grasslands, but encroachment still happens when exposed to seed sources.

Proximity to Seed Sources (Exposure) is the Most Important Predictor of Where Encroachment Occurs



Management Efforts Should Target all Three Stages of Woody Encroachment



Stages of Woody Encroachment

1. Dispersal causes intact grasslands to become compromised by incoming seeds. This is the start of the encroachment process.

2. Recruitment is the active stage of population expansion and occurs when seeds become seedlings.

3. State transition is the endpoint of the encroachment process when a grassland has transitioned to a woody-dominated ecosystem.

Management Efforts Should Target all Three Stages of Woody Encroachment

Up to **1.5** MILLION SEEDS PRODUCED per mature tree every year

Q: What do I need to know to manage all three stages of woody encroachment?

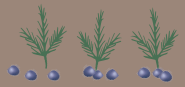
95% SEEDLINGS WITHIN **200** YARDS from mature trees

Less than **5%** SEEDLINGS past 200 yards

TREES PRODUCE SEEDS AT **6-7** years old (~5 ft. tall)

← Eastern redcedar *(Juniperus virginiana)*

HIGH SEED GERMINATION RATE



up to **70%**

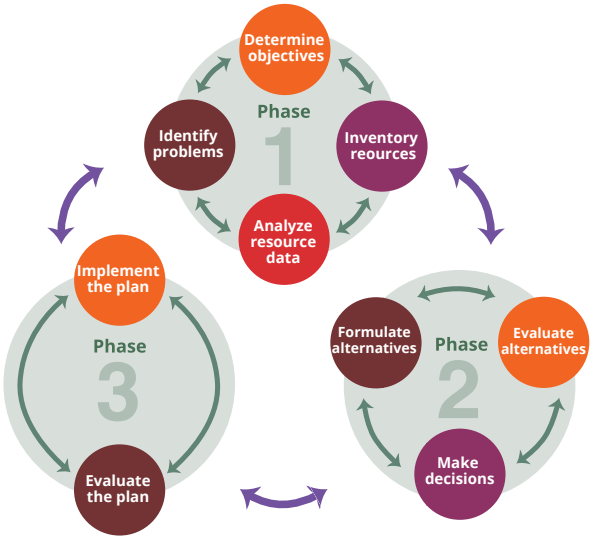
SHORT-LIVED SEEDS

viability

5% at 14 months **3%** at 28 months

Develop a Plan for Every Acre and Track Progress Over Time

Conservation Planning Process

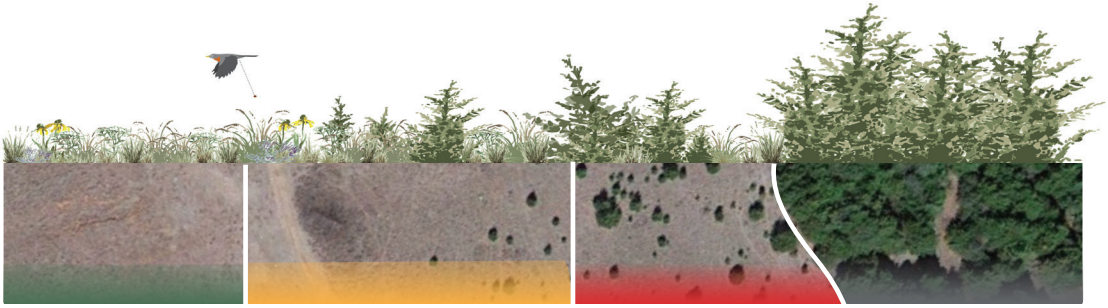


Phase 1. Identify the Problem, Determine Objectives, and Conduct an Inventory
Identify the underlying sources of the problem, determine objectives, and map and inventory resources (landscape context, cultural will, and ecosystem service values).

Phase 2. Decision Support
Use the decision-support process to formulate, evaluate, and select among alternative management strategies that best achieve the manager's objectives.

Phase 3. Implementation
Implement the selected management strategies as part of a spatial game plan. Evaluate progress, adapt, and learn.

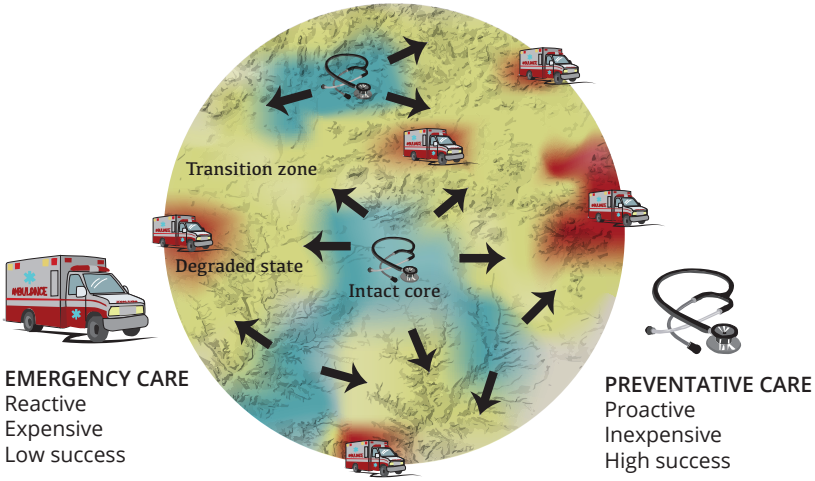
Reducing Grassland Vulnerability is the Cheapest Way to Manage Woody Encroachment



STAGE & DESCRIPTION			
Intact grassland Treeless with no seeds or tree seedlings	**Dispersal & recruitment** Contaminated (looks intact) due to incoming seed dispersal & seedling recruitment	**Encroached** Infested by seed-producing trees (6+ years, 5+ ft. tall for eastern redcedar)	**Transitioned to woodland** Trees dominate
MANAGEMENT ACTION			
Avoid introducing seed Fire	**Remove young trees** Fire, cutting, haying, browsers	**Remove scattered, seed-producing trees** Hand tools, machinery, fire	**Remove large trees** Heavy machinery, fire
MANAGEMENT COST			
¢	$	$$	$$$

Table 1. Rangeland vulnerability to tree encroachment and corresponding management actions and costs.

Anchor to Intact Grasslands and Scale Up Collaboration

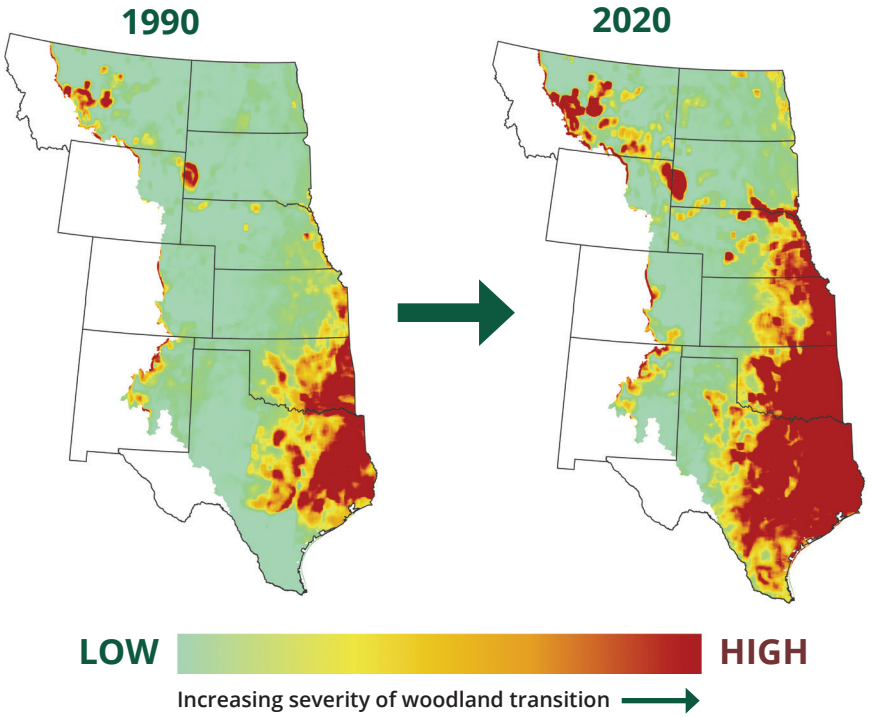


Credit: USDA-NRCS, Working Lands for Wildlife

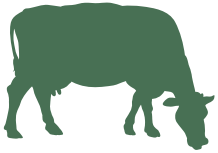
Defend the Core → Grow the Core

Don't Chase the Problem

The Great Plains Biome is Collapsing Due to Woody Encroachment

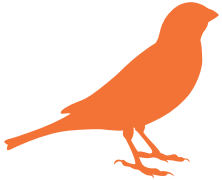


Biome Collapse Leads to Biome-Level Consequences



Loss of Forage Production

Great Plains grasslands lose 22.4 million tons of forage production every year to woody encroachment; the yearly forage need of 4.7 million cows.



Collapse of Grassland Wildlife

Grassland-dependent species thrive in large intact grasslands. Woody encroachment displaces these species and causes population declines.

Reduced Water Quantity and Quality

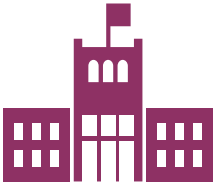
Woody encroachment in grasslands can reduce stream flow and aquifer recharge, while increasing pollutant concentrations.

Wildfire Risk

The number and severity of wildfires are increasing due to the expansion of volatile woody fuels.

Vector-Borne Disease Risk

Woody encroachment increases the risk of vector-borne diseases like West Nile virus and Rocky Mountain spotted fever.



Public School Funding

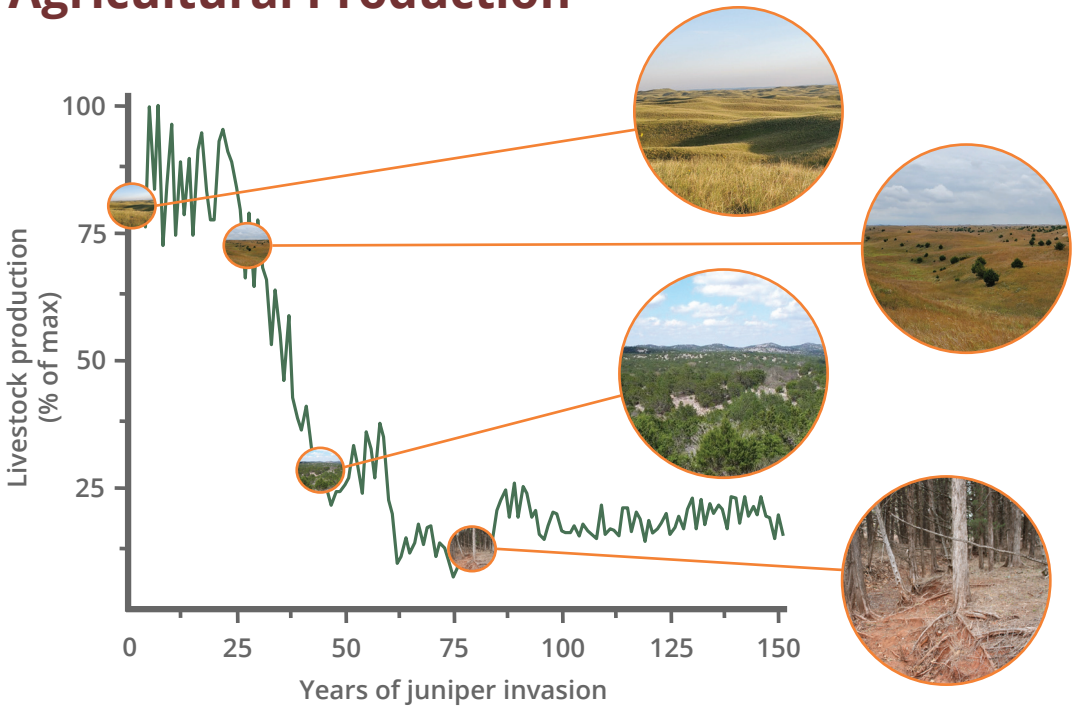
School lands generate income from grazing leases to support public education. Woody encroachment decreases the profitability and future school funding from these lands.

Every State in the Great Plains is Experiencing Woody Encroachment

Colorado Kansas Montana Nebraska New Mexico

North Dakota Oklahoma South Dakota Texas Wyoming

Woody Encroachment Takes Land Out of Agricultural Production



Fuhlendorf *et al.* 2008

WHAT IS THE PROBLEM?

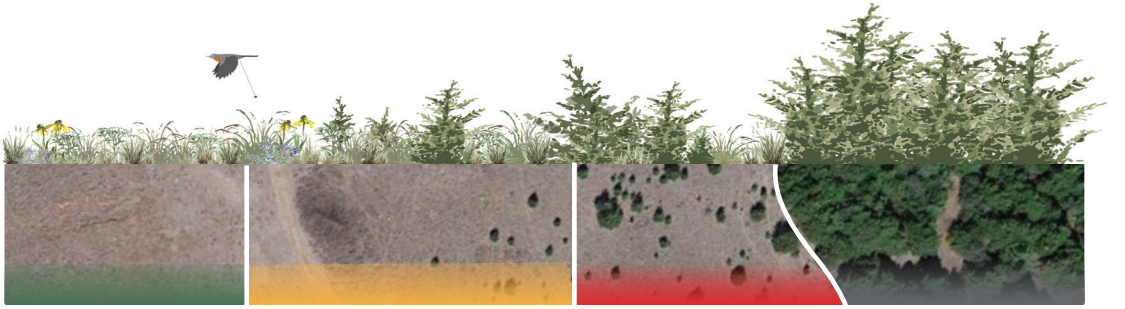
? Where **HAVE WE USUALLY** worked in this landscape?

? Where **SHOULD WE START** working in this landscape?

! **Past approaches did not put the RIGHT practice in the RIGHT place at the RIGHT time.**


? Where HAVE WE USUALLY worked in this landscape?
? Where SHOULD WE START working in this landscape?
? How would you IMPROVE UPON past approaches?

New Order of Business: Recognize and Reduce Vulnerability on our Grasslands



STAGE & DESCRIPTION	Intact grassland	Dispersal & recruitment	Encroached	Transitioned to woodland
	Treeless with no seeds or tree seedlings	Contaminated (looks intact) due to incoming seed dispersal & seedling recruitment	Infested by seed-producing trees (6+ years, 5+ ft. tall for eastern redcedar)	Trees dominate
MANAGEMENT ACTION	**Avoid introducing seed** Fire	**Remove young trees** Fire, cutting, haying, browsers	**Remove scattered, seed-producing trees** Hand tools, machinery, fire	**Remove large trees** Heavy machinery, fire
PRIORITY FOR MANAGEMENT	1	2	3	4

Table 1. Rangeland vulnerability to tree encroachment and corresponding management actions and priorities.

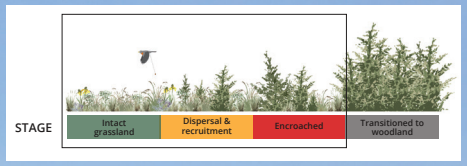
Q: Based on page 18, which of the following best describes this landscape?

a. mostly intact

b. mostly contaminated

c. mostly infested

WHAT IS THE OBJECTIVE?



Infested
seed-producing trees present

Contaminated (but looks intact)
seeds & seedlings present

Intact grassland
treeless and not contaminated by seed

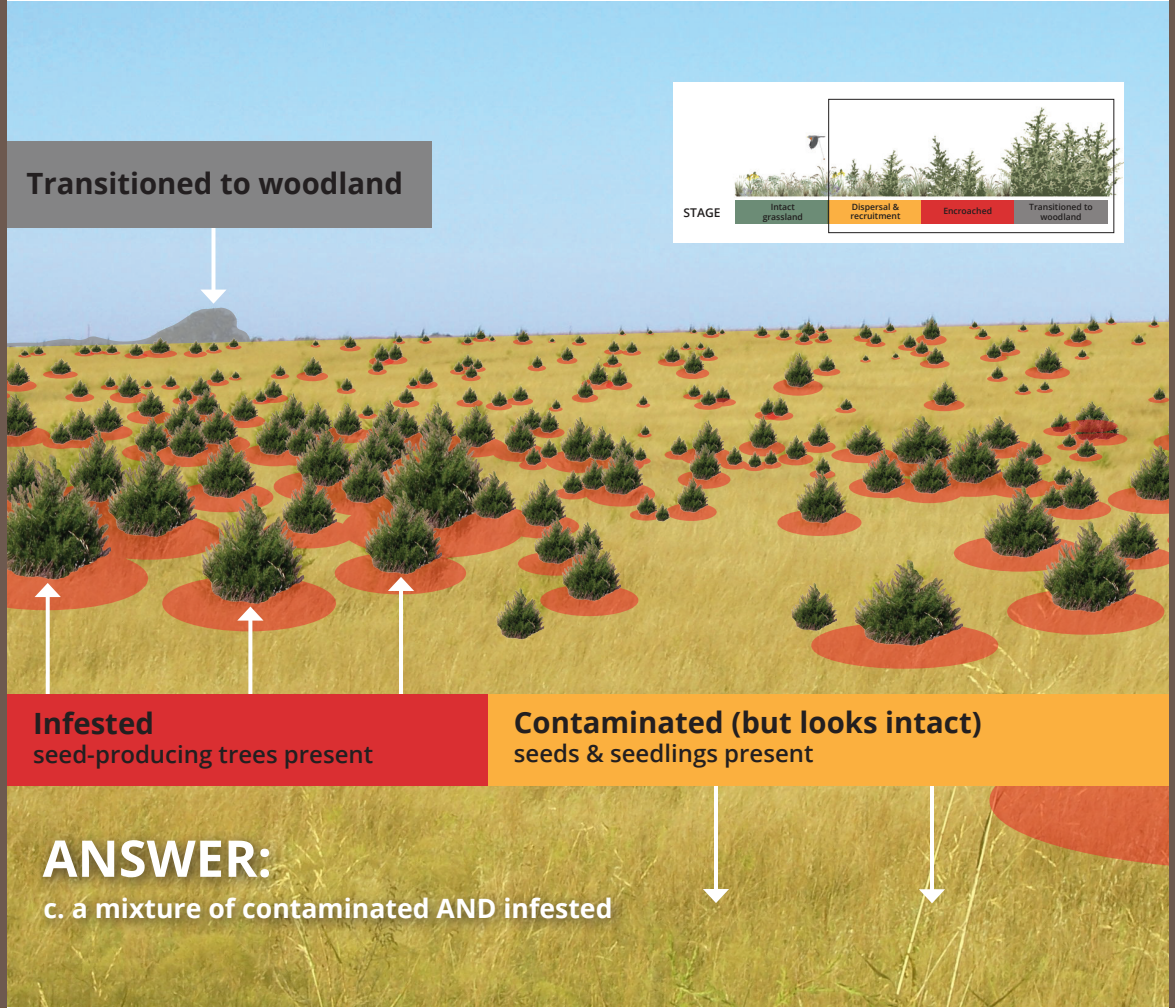
ANSWER:

b. mostly contaminated

Q: Based on page 18, which of the following best describes this landscape?

a. mostly contaminated
b. mostly infested
c. a mixture of contaminated AND infested

WHAT IS THE OBJECTIVE?



ANSWER:

c. a mixture of contaminated AND infested

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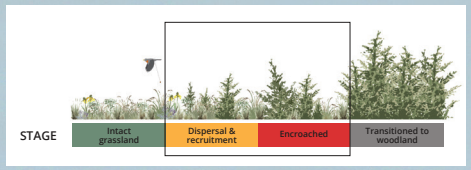

Infested
seed-producing trees present

ANSWER:
b. mostly infested

Contaminated (but looks intact)
seeds & seedlings present

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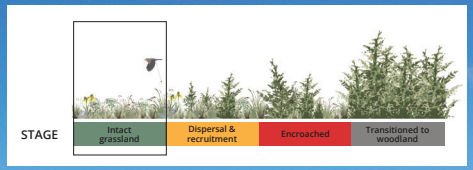


Intact grassland
treeless and not contaminated by seed

ANSWER:

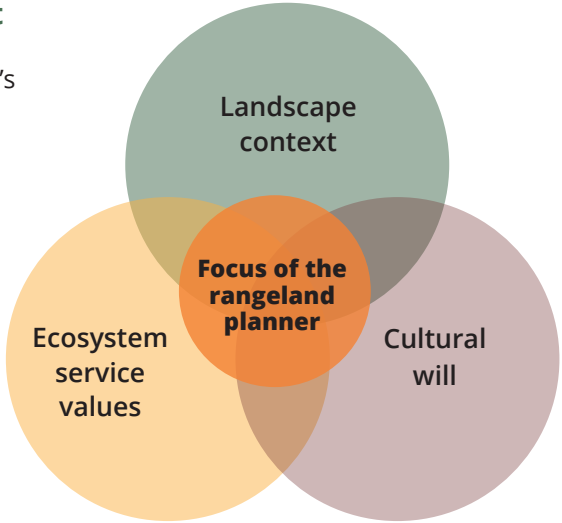
a. mostly intact

Recommendations for the Inventory Process

Conservation is most successful when cultural will demonstrates a desire to maintain intact landscapes and the services they provide.

Landscape context provides critical information on the site's vulnerability to woody encroachment.

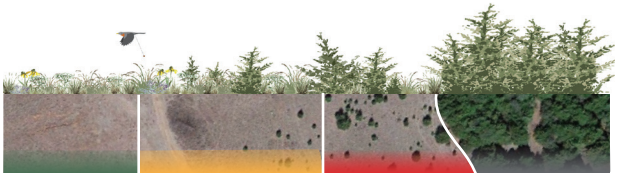
Ecosystem service values illustrate the broader benefits of your work to the people, plants, and animals that depend on intact grasslands.



Cultural will outlines the potential to partner with neighbors and scale up management.

Part I. Inventory and Map Vulnerability and Encroachment on the Landscape

The first step of inventory is to understand the scale and context of woody encroachment (use Table 1 as a guide). This step provides the rangeland planner with critical information that is useful for the decision-support planning phase.



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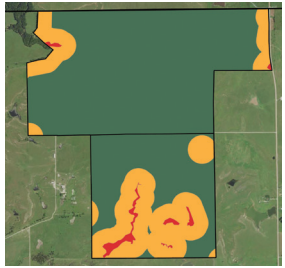
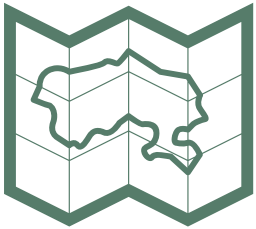
PRIORITY FOR MANAGEMENT			
1	**2**	**3**	**4**

Use this table to create a map of on-the-ground conditions.

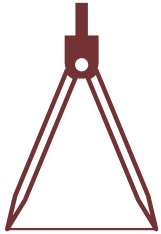


Recommended Minimum Landscape Inventory

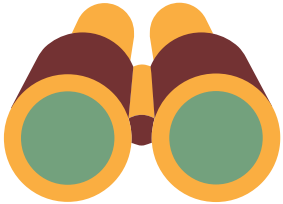
Step 1. Map vulnerability and encroachment.



Step 2. Adjust/correct the map with field inventory.



Step 3. Map your vision for the site's future.



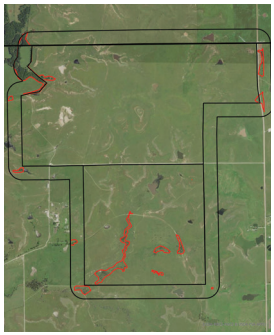
Step 4. Track progress.

Approach I. Mapping Vulnerability on Your Own

Step 1. Create an initial inventory map.

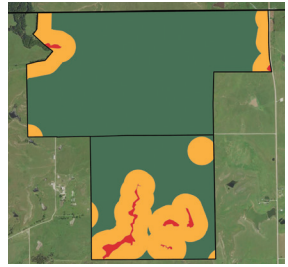
It does not need to be perfect. You can use remote sensing products like Google Earth, the back of an envelope, or a piece of scratch paper.

Identify the location of potential seed sources (shown as red).



Delineate contamination zones (200-yard buffer; shown as yellow) around seed sources.

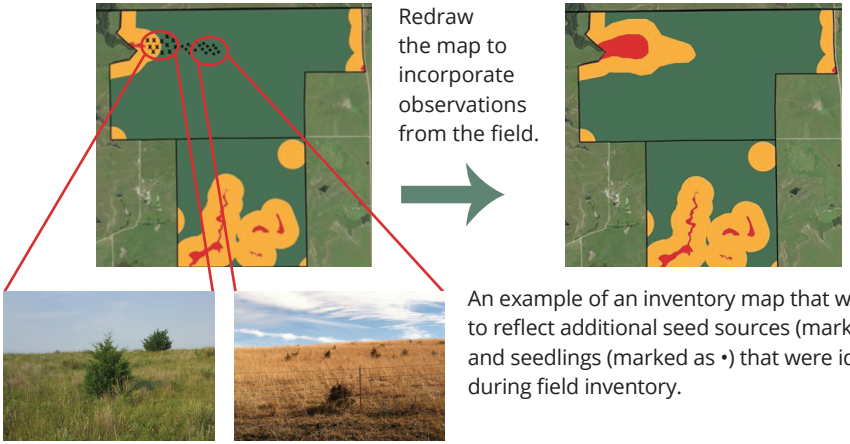
Designate remaining areas as intact (shown as green). This identifies anchor locations for management.



Approach I. Mapping Vulnerability on Your Own

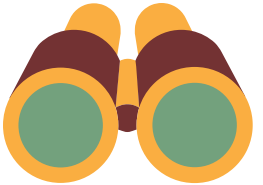
Step 2. Adjust/correct the map in the field.

Remote sensing products and aerial imagery used to create initial inventory maps often miss scattered seed sources and are unable to capture seedlings, especially those hidden in the grass layer. Refine the map by doing a rapid field inventory to validate, correct, and adjust the initial inventory map.



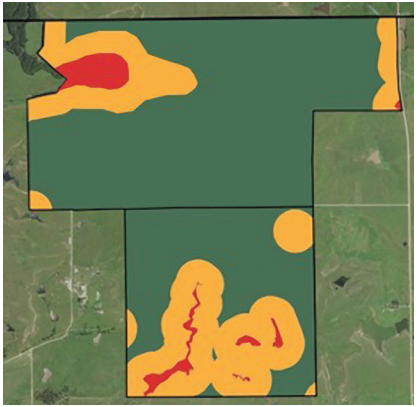
An example of an inventory map that was redrawn to reflect additional seed sources (marked as x) and seedlings (marked as •) that were identified during field inventory.

Approach I. Mapping Vulnerability on Your Own



Step 3. Map the long-term vision and compare to the current inventory map.

Current inventory map



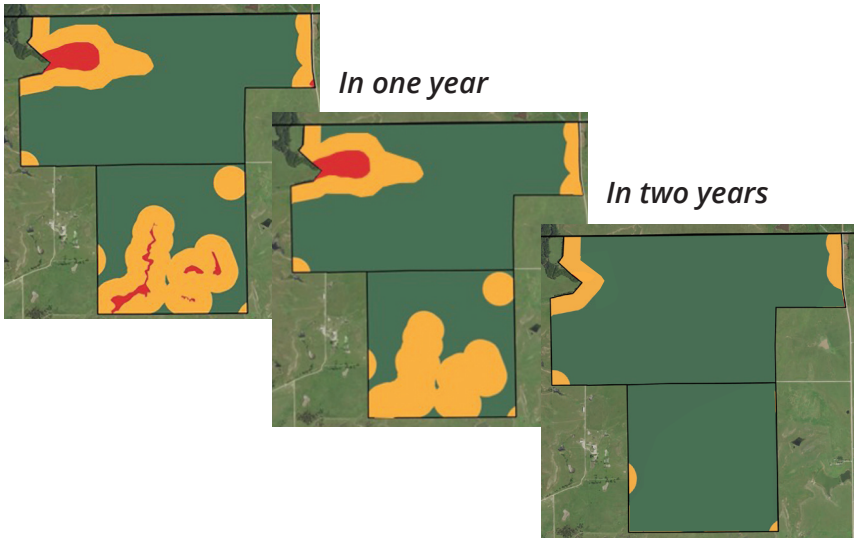
VS.

Long-term vision

Approach I. Mapping Vulnerability on Your Own

Step 4. Track progress over time and assess whether you are progressing towards your long-term vision.

Today



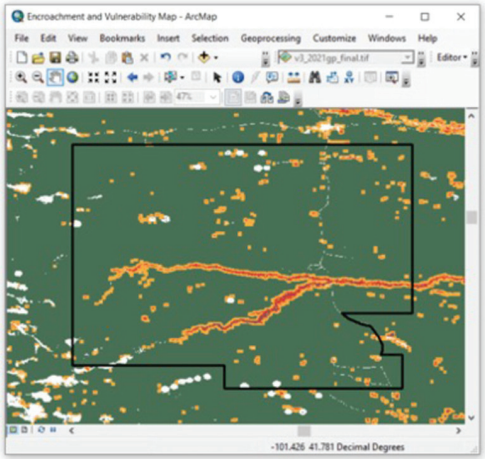
Approach II. Mapping Vulnerability Using National Data

Step 1. Download an initial inventory map.

Rangeland vulnerability to tree encroachment maps are available online. These maps were developed by a national team of rangeland scientists and can be used as an initial inventory map of vulnerability and encroachment for western U.S. rangelands.

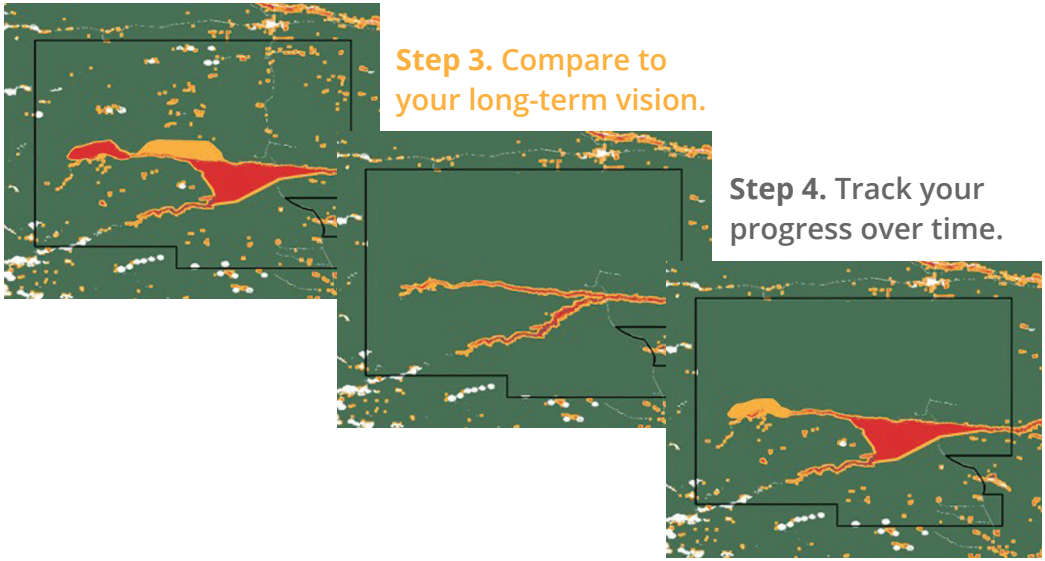
To download map:

https://www.wlfw.org/pocketguideqr



Approach II. Mapping Vulnerability Using National Data

Step 2. Adjust/correct the map in the field.



Step 3. Compare to your long-term vision.

Step 4. Track your progress over time.

Part II: Inventory and Map Cultural Will

Efforts to solve the woody encroachment problem are more successful when neighbors work together across property lines. An inventory and map of cultural will allows the conservation planner to more efficiently allocate resources, including time, money and labor, than is possible when focusing only on an individual pasture or property.

The Scale of Conservation Impact is Tied to the Scale of Collaboration

Individual property

Multiple properties

Statewide

Biome

Potential Scale of Impact

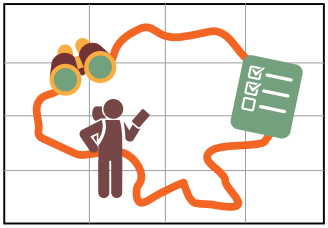
Individual impact	Conservation of ecosystem service values	Biome impact
Individual/internal dependence	Adaptive capacity of grassland partnerships	Biome support
Individual change	Cultural change	Biome change
Individual influence	Legislative influence	Biome influence

Recommended Minimum Inventory for Cultural Will

Step 1. Identify neighbors with shared values.

Step 2. Determine your potential to partner with neighbors.

Step 3. Map cultural will.



Step 4. Track progress in building cultural will.

Real-World Example of Building Cultural Will

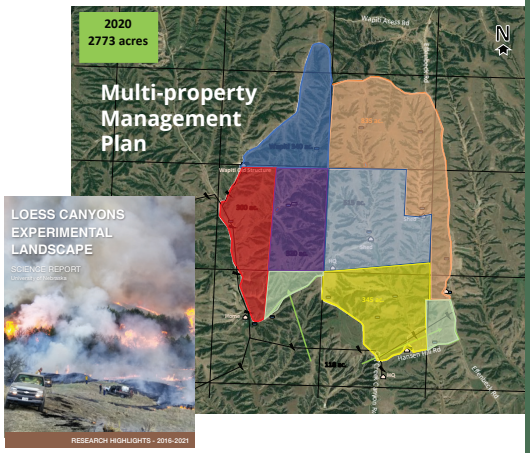
From early adoption to a regional partnership

The landowner-led effort to counteract woody encroachment in Nebraska's Loess Canyons is an example of how cultural will expanded, improving planning efforts and coordination across property lines.

Benefits of Building Cultural Will

Mapping cultural will in the Loess Canyons has helped landowners...

- Coordinate more targeted treatments across property lines,
- Scale up the size of treatments and thereby reduce implementation costs,
- Develop long-term plans on where to defend and grow intact grassland cores,
- Recruit new members and grow their partnership,
- Scale up the vision for what is possible in the region, and
- Produce unprecedented outcomes for landowner livelihoods, wildlife, and other ecosystem services.



The picture shows an actual example of management planning across multiple properties in the Loess Canyons. The ability to coordinate management across property lines has allowed rangeland planners to manage more acres while minimizing implementation costs.

Part III. Inventory and Map the Benefits that Intact Grasslands Provide

Ecosystem services are the benefits nature provides to people. Grasslands provide numerous ecosystem services including livestock production, wildlife habitat, water supply, pollination, and regulation of wildfire risk and natural disasters. The final inventory step is to overlay ecosystem services.

Livestock production

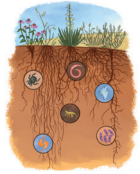
Biodiversity

Natural disaster avoidance

Water

Ecotourism

Wild food

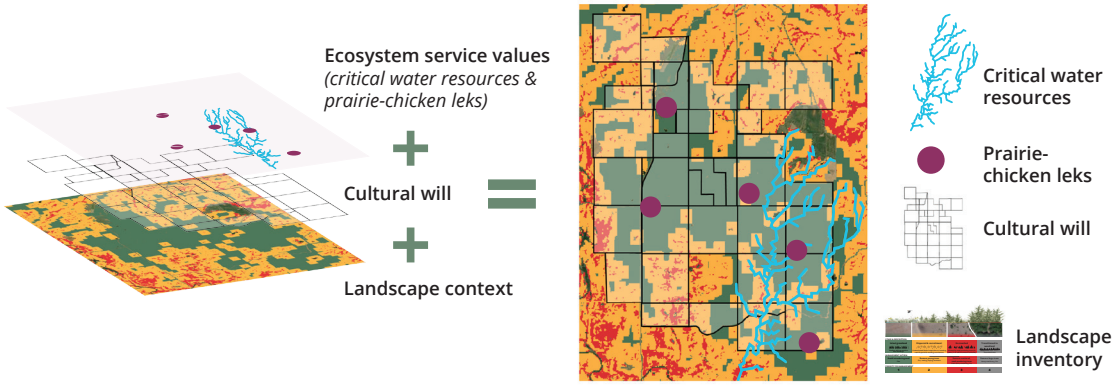


Carbon capture

Illustrations are from the Central Grasslands Roadmap's Grasslands and You campaign. Illustrations were created by Jessica French. https://www.grasslandsroadmap.org/grasslandsandyou

If Available, Stack Ecosystem Service Values on Top of Landscape and Cultural Will Inventory Maps

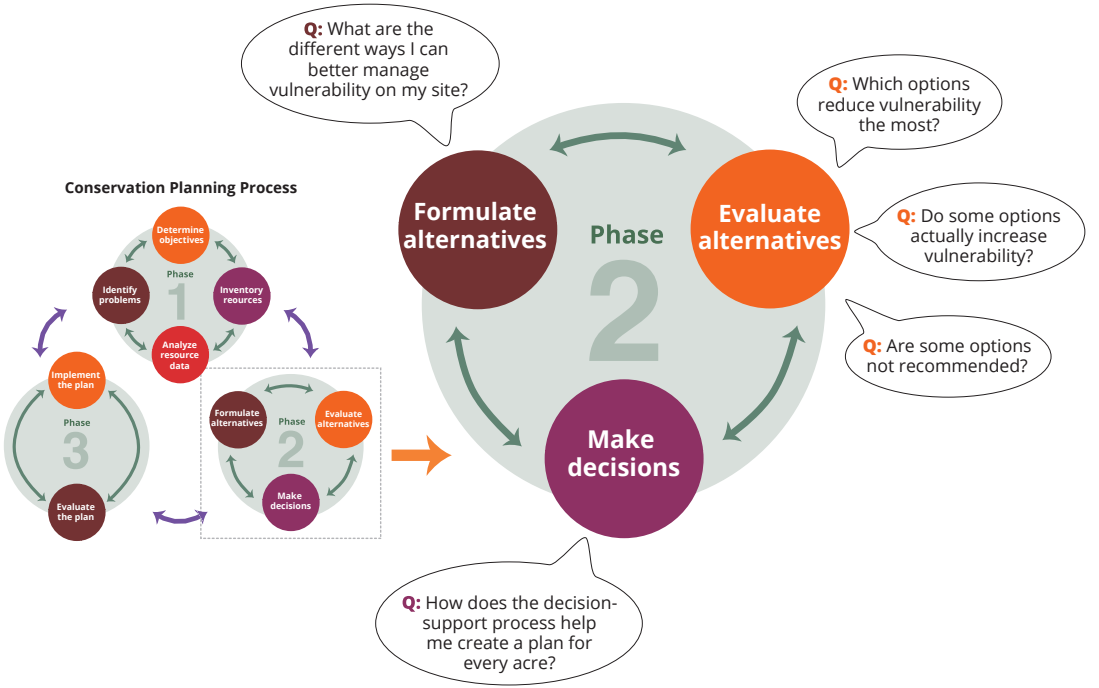
To further prioritize conservation planning, stack critical ecosystem services, if known, on top of inventory maps developed for landscape context and cultural will.



Stacked inventory maps better inform the conservation planning process.

Phase II. Decision Support

Developing solutions to reduce grassland vulnerability to woody encroachment.




CORTEVA
ARIAT

Designing Landscapes that are Less Vulnerable to Encroachment

This decision-support process helps the rangeland planner evaluate alternative strategies for reducing vulnerability under different landscape contexts. As part of this process, the rangeland planner must delineate the following encroachment stages on the site and consider alternative strategies for each stage as part of a spatial game plan.

Intact grassland (pg. 46)
Treeless sites with no incoming seeds

Contaminated (pg. 48)
Sites with incoming seed dispersal and seedling recruitment

Ultra-low infestation (pg. 50)
Sites that contain scattered seed sources

Severe infestation (pg. 52)
Sites that are dominated by mature woody plants

Rehabilitation (pg. 54)
Sites where all seed sources have been removed

Special cases (starting on pg. 56)
Tree plantings, watershed restoration, and more

How to Read the Decision Support Flow Charts

Low-to-no vulnerability pathway (optimal)

Moderate vulnerability pathway

High vulnerability pathway

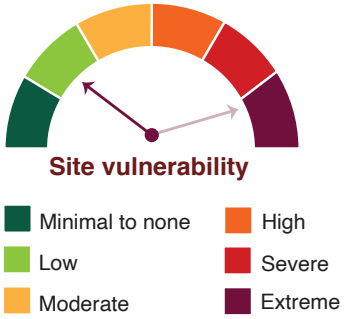
Decision point

Action

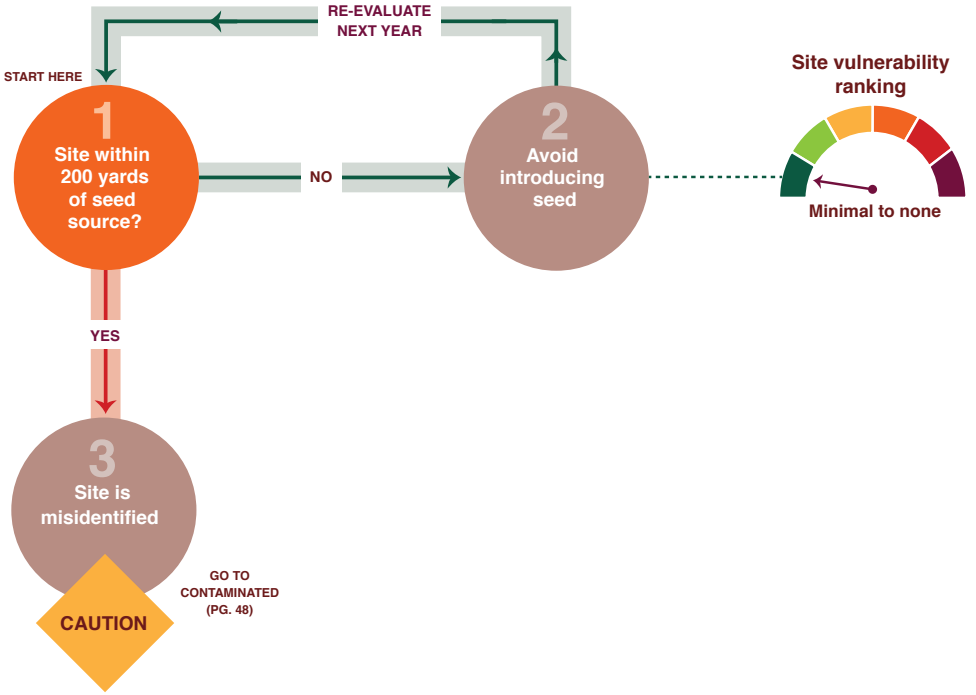
CAUTION

Caution points for action with higher vulnerability potential

How to read vulnerability rating dials



Intact


RE-EVALUATE
NEXT YEAR
START HERE
1
Site within 200 yards of seed source?
NO
2
Avoid introducing seed
Site vulnerability ranking
Minimal to none
YES
3
Site is misidentified
CAUTION
GO TO CONTAMINATED (PG. 48)

Supporting Details

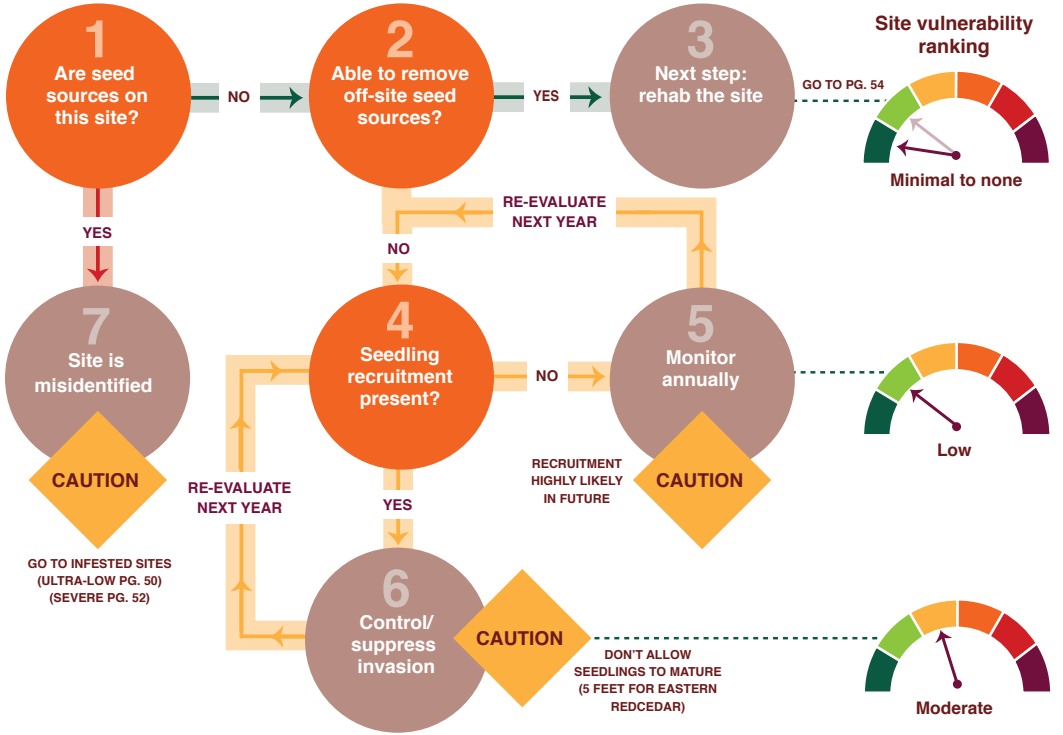
1. An intact grassland is not contaminated by seed. It is "Tree Free, Seed Free." Nearly all recruitment occurs close to existing seed sources, so 200 yards is used as a general guideline to monitor recruitment and invasion (see pg. 8); however, recruitment can occur at farther distances given local site conditions.

1 → 2. The best management practice for intact grasslands is to prevent the introduction of new seed sources. New seed sources increase your vulnerability and require more resources to manage. Recognize that problematic and invasive woody species used in tree/shrub plantings increase risk to grasslands. These can be native (e.g., eastern redcedar and honey mesquite) or non-native (e.g., Chinese tallow and Russian olive). Avoid introducing these species and watch for seed sources advancing from neighboring properties that could cause an intact site to become contaminated.

1 → 3. Sites that are within 200 yards of a seed source are contaminated and have different management guidelines from intact grasslands. See next page for appropriate decision support.

No longer recommended: 1. Planting known invasive and problematic woody species in grasslands. 2. Assuming woody encroachment will not happen on my property.

Contaminated (but looks intact)



Supporting Details

1 → 2 → 3. A contaminated grassland looks intact and is "Tree Free" but not "Seed Free." The site is exposed to seed sources located off-site. Removal of these seed sources is the only way to reduce vulnerability of the site and restore an intact state through site rehabilitation (pg. 54).

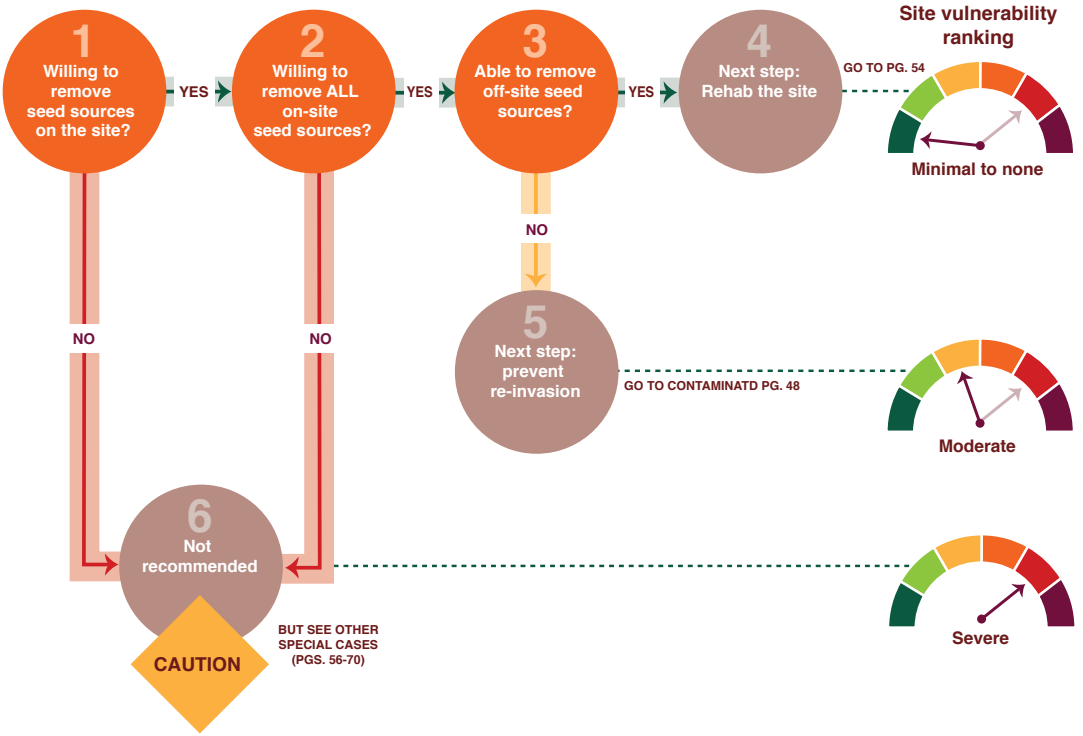
2 → 4 → 5. Annual monitoring is recommended to prevent the site from becoming infested, which increases the site's vulnerability. Seedling recruitment is expected on contaminated sites. Taller seedlings are easily seen above the grass layer, but don't assume "no encroachment" just because seedlings are not visible. Watch out for seedlings hidden in the grass layer. Rely on field monitoring to search for seedling recruitment within the grass layer and recognize that remote sensing products are not suitable for seedling detection.

2 → 4 → 6. The best management practice when off-site seed sources cannot be removed is to prevent vulnerability from increasing and stop the site from becoming infested. Immediately control and suppress invasions at the seedling stage to avoid the establishment of new seed-bearing individuals. Because this site is contaminated, it requires higher maintenance and perpetual monitoring to manage the increased vulnerability, unless off-site seed sources are removed. Failure at this stage results in infestation of the site and more costly control treatments.

1 → 7. Sites that contain mature seed sources are infested and have different management guidelines from contaminated grasslands. See next page for appropriate decision support.

No longer recommended: 1. Waiting to act until contaminated sites become infested. 2. A lack of monitoring next to seed sources on your property.

Ultra-Low Infestation



Supporting Details

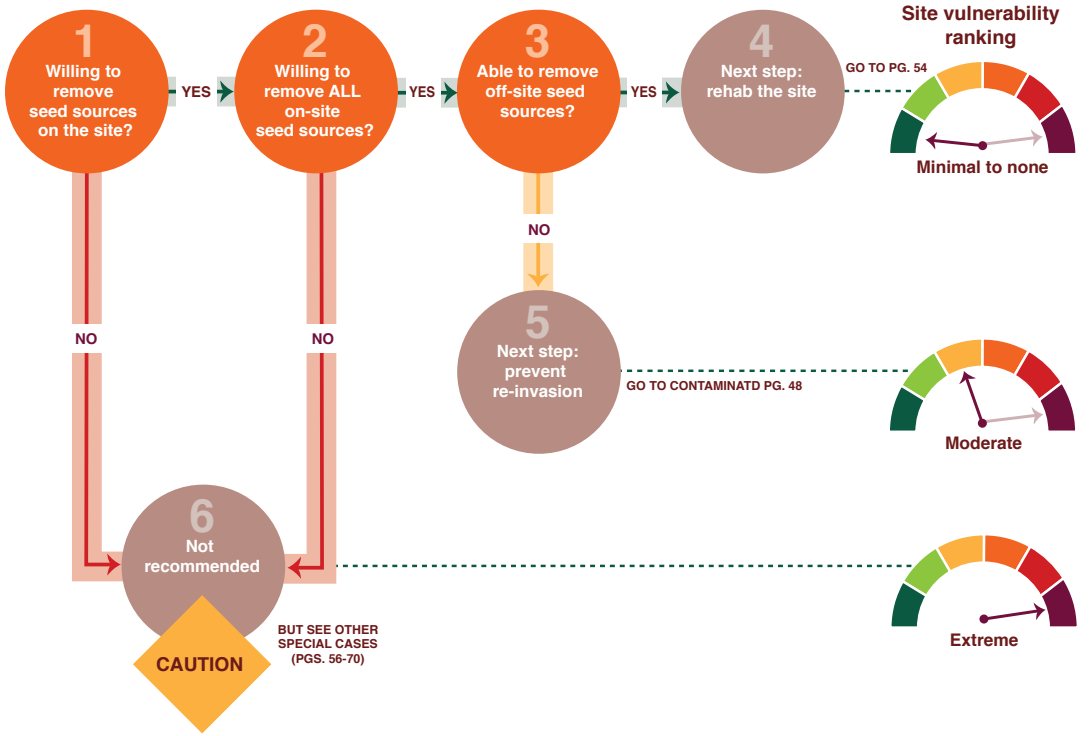
1 → 2 → 3 → 4. Restoration of ultra-low infestations requires the removal of ALL on-site and off-site seed sources followed by site rehabilitation to reduce the site's vulnerability to re-invasion (pg. 54). A single restoration treatment, even if it removes all seed sources, does not restore the site. The site must go through multiple control treatments to prevent re-invasion before restoration is complete.

3 → 5. If off-site seed sources cannot be removed, restoration of the site is not feasible, and it needs to be managed as a contaminated site to prevent re-invasion (pg. 48). The removal of on-site seed sources still reduces vulnerability of the site when followed by the control and suppression of re-invading seedlings, but less-so than when off-site seed sources can also be removed. Failure at this stage results in a waste of the initial treatment investment because another costly control treatment will be required when the site becomes re-infested.

1 → 6. "No seed source left behind." Leaving seed sources behind is not recommended because the vulnerability of the site has not changed. Leftover seed sources continue to contaminate the site, resulting in more rapid rates of re-invasion. Failure to act at ultra-low infestations results in more expensive control costs at more severe infestation levels (even though the decision-support process is the same; see next page). See special cases for decision support on rare instances when all seed sources are not removed from grassland sites.

No longer recommended: 1. A single 'restoration' treatment.
2. Leaving behind seed sources.

Severe Infestation



Supporting Details

**All infested sites require the same planning process but differ in the costs required to control infestations; control costs increase as infestations increase.*

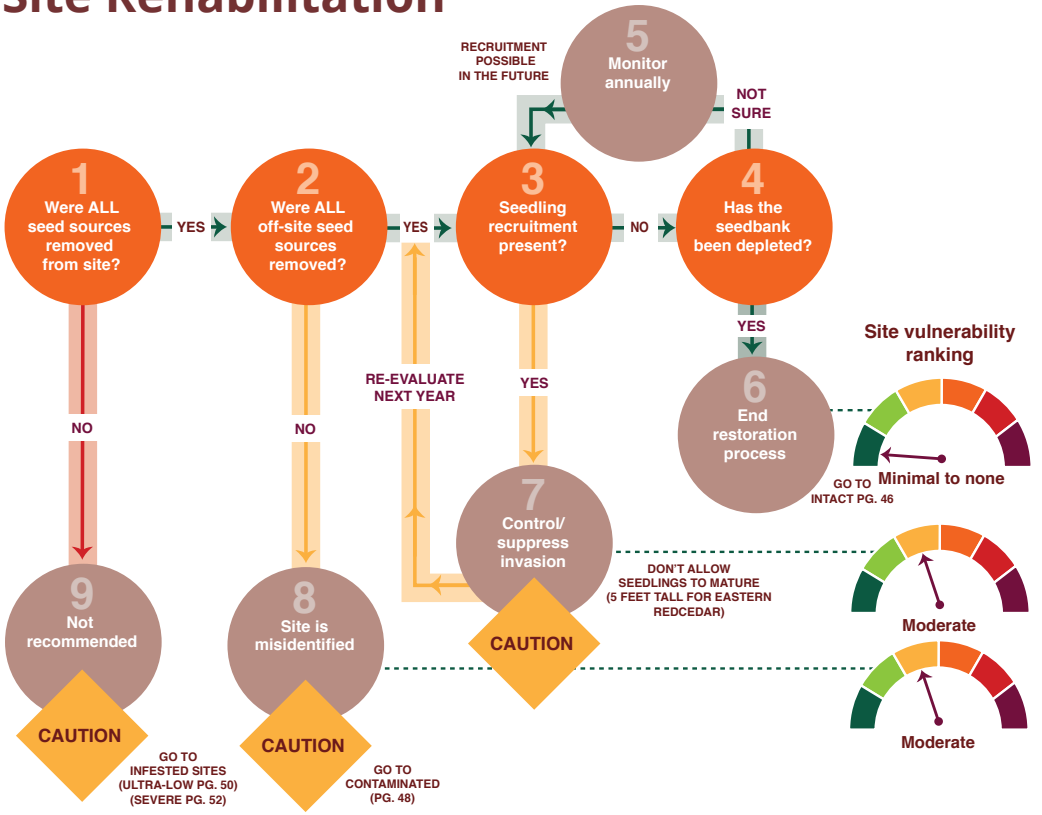
1 → 2 → 3 → 4. Restoration of infested sites requires the removal of ALL on-site and off-site seed sources followed by site rehabilitation to reduce the site's vulnerability to re-invasion (pg. 54). A single restoration treatment, even if it removes all seed sources, does not restore the site. The site must go through multiple control treatments to prevent re-invasion before restoration is complete.

3 → 5. If off-site seed sources cannot be removed, restoration of the site is not feasible, and it needs to be managed as a contaminated site to prevent re-invasion (pg. 48). The removal of on-site seed sources still reduces vulnerability of the site when followed by the control and suppression of re-invading seedlings, but less-so than when off-site seed sources can also be removed. Failure at this stage results in a waste of the initial treatment investment because another costly control treatment will be required when the site becomes re-infested.

1 → 6. "No seed source left behind." Leaving seed sources behind is not recommended because the vulnerability of the site has not changed. Leftover seed sources continue to contaminate the site, resulting in more rapid rates of re-invasion. Failure to act at any level of infestation results in more expensive control costs as infestations become worse. See special cases for decision support on rare instances when all seed sources are not removed from grassland sites.

No longer recommended: 1. A single 'restoration' treatment.
2. Leaving behind seed sources.

Site Rehabilitation



Supporting Details - *Complete removal of seed sources from the site is required.*

1 → 2 → 3 → 4 → 5 → 6. Site rehabilitation is required to restore contaminated and infested sites back to an intact condition. This requires depleting the seedbank. Depletion of the seedbank is the only biological pathway that can restore the site back to a vulnerability score of minimal to none. Seedbank depletion has received very little scientific study. Multiple control treatments will be required that target either the seedbank, new re-invading seedlings, or both. Annual monitoring is recommended to confirm the seedbank has been depleted (as evidenced by the long-term absence of re-invading seedlings) and to avoid re-infestation of the site and re-doing costly restoration treatments.

3 → 7. Rehabilitation is a series of interventions and requires long-term commitment. Control treatments will need to be repeated over multiple years to suppress re-invasion because the site is contaminated from the long-term exposure to seed sources on or nearby the site. The timeline for control/suppression will depend on the life history of the woody species (e.g., seed longevity) and its interaction with site conditions. Once new recruits are no longer occurring, the site should be annually monitored to determine if the seedbank has been depleted.

2 → 8. Sites that have not removed off-site seed sources are not ready for rehab. See contaminated sites on page 48 for appropriate decision support.

1 → 9. Sites that contain on-site seed sources are infested and are not ready for rehabilitation. See infested sites on page 50 or 52 for appropriate decision support.

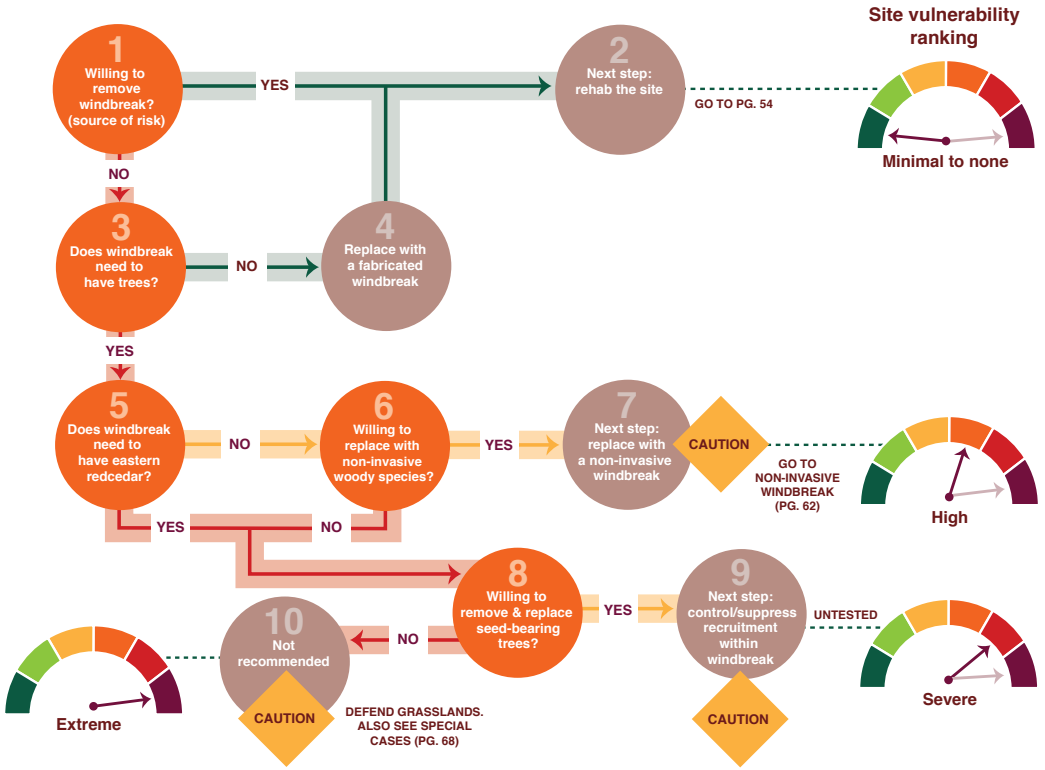
No longer recommended: Restoration without rehabilitation.

Windbreaks & Tree Plantings

Windbreaks & Tree Plantings

Windbreaks and other tree plantings represent special cases for planning and conservation design because they increase vulnerability in grasslands. Tree plantings that contain problematic and invasive species contaminate surrounding grasslands and increase long-term maintenance costs. While these plantings are typically introduced for a specific resource objective, their presence creates new resource concerns and problems for managing woody encroachment. Unfortunately, these problems are rarely considered at the time of introduction. This section introduces a decision-support process for navigating the management challenges that surround windbreaks and other tree plantings in grasslands. Decision support provides various options that reduce vulnerability from existing tree plantings and minimize vulnerability for new tree plantings.

Windbreak Management



Supporting Details

**The decision-support process to manage windbreaks introduces several alternative options for reducing grassland vulnerability. Future innovation in windbreak design may further reduce vulnerability to surrounding grasslands. Current decision support is most applicable for windbreaks consisting of eastern redcedar or other problematic/invasive woody species.*

1 → 2. Removing unnecessary windbreaks removes the source of the problem. Windbreaks are one of the top predictors of where woody encroachment occurs (or will occur), and their removal is the only way to reduce vulnerability and contamination in otherwise intact grasslands. Many landowners strategically remove windbreaks that no longer serve their original purpose (e.g., as calving shelter) or in hard-to-reach locations that make monitoring/managing spread more difficult. Removal should be followed by site rehabilitation to reduce vulnerability to re-invasion (pg. 54).

3 → 4 → 2. If wind protection is needed, consider replacing with a fabricated windbreak. Fabricated windbreaks do not contaminate grasslands and are a viable alternative for avoiding the consequences of woody encroachment. If you're concerned about aesthetics, landscaping design with non-invasive species has been used to hide fabricated windbreaks.

5 → 6 → 7. Replacing eastern redcedar with non-invasive substitutes reduces risk in grasslands. Eastern redcedar is one of only a few woody species to cause large-scale grassland collapse across multiple states. However, grasslands are vulnerable to the spread of other woody species and non-invasive replacements should be monitored for spread.

(continued on next page)

No longer recommended: Not managing windbreaks.

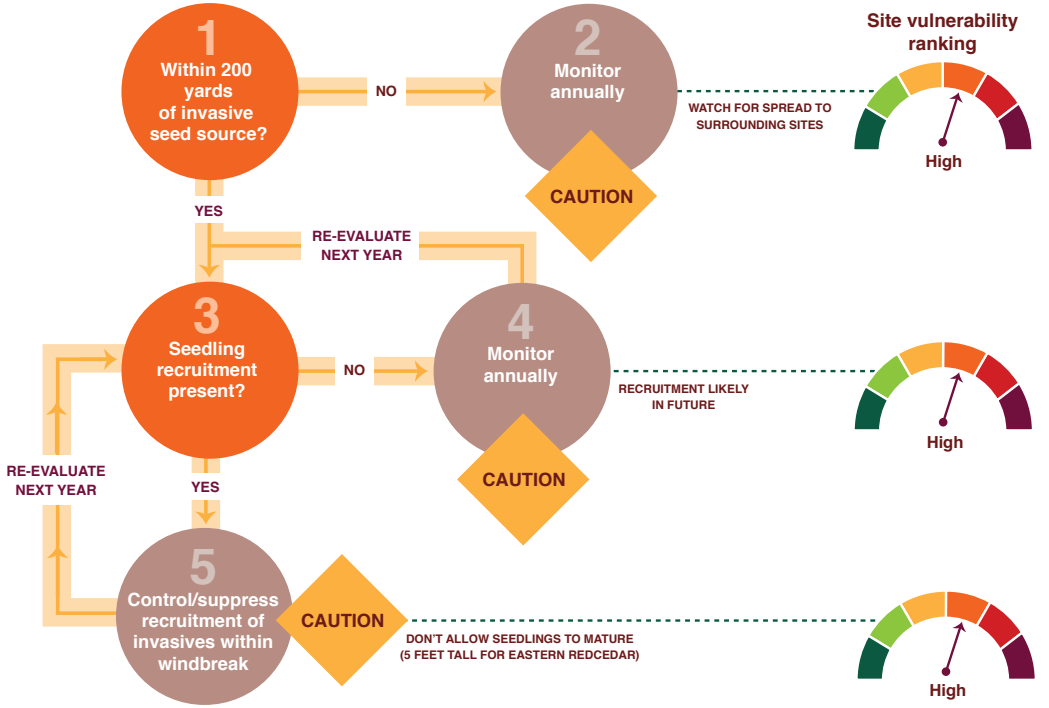
Supporting Details *(continued)*

Eastern redcedar replacement species have not received serious scientific investigation. In principle, this strategy should reduce risk but there are multiple untested assumptions that might compromise outcomes.

8 → 9. Selectively removing seed-bearing trees (females) has been proposed as an experimental practice for reducing risk in grasslands. Unfortunately, sex cannot be distinguished in juvenile woody plants, so long-term plans involve planting unsexed juveniles followed by selective culling of females at first sign of seed production. In windbreaks that have already matured, the long-term presence of seed sources can result in volunteer replacements after the removal of female trees. Selective culling of those volunteers should be conducted at first sign of seed production. **IMPORTANT: This approach is untested within the scientific literature!**

8 → 10. "No seed source left behind." Windbreaks serve as seed sources and create high-maintenance grasslands that need to be defended from invasion over time. Choosing to leave seed sources on-site is not recommended, even for existing windbreaks, because the vulnerability of the site remains high. Multiple other options exist to reduce vulnerability caused by eastern redcedar windbreaks.

Non-Invasive Windbreak or Tree Planting



Supporting Details

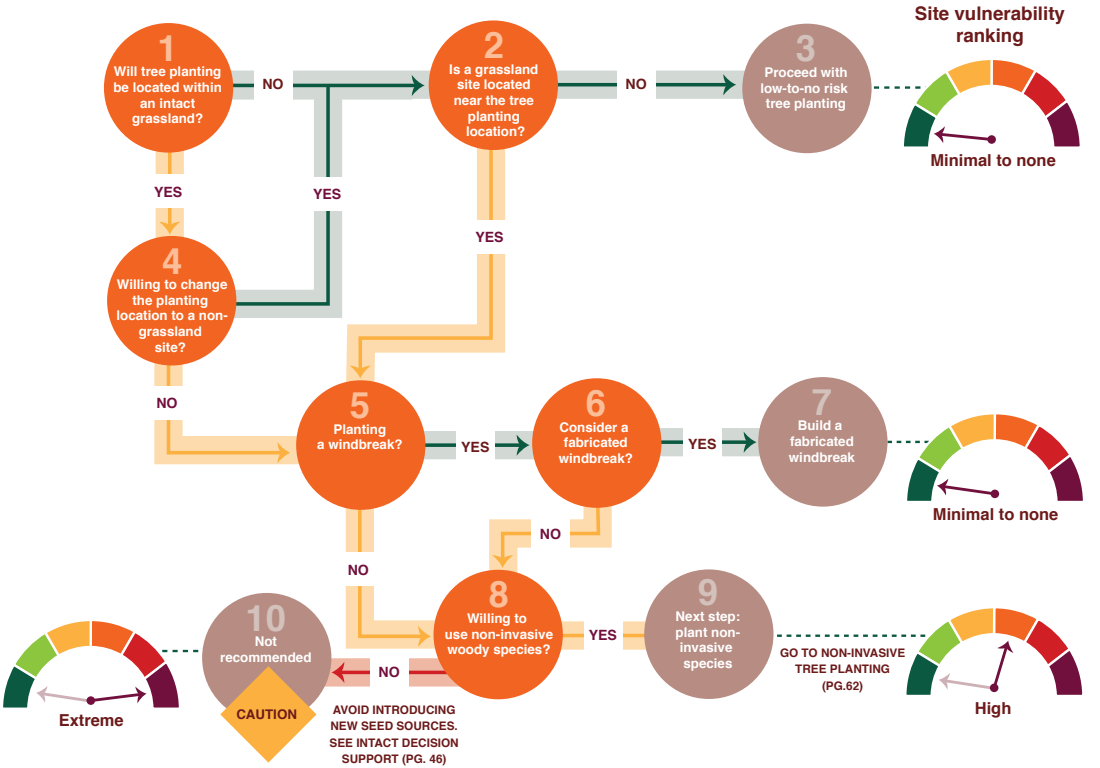
**Non-invasive tree species as replacements for invasive windbreak plantings have not received serious scientific investigation. In principle, this strategy should reduce risk but there are multiple untested assumptions that might compromise outcomes.*

1 → 2. Grasslands are less vulnerable to non-invasive woody species, but these species still have the potential to spread. Annual monitoring is recommended to identify and suppress spread.

3 → 4 & 3 → 5. Non-invasive woody plantings are vulnerable to invasion from other woody species. When located near invasive woody plants, non-invasive plantings can become compromised and unintentionally host invasive and problematic woody species (e.g., eastern redcedar). As in grasslands, immediately control and suppress invasions to avoid the establishment of unwanted seed-bearing individuals. Unless off-site seed sources are removed, non-invasive windbreaks/plantings should be managed as a contaminated site (pg. 48). This site requires higher maintenance and perpetual monitoring to control and suppress invasives within the windbreak/planting.

No longer recommended: 1. Failure to innovate historical windbreak designs. 2. Planting known invasive and problematic woody species in grasslands. 3. A lack of monitoring.

Planting Trees in Grasslands (including windbreaks)



Supporting Details

**Tree plantings have been considered a rangeland improvement practice for decades, and this practice requires careful decision support and long-term planning to avoid the consequences of future woody encroachment.*

1 → 2 → 3. The best management practice for tree plantings is to locate plantings where they do not contaminate and compromise grassland sites. Tree plantings are low-to-no risk when placed to avoid introducing new seed sources into intact grasslands (see intact sites on pg. 46).

4 → 2 → 3. Evaluate and choose alternative sites that do not contaminate surrounding grasslands. Tree plantings located in croplands, yards, or other non-grassland sites pose minimal risk to grasslands. Formulating and evaluating alternative locations should be a key planning requirement to ensure tree plantings are low-to-no risk in the future. Accomplish this by maximizing the distance between grassland sites and tree plantings.

5 → 6 → 7. Consider fabricated alternatives to living windbreaks. Fabricated windbreaks do not introduce seed sources and are a viable way to avoid future consequences from woody encroachment. If you're concerned about aesthetics, landscaping design with non-invasive species has been used to hide fabricated windbreaks.

(continued on next page)

No longer recommended: 1. Planting known invasive and problematic woody species in grasslands. 2.Tree planting as a range improvement practice.

Supporting Details *(continued)*

2 → 5 → 8 → 9 & 4 → 5 → 8 → 9. Use non-invasive woody species in tree plantings. Recognize that problematic and invasive woody species used in tree/shrub plantings increase risk to grasslands. These can be native (e.g., eastern redcedar and honey mesquite) or non-native (e.g., Chinese tallow and Russian olive). Avoid introducing these and other well-known problematic and invasive species. Non-invasive woody species are more ecologically appropriate, but there is scientific concern about the potential for these plantings to spread in the future or to facilitate the spread of other woody invaders.

8 → 10. Tree plantings do not improve grasslands. They increase grassland vulnerability. Introducing invasive and problematic woody species has consistently caused grassland conservation plans to eventually fail. Woody encroachment poses such a large threat to grasslands that the introduction of well-known invasive and problematic woody species should no longer be recommended. Species like eastern redcedar cause broad-scale consequences that occur down the road involving water quality/quantity degradation, rancher profitability declines, grassland biodiversity loss, heightened wildfire danger, reductions in school funding, and increased risk of vector-borne disease (among others). These consequences far outweigh local aesthetic and wind-protection benefits. Avoid denial and the notion that "it will not happen to me." Woody encroachment is occurring throughout many regions in the Great Plains for the first time and it's happening where there is no history of a woody encroachment problem. Unfortunately, the vast majority of woody plantings occur within intact grassland regions, which stand the most to lose. There are opportunities to make better-informed decisions about where certain well-known problematic woody species are planted and selecting less-problematic species to prevent grassland degradation.

Photo courtesy of USDA NRCS.

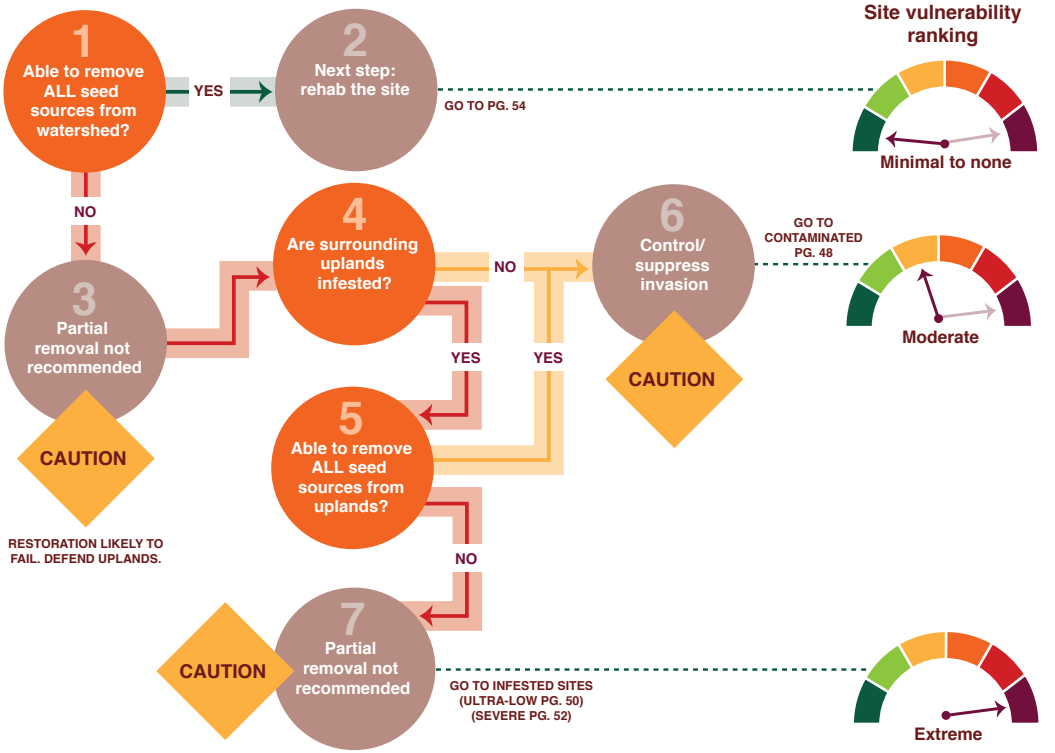
Other Special Cases

Other Special Cases

There are numerous cases where seed sources pose challenges for planning and conservation design. This section introduces a decision-support process to help navigate these challenges. Watersheds with infested riparian zones are used as a featured example of how to best reduce vulnerability. The same decision-support process can be applied to other special cases, including:

- Woody infestations in canyons, ravines, gullies, and other steep slopes
- Neighbors that do not manage woody encroachment
- Infestations on roadsides and other right of ways (e.g., railroad)
- Infestations on fence lines
- Defending core grasslands from historic woodlands and forests
- Defending core grasslands from protected habitats for forest specialists (e.g., golden-cheeked warbler)
- Defending core grasslands from encroachment by partnering across public-private land boundaries

Watershed Restoration & Other Special Cases



Supporting Details

**Watershed restoration occurs on infested sites where large-scale planning is needed to 1) restore the watershed, and/or 2) reduce vulnerability to the surrounding uplands.*

1 → 2. Restoration of infested sites requires the removal of all on-site and off-site seed sources followed by site rehabilitation to reduce the site's vulnerability to re-invasion (pg. 54). A watershed-scale plan that eradicates seed sources for the entire watershed is needed to accomplish restoration objectives. A long-term rehabilitation plan is then needed for the watershed (and the surrounding uplands).

1 → 3. "No seed source left behind." Leaving behind scattered seed sources or implementing a small, isolated treatment within the watershed is not recommended. The watershed is still exposed to seed sources, which results in rapid re-invasion and wastes the initial removal treatment. This causes restoration plans to fail. If eradication is not feasible, then uplands should be defended until a workable plan can be put into action.

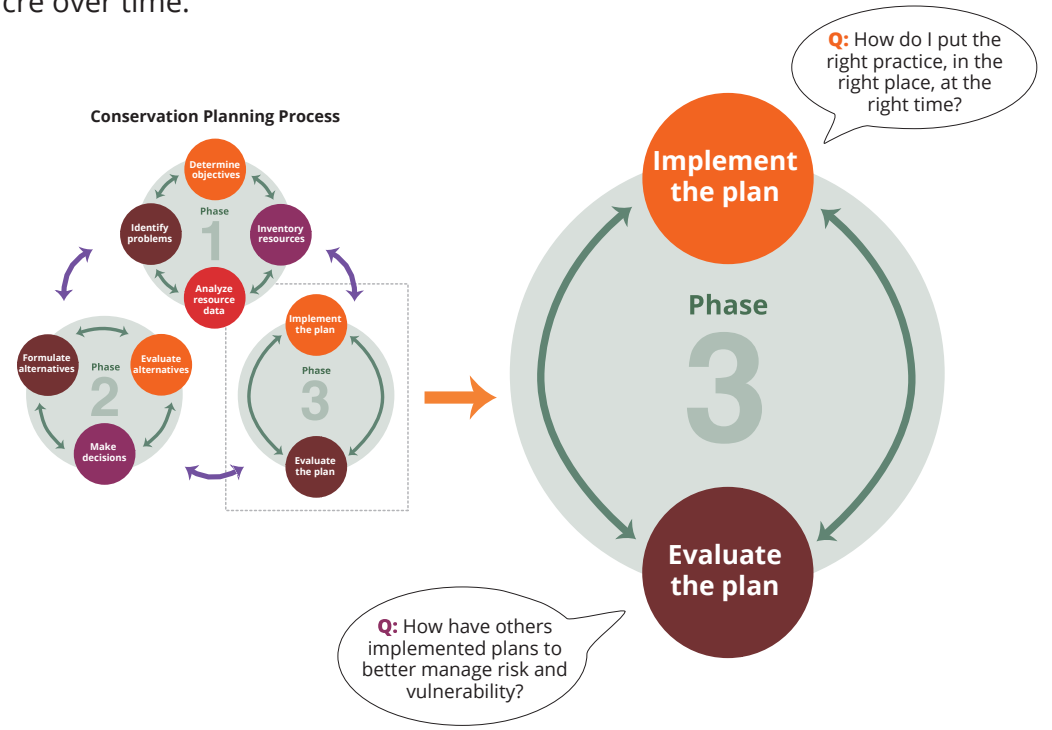
4 → 5 → 6 & 4 → 6 If seed sources cannot be removed from the riparian area, the best management practice is to prevent/remove seed sources from the uplands. Treat uplands as contaminated sites. See page 48 for appropriate decision support.

4 → 5 → 7. "No seed source left behind." Leaving behind seed sources is not recommended on uplands because the vulnerability of the site has not changed. Leftover seed sources continue to contaminate the site, resulting in more rapid rates of re-invasion. See infested sites on pgs. 50 & 52 for appropriate decision support.

No longer recommended: The absence of a watershed-scale restoration plan.

Phase III. Implementation

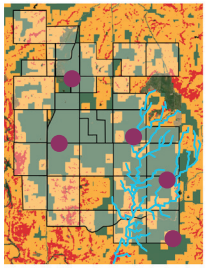
Putting it all together and implementing a spatial game plan for every acre over time.



Right Practice, Right Place, Right Time

Use the inventory process and decision support to implement your plan and reduce vulnerability on every acre. Adjust, as needed, over time.

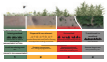
Stacked inventory map



Critical water resources

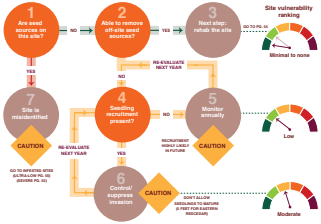
Prairie-chicken leks

Cultural will

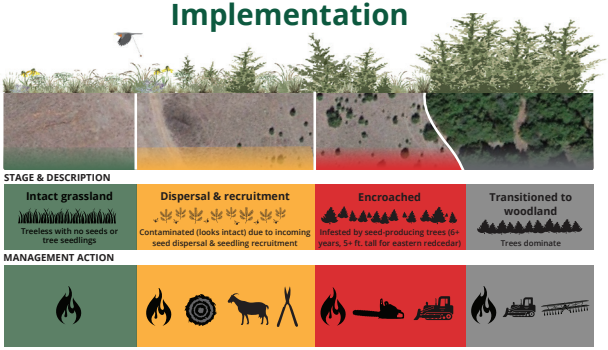


Landscape inventory

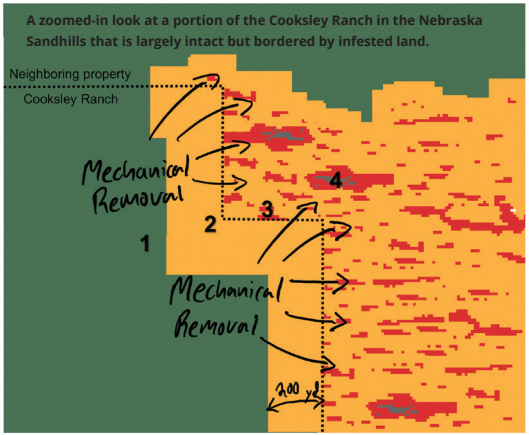
Decision support



Implementation



Taking Pressure Off Your Neighbors



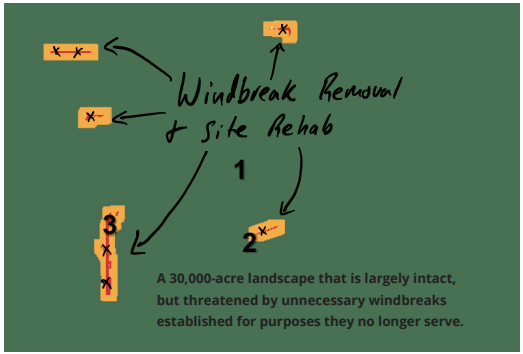
Decision support	Page number	Actions
1. Intact	46	Monitoring
2. Contaminated	48	Hand tools (loppers)
3. Infested	50	Mechanical clearing
4. Severely Infested	52	Mechanical clearing

Cooksley family/ Photo: Nebraska Cattlemen

The only way to reduce vulnerability on sites contaminated by off-site seed sources is to work with neighboring properties to remove the seed sources. In this example, a neighbor of the Cooksleys took pressure off their ranch by removing trees within 200 yards of the property line. This moved the seed contamination zone off of the Cooksley Ranch and allowed them to restore their land back to an intact grassland by lopping off seedlings as the seedbank exhausted itself over time.

"My neighbors cleared every cedar tree within 200 yards of our ranch to reduce the vulnerability on our side of the fence." -Barb Cooksley, Cooksley Ranch

Removing Threats of Unnecessary Windbreaks



A 30,000-acre landscape that is largely intact, but threatened by unnecessary windbreaks established for purposes they no longer serve.

Decision support	Page number	Actions
1. Intact	46	Monitoring
2. Contaminated	48	Hand tools & haying
3. Windbreaks	58	Mechanical clearing

"We are eliminating the threat to our livelihoods and increasing rancher profitability by identifying and removing windbreaks that are no longer needed."
-Shelly Kelly, Sandhills Task Force

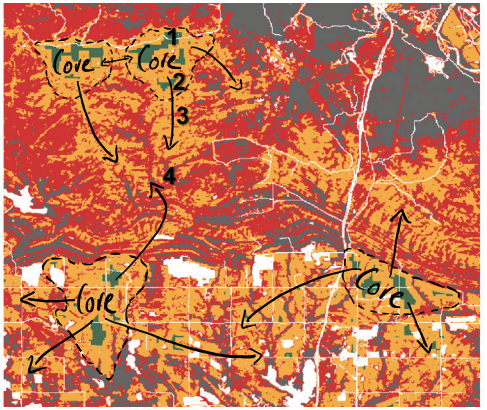

Shelly Kelly

Windbreaks that contain problematic and invasive woody plants increase grassland vulnerability to encroachment and require constant management to contain. In this example, the Sandhills Task Force worked with ranchers to identify and remove unneeded windbreaks. This reduced the ranches' overall vulnerability to encroachment and long-term maintenance costs. After removal, managers rehabilitate the site using prescribed fire or by cutting seedlings until the seedbank is exhausted and the site reverts back to an intact grassland.


BEFORE **AFTER**

Defend the Core → Grow the Core

(in infested landscapes)



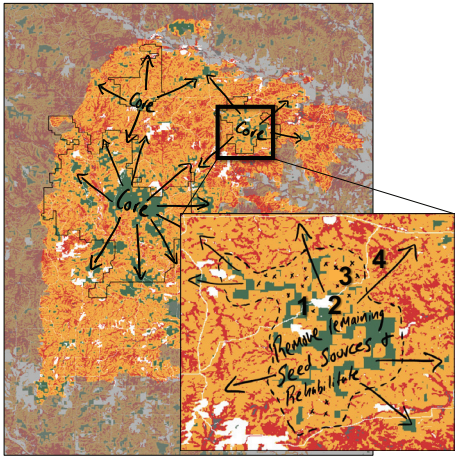
A 130,000-acre multi-landowner landscape showing the last remaining grasslands in Oklahoma's Arbuckle Mountains (white areas represent non-rangeland).

Decision support	Page number	Actions
1. Intact	46	Fire
2. Contaminated	48	Fire
3. Infested	50	Mechanical clearing & Fire
4. Severely Infested	52	Mechanical clearing & Fire

Defending and growing grassland cores in heavily encroached landscapes preserves critical grassland values. In this example, stewards of the last grasslands in Oklahoma's Arbuckle Mountains operationalized the Defend the Core, Grow the Core approach to safeguard the region's grassland cores for future generations. The plan anchors efforts to intact grasslands and uses prescribed fire and mechanical cutting to re-establish and grow grassland cores. The plan provides a sustainable approach for conserving grasslands in heavily converted landscapes and buys time to grow and connect cores as opportunities, like wildfire, arise.

"After decades of battling cedar, we now have a better plan to defend our grassland and work with our neighbors to reclaim the land for future generations."
-Chuck Coffey, Double C Cattle Co.

Defending & Connecting Cores After Wildfire



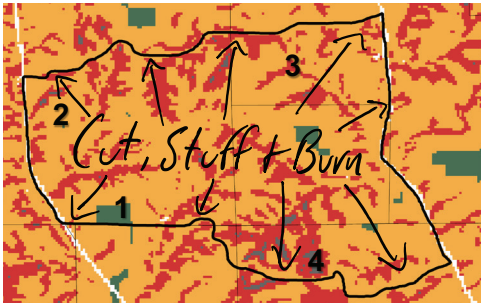
The footprint of the 400,000-acre Anderson Creek fire and a network of private properties working to establish grassland cores in Kansas's Gypsum Hills (white areas represent non-rangeland).

Decision support	Page number	Actions
1. Intact	46	Fire
2. Contaminated	48	Fire
3. Rehabilitation	54	Fire
4. Infested	50	Mechanical clearing & Fire

High costs often prohibit large-scale restoration of severely infested landscapes. But sometimes events like a wildfire can provide unforeseen opportunities for large-scale restoration. In this example, managers in Kansas's Gypsum Hills capitalized on the massive hit woody plants took during the Anderson Creek fire in 2016. Managers worked to "finish the job" by removing isolated trees that escaped the wildfire and using prescribed fire to rehabilitate contaminated areas. Ultimately, the plan minimizes vulnerability in the landscape by connecting large grassland cores across a network of private properties.

"The collapsing biome is at our front door and the wildfire bought us time to come together as a rancher community and defend our lands. Tree-free, seed-free is now the philosophy around here."
– Russell Blew, Nichols Ranch

Growing Cultural Will to Manage at Scale



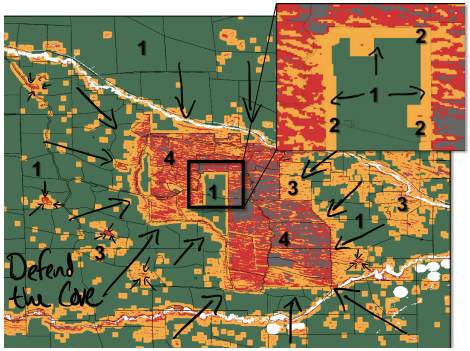
2,500 of 264,000 acres in the collaboratively managed, privately owned Loess Canyons landscape.

Decision support	Page number	Actions
1. Intact	46	Fire
2. Contaminated	48	Fire
3. Infested	50	Fire & Mechanical cut-and-stuff
4. Severely Infested	52	Fire & Mechanical cut-and-stuff

Growing the cultural will to act can be one of the most challenging aspects of managing woody encroachment at regional scales. In this example, ranchers in Nebraska's Loess Canyons form alliances as part of a large-scale restoration effort. Ranchers work together to plan and coordinate management treatments across property lines. Mechanical clearing and fire are integrated as part of the cut-and-stuff technique that allows managers to target all stages of encroachment at once—something that gives landowner alliances a huge advantage in their ability to manage at the scale of the problem.

"If we were going to save our ranches from eastern redcedar, we had no choice but to work together and restore fire to the Loess Canyons. Fifteen years later, fire is the culture of the region." –Scott Stout, N-N Ranch, President of the NE Prescribed Fire Council

Defend the Core Across Public & Private Property



USDA Joint Chiefs' Agreement to collaboratively reduce vulnerability on 90,000-acres of public and 40,000 acres of surrounding private land. Lines show pasture boundaries on public and private land.

Decision support	Page number	Actions
1. Intact	46	Fire
2. Contaminated	48	Fire
3. Infested	50	Mechanical clearing
4. Woody plantings	58	Contain dispersal with fire

Managing infested lands is expensive, so a strategic approach that maximizes return on investment is critical. In this example, public- and private-land managers within and near the Nebraska National Forest at Halsey use the Defend the Core, Grow the Core approach to contain the nation's largest hand-planted forest. Their plan is to establish a grassland core surrounding planted forests and windbreaks that can be defended over time with prescribed fire. Cores are established one pasture at a time using mechanical cutting followed by prescribed fire to remove seed sources and then clean out the remaining seedlings and seed, respectively.

"We can remove isolated parent trees from otherwise treeless pastures for just $1-2 per acre, which allows our managers to cover more ground and get ahead of encroachment."
–Julie Bain, Bessey Ranger District, U.S. Forest Service

Checklist for Implementation

Avoid These Common Mistakes

Avoid scattered, random acts of conservation. Scattered treatments result in short-lived projects and do little to reduce risk and vulnerability. Clustered and spatially targeted treatments reduce exposure and build upon previous management investments.

Avoid leaving seed sources behind. Leaving behind seed sources fails to reduce exposure. Leaving trees does not reduce risk to future woody encroachment, meaning costly treatments will be needed again in the near future.

Avoid the myth of a single restoration treatment. Sites remain highly vulnerable to encroachment after a single restoration treatment. Follow-up management is required to prevent re-encroachment due to remaining seeds and seedlings that escaped the initial treatment. No pathway exists to restore grasslands using a single action.

Avoid narrow targets during restoration. Restoration requires integrating management across all stages of encroachment. Fixating on a single stage during the restoration process leaves sites vulnerable to encroachment. This happens most often when actions prioritize the removal of mature trees, but neglect management of seeds and seedlings that are left behind.

Avoid waiting until later stages of encroachment. Waiting to act results in the need for expensive restoration treatments that often exceed a site's annual grazing value. Moreover, waiting to act creates a larger land base that is vulnerable to encroachment.

Checklist for Implementation

Avoid These Common Mistakes

Avoid assuming re-encroachment is encroachment again. Re-encroachment occurs faster than initial rates of encroachment. Good planning accounts for the increased management inputs required by restored lands vs. lands experiencing encroachment for the first time.

Avoid chasing the problem. Strategies that do not recognize seed dispersal and recruitment as the leading edge of encroachment chase the problem over time. Restoring infested areas, while ignoring the leading edge, has not worked at large scales. Anchor management to intact grasslands and prioritize efforts on the leading edge of encroachment.

Avoid making the tool the goal. Implementing a treatment is not a goal. Dollars spent and acres treated are not goals. Set management goals based on desired outcomes like reducing vulnerability and conserving intact grasslands. These goals should account for scale – from individual properties to regional conservation efforts.

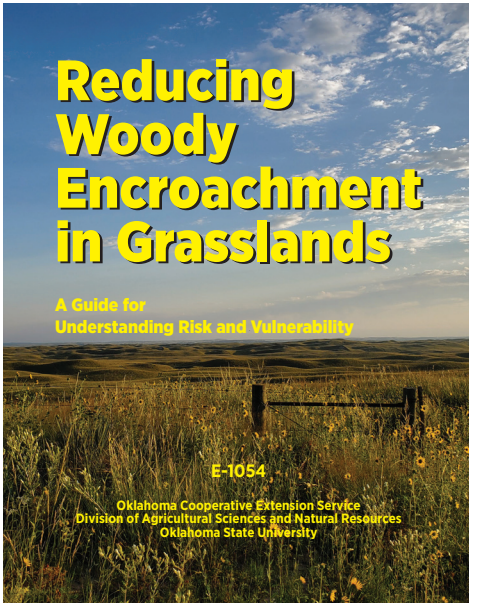
Avoid a single silver bullet. Traditional brush management results in constant management of brush. Sites remain highly vulnerable to encroachment. An integrated approach, not a silver bullet, is needed to minimize vulnerability in grasslands and sustain large-scale grassland ecosystems.

Avoid denial. Woody encroachment is happening in areas where it has never happened before. Research shows that exposure to seed sources is the most important determinant of whether encroachment occurs in the future. Don't repeat the mistakes of past rangeland planners and assume, "It won't happen to me."

A Guide for Understanding Risk and Vulnerability

In 2021, Twidwell and others published: *Reducing Woody Encroachment in Grasslands: A Guide for Understanding Risk and Vulnerability.* This "Vulnerability Guide" introduced a new approach for managing woody encroachment. Instead of waiting to act until grasslands are infested, the new approach focuses on proactive management and reducing risk and vulnerability in grasslands.

Check out the full Vulnerability Guide for additional information about the original framework introduced for reducing grassland vulnerability to encroachment.



GREAT PLAINS
Grasslands Extension Partnership

The Great Plains Grasslands Extension Partnership is comprised of rangeland scientists and extension faculty from all land-grant universities in the Great Plains. Our mission is to provide the information, resources, and tools necessary to improve the performance of grassland conservation and speed-up the adoption of new science-based solutions. The Extension Partnership embraces a vision of sustainable grasslands that are intertwined with rural livelihoods and communities in the Great Plains. This guide is the first product from the Extension Partnership to support citizen efforts to confront the impending collapse of the Great Plains grassland biome due to woody encroachment.

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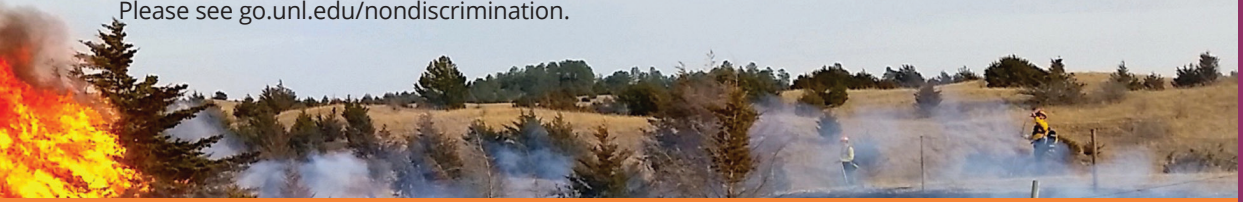

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