Weed management at the landscape scale; A review of control actions for temperate grasslands

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REVIEW ARTICLE

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Weed management for landscape scale restoration of global temperate grasslands

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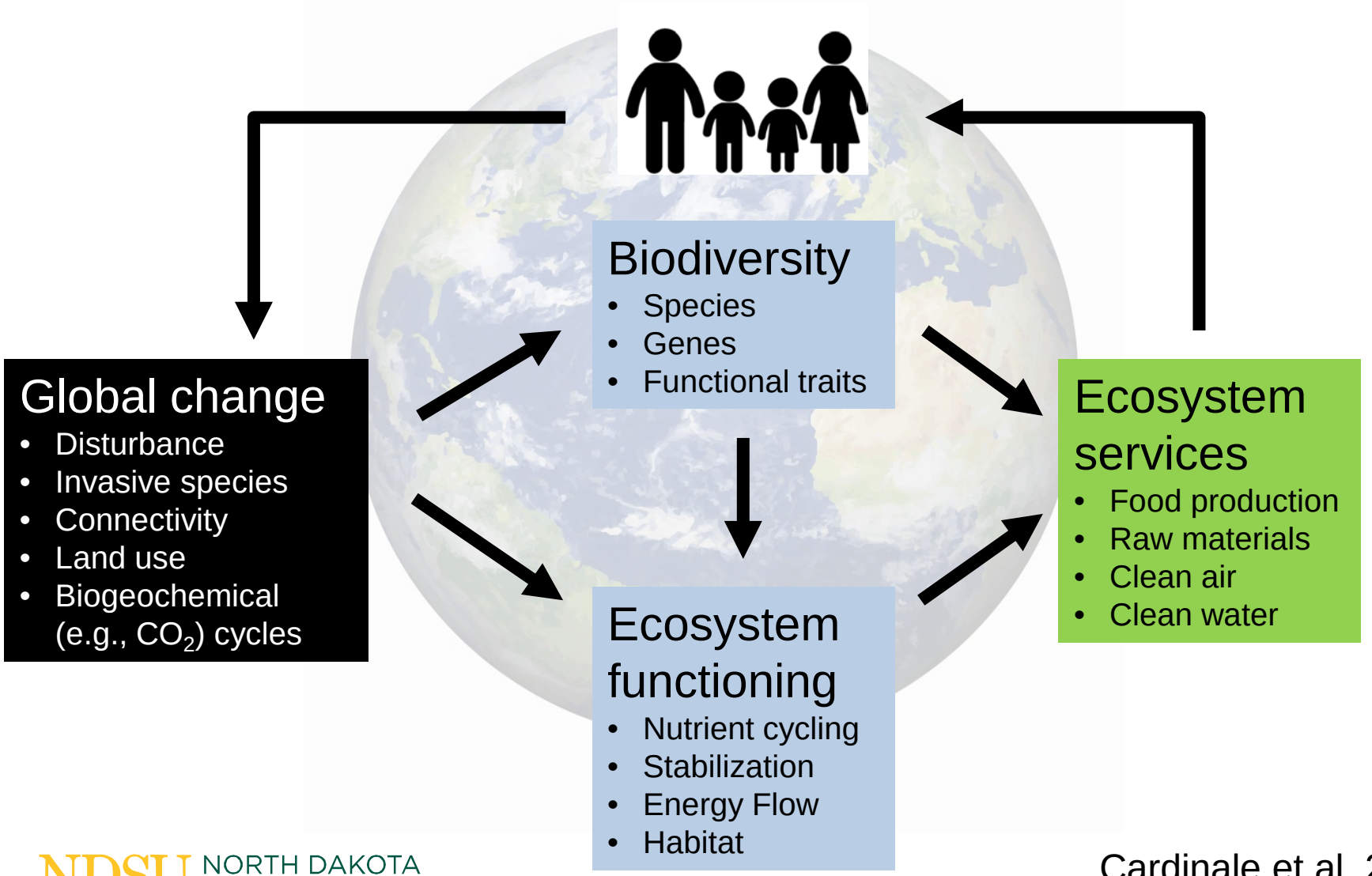
Abstract

Globally, temperate grasslands have been significantly degraded as a result of urbanisation, grazing and agriculture. Weeds now dominate most of these ecosystems, resulting in the loss of ecosystem services, reduced carrying capacity for farmers, and reduction of habitat for native plants and animals. This paper reviews the literature relating to temperate grassland restoration efforts across the globe, noting which techniques and combinations have been used successfully to reduce weed dominance and promote native recruitment and establishment. This review concludes that, using a combination of four restoration techniques, provided the highest level of success, with the caveat that, ongoing weed management should be budgeted for in all projects. There is no single optimal method for restoration and weed control, with success depending on specific site conditions and the scope and aims of particular projects. However, any form of target plant transfer was observed to significantly enhance the restoration's success and reduce exotic plant biomass. There is clearly a need for an increase in long-term monitoring of restoration projects in order to make more confident assumptions.

KEYWORDS

grassland degradation, pampas, prairie, restoration ecology, steppe, veldt



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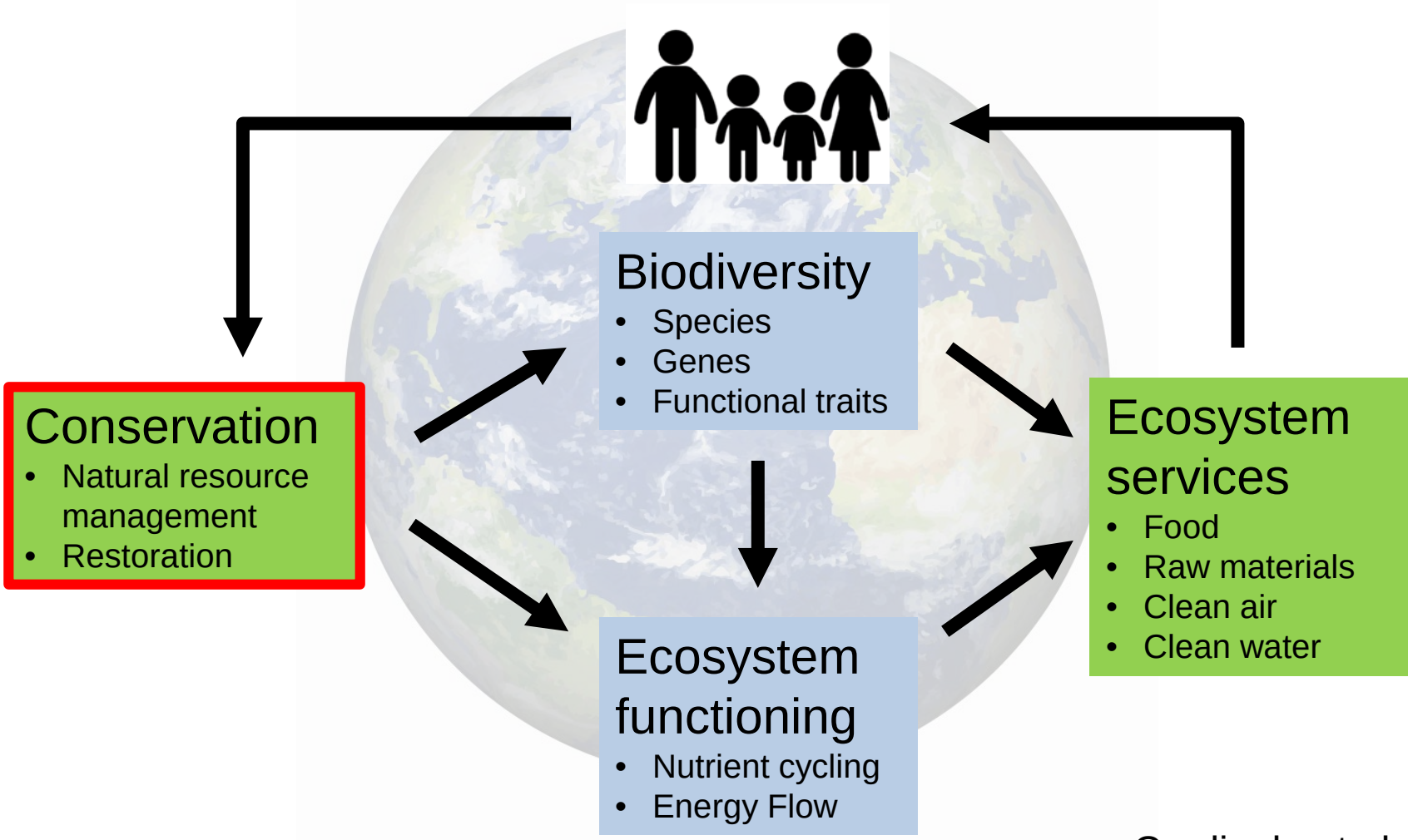
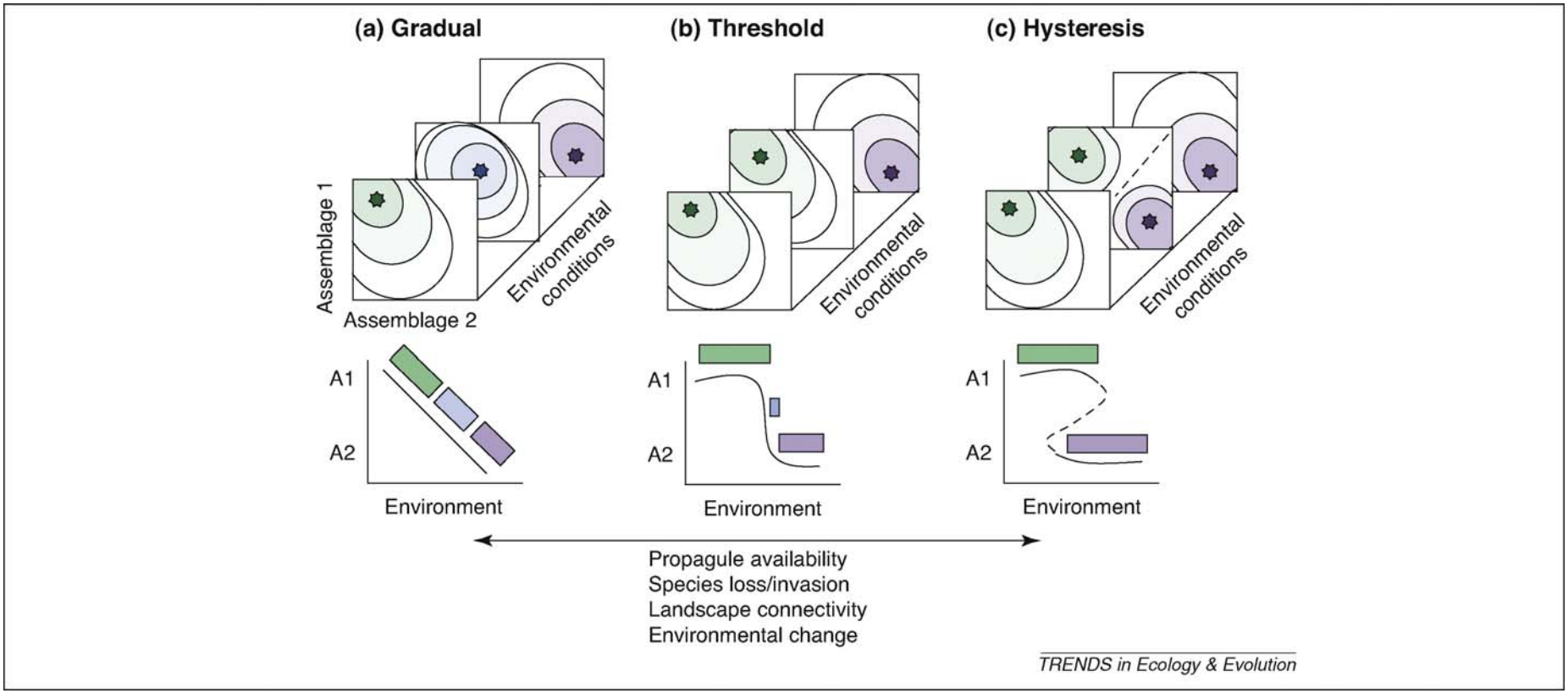
Cardinale et al. 2012

Country/region	Grassland name	Historic (km^2)	Current (km^2)	Total loss (km^2)	Reference
America					
North America	Prairies	2,679,900	107,196	2,572,704	Henwood, 2010
South America	Pampas and Campos	2,325,700	109,600	2,216,100	Henwood, 2010
Africa					
South Africa	Veld	360,590	234,383	126,207	Henwood, 2010; Cadman, deVilliers, Lechmere-Oertel, & McCulloch, 2013
Eurasia					
China	Steppe	3,386,000	1,794,580	1,591,420	Henwood, 2010; Ye & Feng, 2011
Mongolia	Steppe	822,760	740,484	82,276	Henwood, 2010
Eastern Europe	Steppe	440,000	43,120	296,880	Henwood, 2010; Fuchs, Herold, Verburg, & Cleavers, 2013
Russia	Steppe	600,000	50,000	550,000	Henwood, 2010; Ponomarenko, 2019
Oceania					
Southeast Australia	Tussock grassland	60,000	12,000	48,000	Henwood, 2010
New Zealand	Tussock grassland	83,700	23,300	60,400	Mark, 2007; Henwood, 2010

Note: The approximate current cover is based on most recently published works but it is postulated that this coverage is likely to have diminished below these levels in most cases given lack of restoration action.



Cardinale et al. 2012



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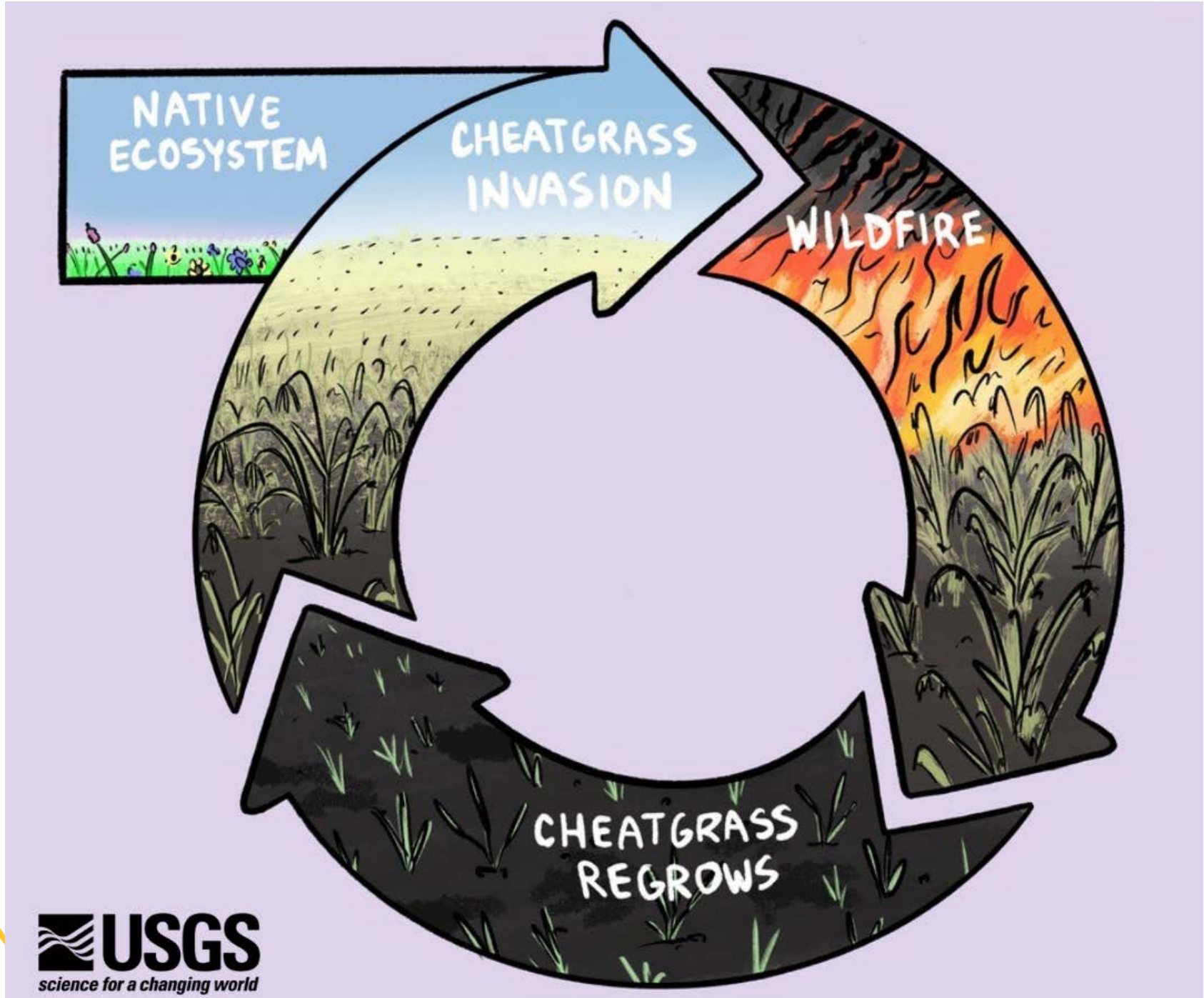
Suding and Hobbs 2008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Methods

- *Search requirements* were limited to the English language and selected literature must be:

(a) field-based ecological restoration

(b) study conducted within a temperate grassland

(c) manipulation and measurement of the standing vegetation in the attempt to facilitate target species.

- *Searched terms* included "Ecological Restoration" plus one of; temperate grassland(s); prairie(s); tussock grassland(s); veldt; veld; steppe(s); pampa(s); weeds; invasive plants; exotic plants.

- *Effect* describes as:
- *High* – significant improvements in weed control and target species establishment.
- *Moderate* – significant improvements in either target species establishment or weed control.
- *Low* – no changes observed to either weed control or target species establishment.

TABLE 2 Summary of the data collected from each paper

Author	Location	Journal	Study length (years)	Degrading pressures	Treatments H	F	PSA	CSA	BR	GM	ST	Effect
Ansley & Castellano, 2006	United States	*Restoration Ecology*	8	Agriculture, invasive weeds	✓	✓						Moder
Averett et al., 2004	United States	*Restoration Ecology*	1	Agriculture, fragmentation, loss of target species from seedbank	✓		✓	✓			✓	High
Baasch, Engst, Schmiede, May, & Tischew, 2016	Germany	*Ecological Engineering*	6	Grazing					✓	✓	✓	Moder
Blumenthal, Jordan, & Russelle, 2003	United States	*Ecological Applications*	2	Agriculture, invasive weeds				✓			✓	Low
Brown et al., 2017	Australia	*The Rangeland Journal*	1	Shrub and woody weed encroachment	✓		✓	✓			✓	High
Cuevas & Zalba, 2010	South America	*Restoration Ecology*	4	Fragmentation, grazing					✓			Moder
Foster et al., 2007	United States	*Restoration Ecology*	6	Grazing, invasive weeds					✓		✓	Moder
Jaunatre, Buisson, & Dutoit, 2014	France	*Applied Vegetation Science*	3	Agriculture, fragmentation, loss of target species seedbank			✓				✓	Low
John, Dullau, Baasch, & Tischew, 2016	Germany	*Ecological Engineering*	1	Invasive weeds, altered fire regimes				✓	✓		✓	High
Johnson, Catford, Driscoll, & Gibbons, 2018	Australia	*Applied Vegetation Science*	1	Invasive weeds, loss of target species from seedbank	✓				✓		✓	Moder
Klaus et al., 2018	Germany	*Restoration Ecology*	9	Invasive weeds			✓				✓	Low
Marushia & Allen, 2011	United States	*Restoration Ecology*	2	Invasive weeds	✓		✓		✓		✓	High
McManamen, Nelson, & Wagner, 2018	United States	*Restoration Ecology*	1	Grazing, invasive weeds	✓		✓		✓		✓	Moder
Musil et al., 2005	South Africa	*South African Journal of Science*	2	Fragmentation, invasive weeds	✓	✓			✓			High
O'Dwyer & Attiwill, 2000	Australia	*Restoration Ecology*	1	Grazing, bush encroachment, altered fire regimes					✓		✓	Moder
Page & Bork, 2005	United States	*Restoration Ecology*	1	Altered fire regimes, agriculture, local extinction of keystone grazers (elephant and rhino)	✓						✓	High
Radloff, Ladislav, & Snyman, 2014	South Africa	*Applied Vegetation Science*	6	Altered fire regimes, agriculture, loss of native seedbank		✓				✓		Moder
Ruprecht et al., 2016	Romania	*Applied Vegetation Science*	9	Fragmentation, agriculture		✓			✓			Moder
Sengel et al., 2016	Austria	*Basic and Applied Ecology*	3	Agriculture, altered soil nutrients			✓				✓	Moder
Tikka, Heikkilä, Heiskanen, & Kuitunen, 2001	Finland	*Applied Vegetation Science*	3	Fragmentation, agriculture, invasive weeds					✓		✓	Moder

(Conti

TABLE 2 (Continued)

Author	Location	Journal	Study length (years)	Degrading pressures	Treatments H	F	PSA	CSA	BR	GM	ST	Effect
Tognetti & Chaneton, 2012	Argentina	*Biological Invasions*	2	Invasive weeds, native seedbank depletion, local extinction of large herbivores, altered fire regimes					✓		✓	High
van Dyke, Van Kley, Page, & Van Beek, 2004	United States	*Restoration Ecology*	14	Fragmentation, agriculture, invasive weeds, shrub encroachment, altered fire regimes		✓			✓			Low
Waller, Anderson, & Allsopp, 2016	South Africa	*South African Journal of Science*	2	Invasive weeds	✓	✓	✓			✓	✓	High
Wilson & Pärtel, 2003	United States	*Restoration Ecology*	7	Invasive weeds, agriculture	✓				✓		✓	High
Wohlwend, Schutzenhofer, & Knight, 2019	United States	*Restoration Ecology*	7	Grazing, agriculture	✓		✓	✓	✓		✓	High
Zhou, Wilson, Cobb, Yang, & Zhang, 2019	China	*Land Degradation and Development*	2	Agriculture, invasive weeds				✓	✓		✓	High

Note: The ✓ is used to show what treatments were used in each of the reviewed papers.

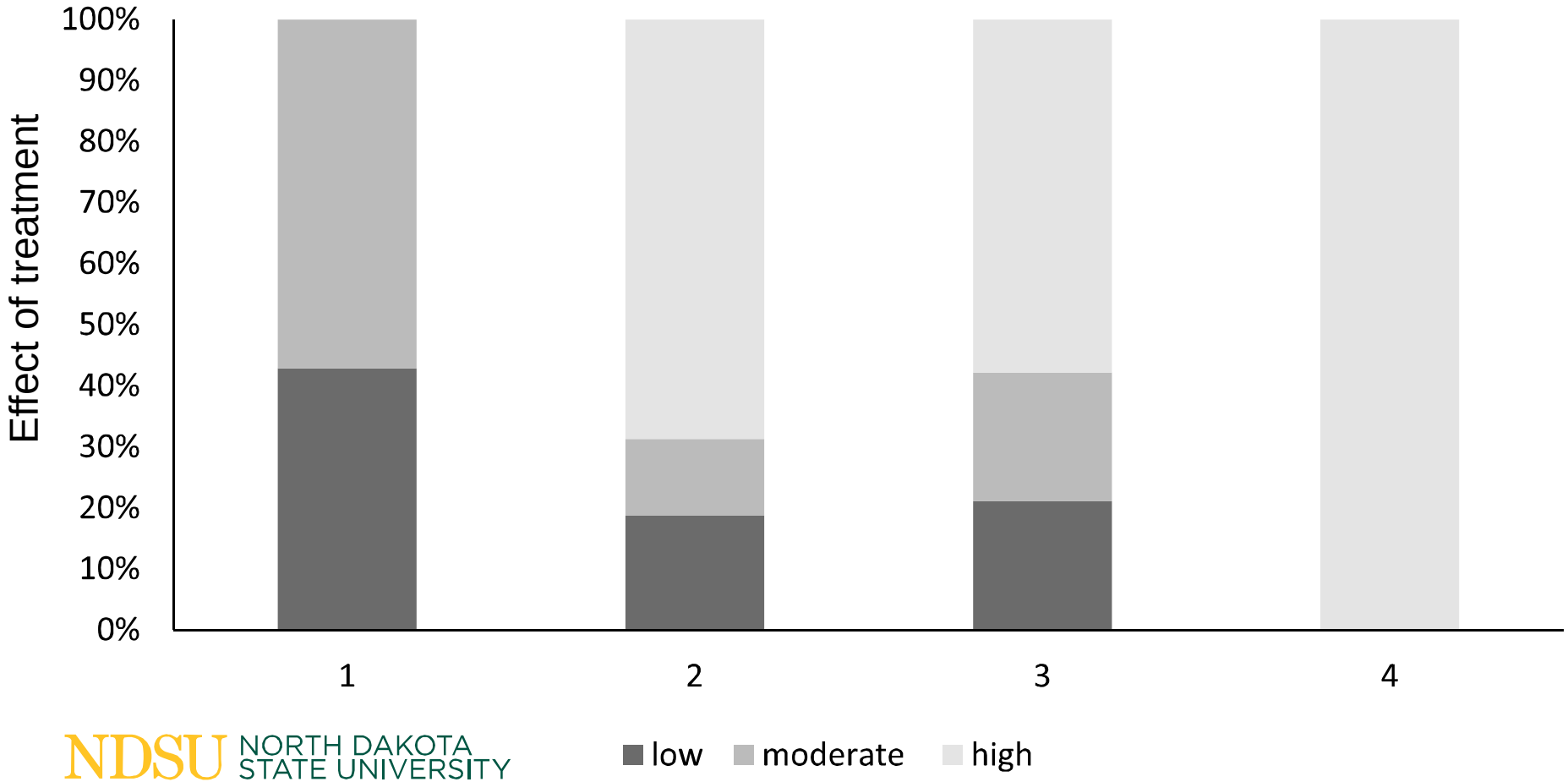
Top degrading pressures:

1) Exotic plants
2) Agriculture
3) Altered grazing/fire regimes

Most frequently used control actions for grassland restoration were:

1) seeding
2) mowing/clipping
3) physical soil manipulation/ herbicide

Effect of integrating treatments



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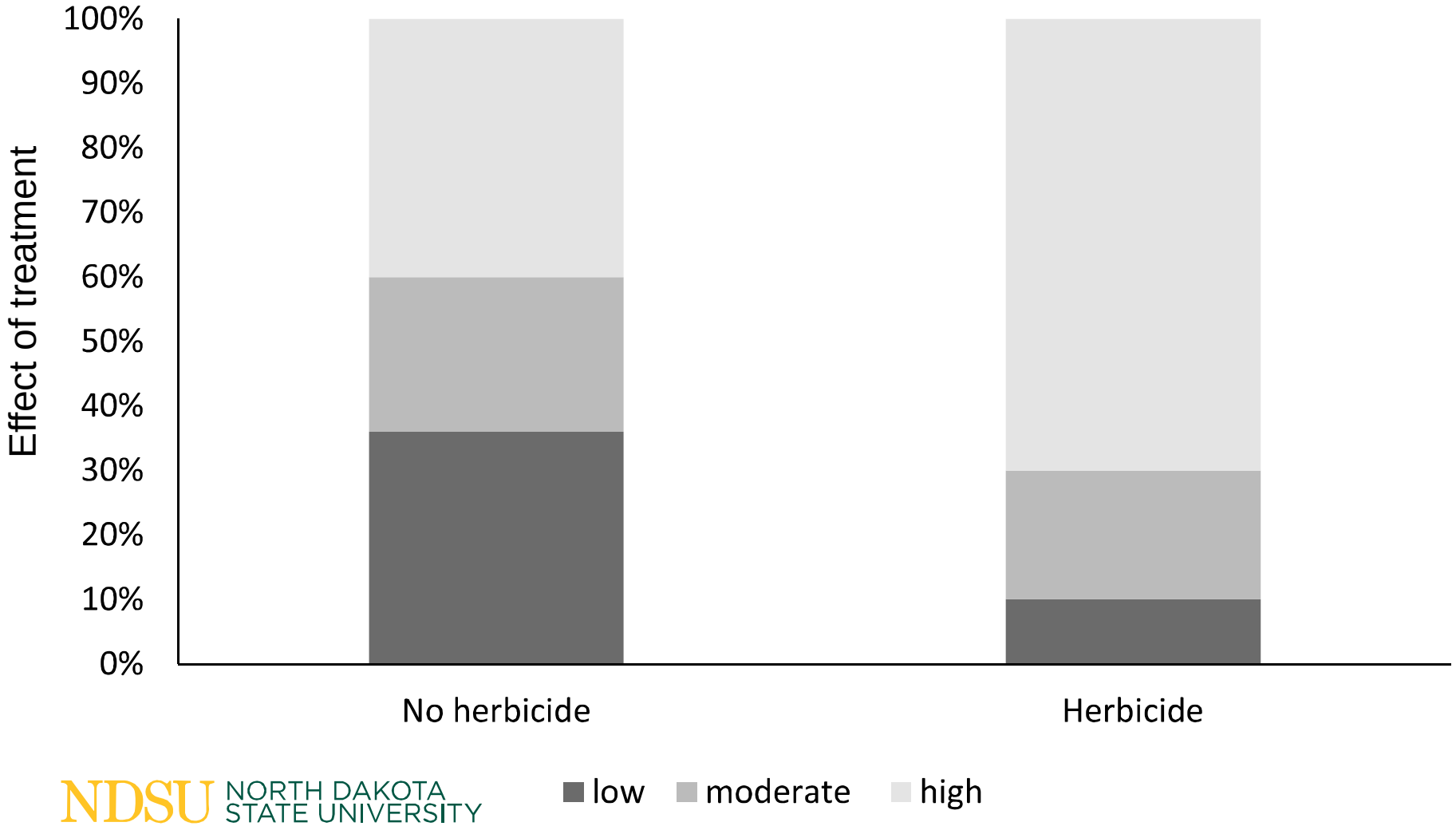
Effect of herbicide



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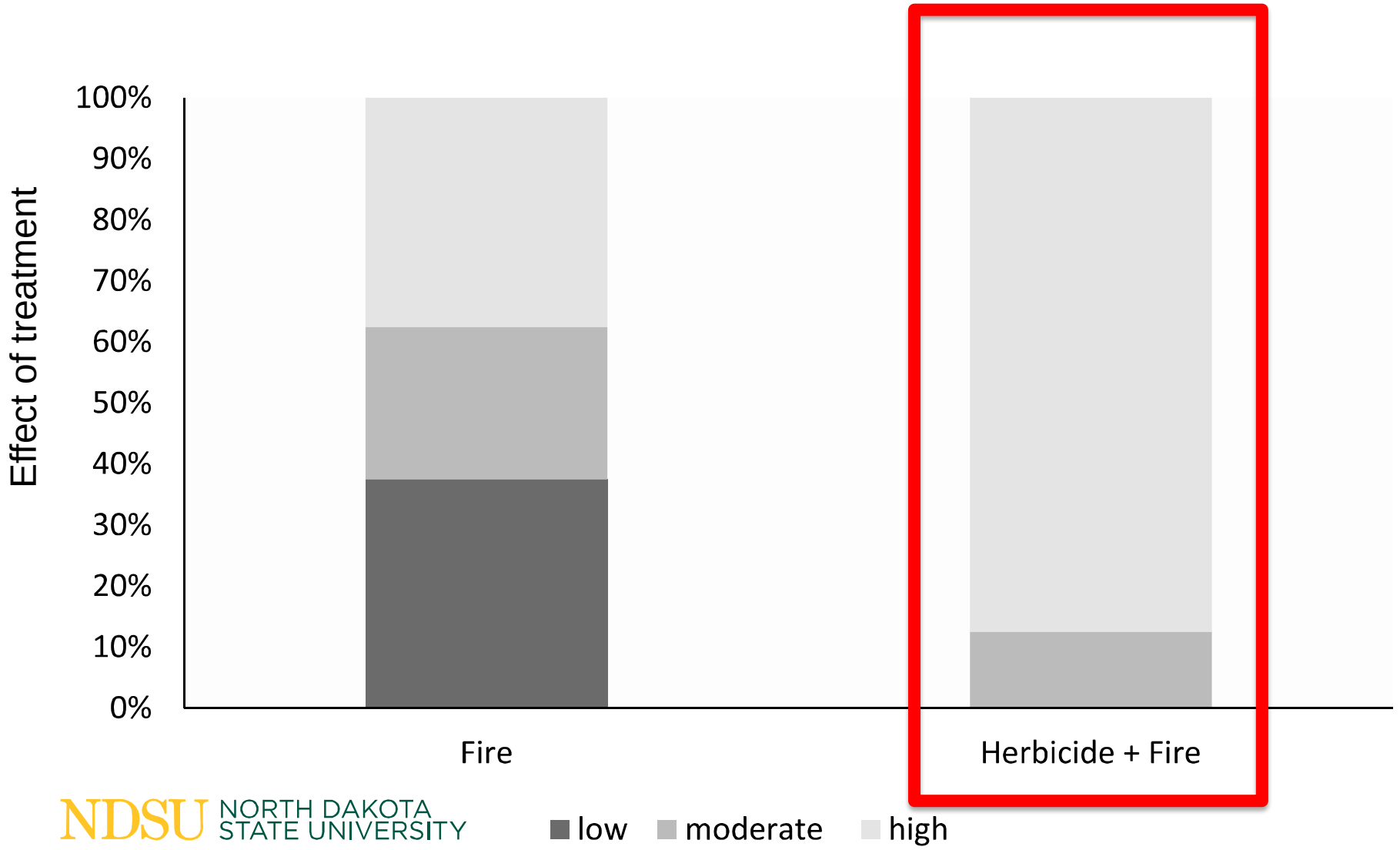
Effect of fire



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Management strategy recommendation

1. Reduce/remove weed biomass
2. If necessary, manipulate the soil
3. Incorporate revegetation of native propagules
4. Implement site-specific grazing management
5. Ecological corridors

Dependent factors

Specific actions are dependent on:

1. Weed biology
2. Site history
   - soil conditions
   - seed mixture
   - natural disturbance
3. Reintroducing grazing will be determined by the rate of recovery

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Questions