Juniper recovery following initial restoration with fire: Implications for managers

Caitlin de Vries[1], Christine Bielski[2], Dillon Fogarty[2], and Dirac Twidwell[2]
[1]*Department of Natural Sciences and Mathematics, West Liberty University, West Liberty, WV 26003, USA*
[2]*Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583, USA*

Figure 1. Intact grassland. Photo taken by Caitlin de Vries, July 2018

Figure 2. Fragmented grassland. Photo taken by Caitlin de Vries, July 2018

Background: Intact grassland landscapes support resilient communities that benefit from the natural and economic benefits associated with grasslands. The unfolding invasion of Eastern redcedar (*Juniperus virginiana*) in the Great Plains eliminates and fragments grassland landscapes, resulting in the loss of livestock production, water yield, regulation of wildfire risk, and native biodiversity (Meneguzzo & Liknes 2015, Twidwell et al. 2013).

Providing Management Guidance

There is a large focus on land management strategies that can restore grasslands that have been invaded by Eastern redcedar. Among restoration strategies, use of high intensity prescribed fire is increasing rapidly due to its effectiveness and low cost per acre (Weir et al. 2016).

Figure 3. Juniperus virginiana. Photo taken by US FWS, April 2012, distributed under Public Domain

Figure 4. Recording data in the Loess Canyons. Photo taken by Dillon Fogarty, July 2018

However, after initial restoration by prescribed fire, it is unclear how recovered grasslands should be managed to avoid re-invasion. To provide sound guidance on post restoration management (0-16 years after initial restoration), we measured Eastern redcedar re-invasion at 22 locations in the Loess Canyons, NE that were restored to grassland plant communities using high intensity prescribed fire. Based on these results, we provide recommendations on the timing and application of different intervention techniques capable of maintaining grasslands.

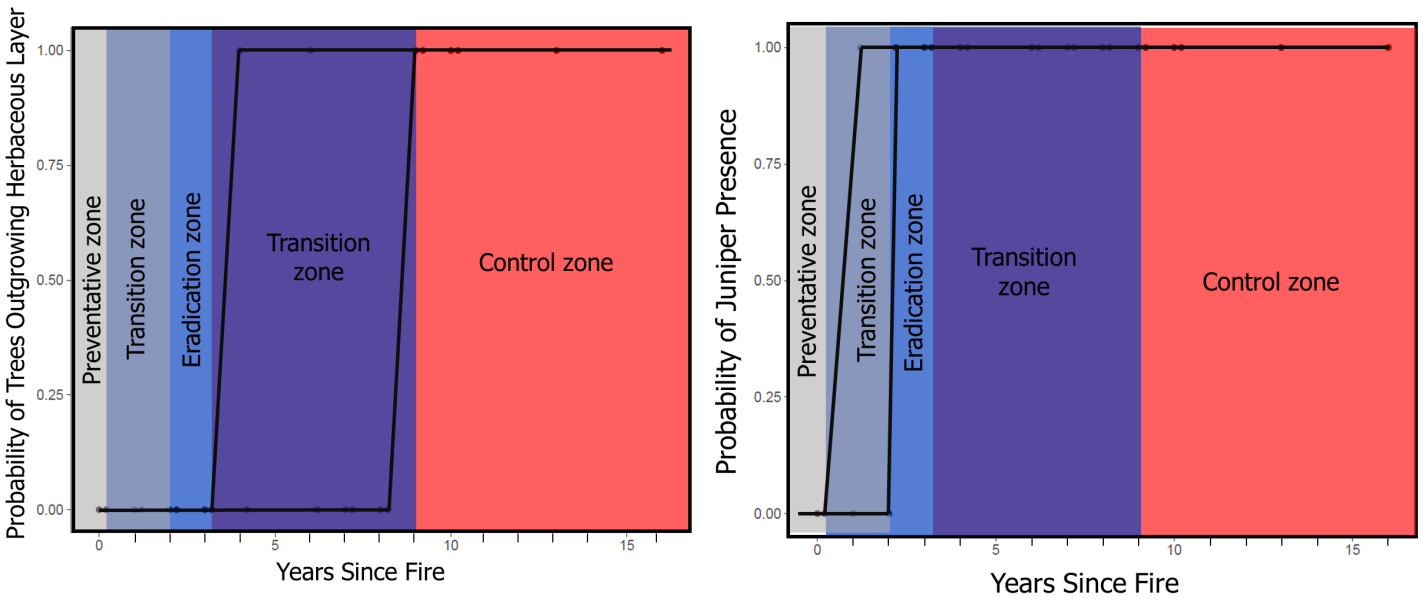

Figure 5. Probability of (A) Eastern redcedar presence and (B) the presence of Eastern redcedars that have outgrown the herbaceous plant layer following restoration with prescribed fire. Probabilities are based on Eastern redcedar reinvasion of restored grasslands in the Loess Canyons, Nebraska. Intervention zones correspond to recommended intervention strategies based on the biological stage of invasion (Blackburn et al. 2011). However, note that eradication can be applied to any stage in the invasion process if proper techniques are applied (e.g., high intensity prescribed fire). Intervention strategies correspond to management techniques in Figure 3.

Intervention Strategies:

Prevention: Intercepting invasion at the outset, that is, preventing the introduction of propagules or preventing propagules from becoming seedlings. Prevention is often a cost-effective option because it avoids costs incurred from invasion (Wittenberg and Cock 2001).

Eradication: Complete elimination of a species from a target area, creating substantial ecological and economic benefits (van Wilgen and Richardson 2014). Eradication is most readily accomplished before trees outgrow the herbaceous layer, at which point herbaceous plants are displaced and growth accelerates (Engle & Kulbeth 1992; Riginos 2009)

Control: Decreasing the amount of the invading organism "to keep it below an acceptable threshold" (Wittenberg and Cock 2001; van Wilgen and Richardson 2014). Emphasis is placed on reducing the number of invading individuals. Some control methods preferentially target small trees (e.g., mowing, low intensity prescribed fire), while others target large trees that have outgrown the grass zone (e.g., hand tools, mechanical).

Restoration: Re-establishment of a community to its pre-invasion conditions following a period of invasive species dominance (Hobbs and Norton 1996).

Management phase	Description of invasion phase	Biological cues	Intervention strategies	Monitoring		Management options				
				In Field	Remote Sensing (Satellite Imagery)	Fire	Goats	Haying	Hand Cutting	Mechanical
Phase 0: Endemic, no pressure for infestation	No propagule pressure; no individuals present	Absence of seed sources; no trees present in herbaceous layer	Processes in place to **prevent** the occurrence/germination of new individuals	×						
Phase 1: Propagule phase	Landscape transition where seeds are entering the site, no propagation	Presence of potential seed sources; no trees present in herbaceous layer	Processes in place to **prevent** the occurrence/germination of new individuals	×		×				
Phase 2: Incipient phase	Propagation and a life stage transition where seeds become seedlings; this life stage transition occurs within the herbaceous layer and not readily identifiable	Incipient trees below the herbaceous layer, detectable only through intense searching	**Eradication** of incipients and removal of seed sources	×		×	×	×	×	
Phase 3: Escape and rapid growth phase	Seedlings escape competitive bottlenecks within the herbaceous layer at which point growth rate accelerates	Presence of trees above herbaceous layer (>0.5 m in most working landscapes); readily identifiable.	**Control** infestations **Bottom-up**: remove trees from herbaceous layer **Top-down**: Remove trees that have escaped herbaceous layer	×	×	×			×	
Phase 4: Exponential spread and recruitment phase	Synchronous phase where propagule pressure, incipient establishment and spread, escape and rapid growth and recruitment occur at an accelerated rate for newly established individuals; increase in total tree cover	Departure from a historical constant in tree cover (ANY increase in canopy cover/density across a landscape); historical context usually 0% woody cover for grasslands	**Control** infestations **Bottom-up**: remove trees from herbaceous layer **Top-down**: Remove trees that have escaped herbaceous layer	×	×	×			×	×
Phase 5: Landscape transition phase	State transition from grassland to woodland; invasion rate is reduced	Woody cover ≥40% based on inflection point in the invasion process (Briggs et al. 2002)	**Adapt** to new conditions / Long term management OR when capacity exists to sustain grassland **Restore** grassland by removing all trees	×	×	×				×

Figure 6

Figure 7. Prescribed fire. Photo taken by Christine Bielski

Prescribed Fire: This is the only technique that is capable of prevention, eradication, control, and restoration, which is made possible by altering the intensity of fire. Prescribed burning can be used to prevent future redcedar invasion, or manage current redcedar invasion by removing established redcedars. Low-intensity prescribed fires remove small to medium sized redcedars, while high-intensity prescribed fires remove redcedars of any size (Simonsen et al. 2015).

Goats: For trees up to 3-4 feet tall, goats work as a biological-control agent. In the first year of grazing, goats can remove most trees under 24 inches. With trees 4-8 feet tall, goats can remove 50% of trees in 3-5 years (Knezevi et al. 2005). It is best to use goats for eradication when incipient trees remain below the herbaceous layer, shown here to be 1-8 years following initial restoration with prescribed fire.

Haying: Redcedar seedlings are removed by haying grasslands. For locations with gentle terrain, haying has potential to remove all seedlings. Therefore haying can be used as an eradication strategy while trees remain small (Simonsen et al. 2015).

Hand Cutting: Most efficient in small areas and on trees under 2 feet tall, but can work on taller ones. When cut below the lowest branches, redcedar will not regrow. Shears, saws, spades, shovels, or hoes are all handheld tools that can be used (Knezevi et al. 2005). Hand cutting is a control method because only easily detectable trees are removed. Hand cutting is best applied 4+ years after initial restoration with prescribed fire when trees outgrow the grass zone and are easily detectable.

Figure 8. Hay bales. Photo taken by Jan van der Crabben, September 2005, distributed under a CC-BY-SA-2.0 License

Mechanical: Used for larger trees, and requires chain saws, vehicle-mounted shears, shredders, or "cedar eaters". This method can be labor-intensive, time consuming, and dangerous (Knezevi et al. 2005; Twidwell et al. 2015). Often this equipment is more expensive, and this is also less effective at removing redcedars from difficult to reach or steep sloped areas (Simonsen et al. 2015). Mechanical methods are best used for localized control and restoration during the mid to late stages of invasion, which we found to be at least 9 years following initial restoration with prescribed fire.

References

Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Richardson DM: Trends Ecol Evol **26**, 333 (2011)

Engle DM, Kulbeth JD: J Range Manage **45**, 301 (1992)

Hobbs RJ, Norton DA: Restor Ecol **4**, 93 (1996)

Meneguzzo DM, Liknes GC: J Forest **113**, 325 (2015)

Riginos C: Ecology **90**, 335 (2009)

Simonsen VL, Fleischmann JE, Whisenhunt DE, Volesky JD, Twidwell D: U Nebraska Lincoln Extension, Act Now or Pay Later (2015)

Stevan Knezevi S, Melvin S, Gompert T, Gramlich S: U Nebraska Lincoln Extension, Integrated Management of Eastern Redcedar (2005)

Twidwell DT, Rogers WE, Fuhlendorf SD, Wonkka CL, Engle DM, Weir JR, Kreuter UP, Taylor CA: Front Ecol Environ 11, e64 (2013)

Twidwell D, Wonkka CL, Sindelar MT, Weir JR: Plos One **10**, e0140410 (2015)

Weir JR, Twidwell D, Wonkka CL: Rangelands **38**, 113 (2016)

Wittenberg R, Cock MJW: Invasive Alien Species: A Toolkit of Best Prevention and Management Practices. CAB International, Wallingford, Oxon, UK, xvii (2001)

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