

Spatial Management of Invasive Alien Species: An Application to Cheatgrass Management in the Great Basin

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Cheatgrass in the Great Basin

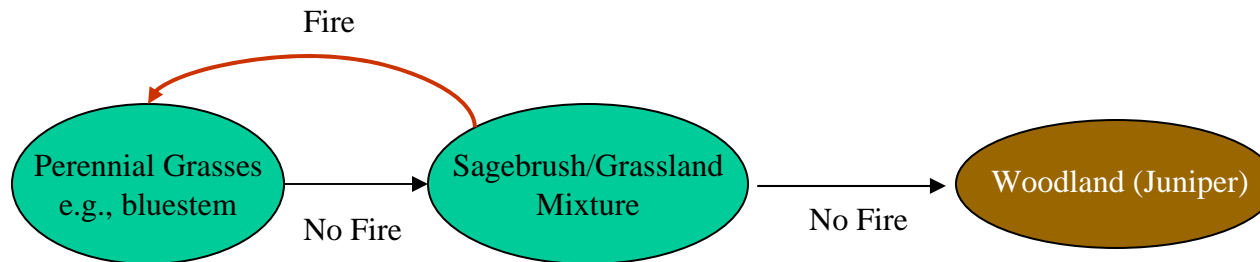
- Weedy, annual invader
- Rapid winter/spring growth
- Dries out early → increase fire risk
 - 1.7 million acres burned in 1999
- About 20% of GB invaded (25 million acres)



Great Basin Restoration Initiative

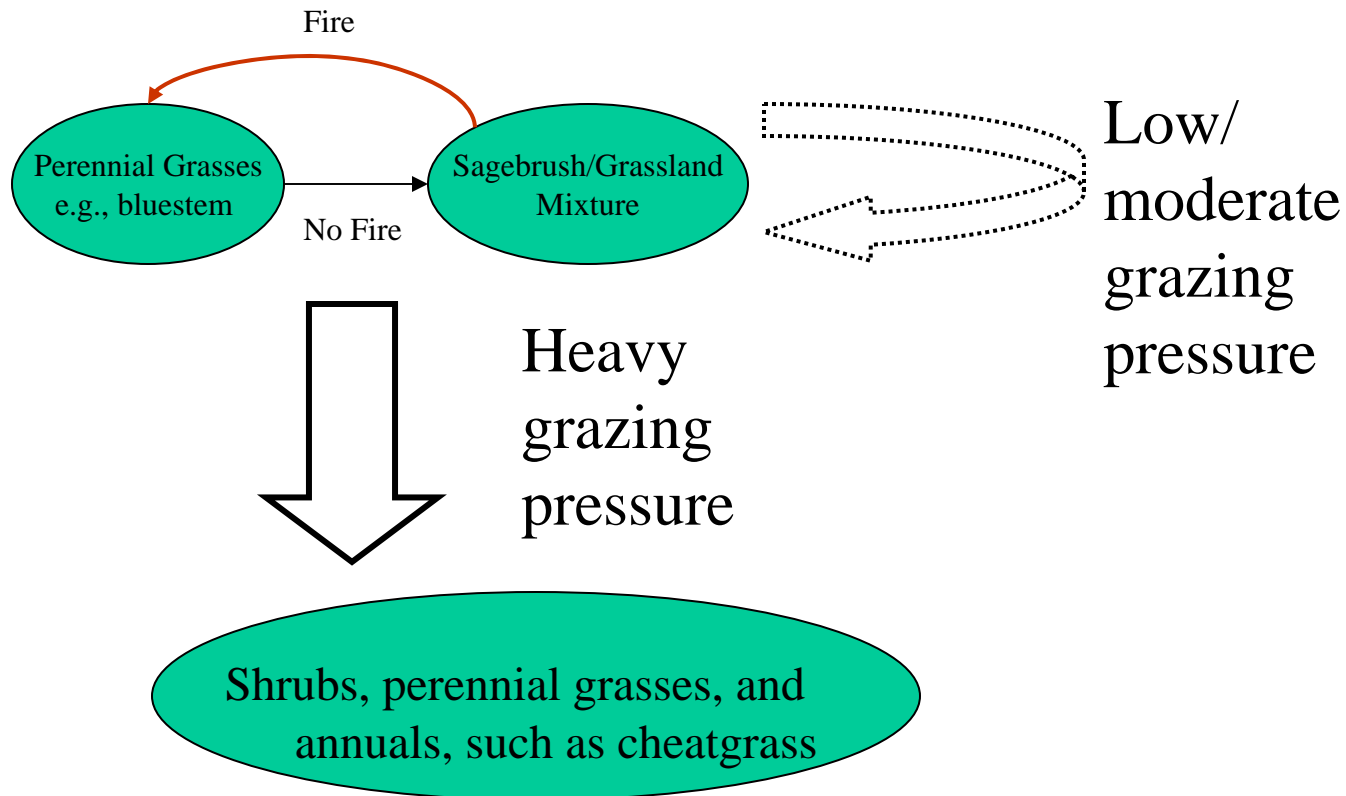
- Goals
 - Protect areas not yet invaded and areas that can be returned to more natural state by modifying current management practices
 - Restore areas that are invaded
 - Sustainable multiple-use of public lands
- Some management levers are
 - Reducing grazing pressure (private vs. public land)
 - Reseeding areas with native and non-native perennials
 - Greenstripping (create fire breaks)
 - Applying of herbicide

Sagebrush-grassland ecosystem

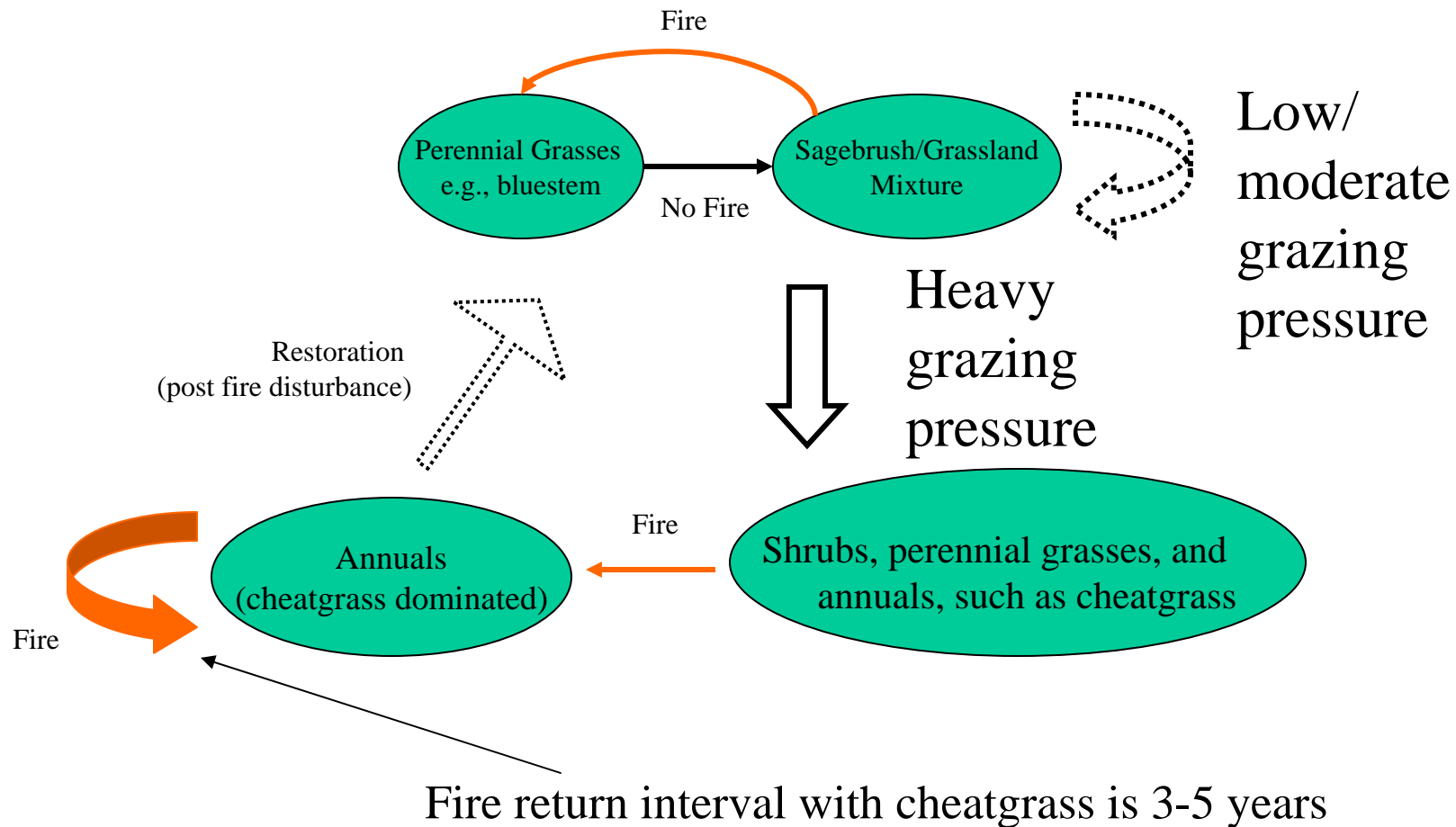


- Fire plays an important role in maintaining balance between grasses (understory of sagebrush) and sagebrush
- Fire return intervals are on average 20-100 years

Sagebrush-grassland ecosystem introducing grazing pressure



Sagebrush-grassland ecosystem with cheatgrass



“State-transition” model

- Native vegetation density (state variable)
- Cheatgrass density (state variable)
- “Stocker” operations (grazing pressure is a flow)
 - Cooper and Huffaker (1997) in Ecological Modeling
 - Choice of grazing stock densities based on profit max.
 - Competition between native perennials and annuals characterized with bistability or “hysteresis”
 - Derive successional threshold as function of ecological and economic parameters
 - Other work done by Ludwig, Walker, and Holling (1997)

Sagebrush - cheatgrass system

- Plant succession model is a special case of interspecies competition model

$$\text{Sagebrush: } \frac{dS}{dt} = \underbrace{w(S; a)}_{\text{Growth}} - \underbrace{uSC}_{\text{Competition}} - \underbrace{gS}_{\text{Grazing}}$$

$$\text{Cheatgrass: } \frac{dC}{dt} = \underbrace{\omega(C)}_{\text{Growth}} - \underbrace{\mu SC}_{\text{Competition}} - \underbrace{gC}_{\text{Grazing}}$$

Control Variables:

Reseeding: a

Grazing intensity: g

with $u > \mu$

How to include the effects of fire?

- Fire occurrences increase with increase in stock of cheatgrass (within patch effect)
 - return intervals are shorter, result is increased competitive advantage of cheatgrass over native perennials.
- Spread increases with higher levels of cheatgrass in surrounding areas (spatial)

Modeling effects of fire

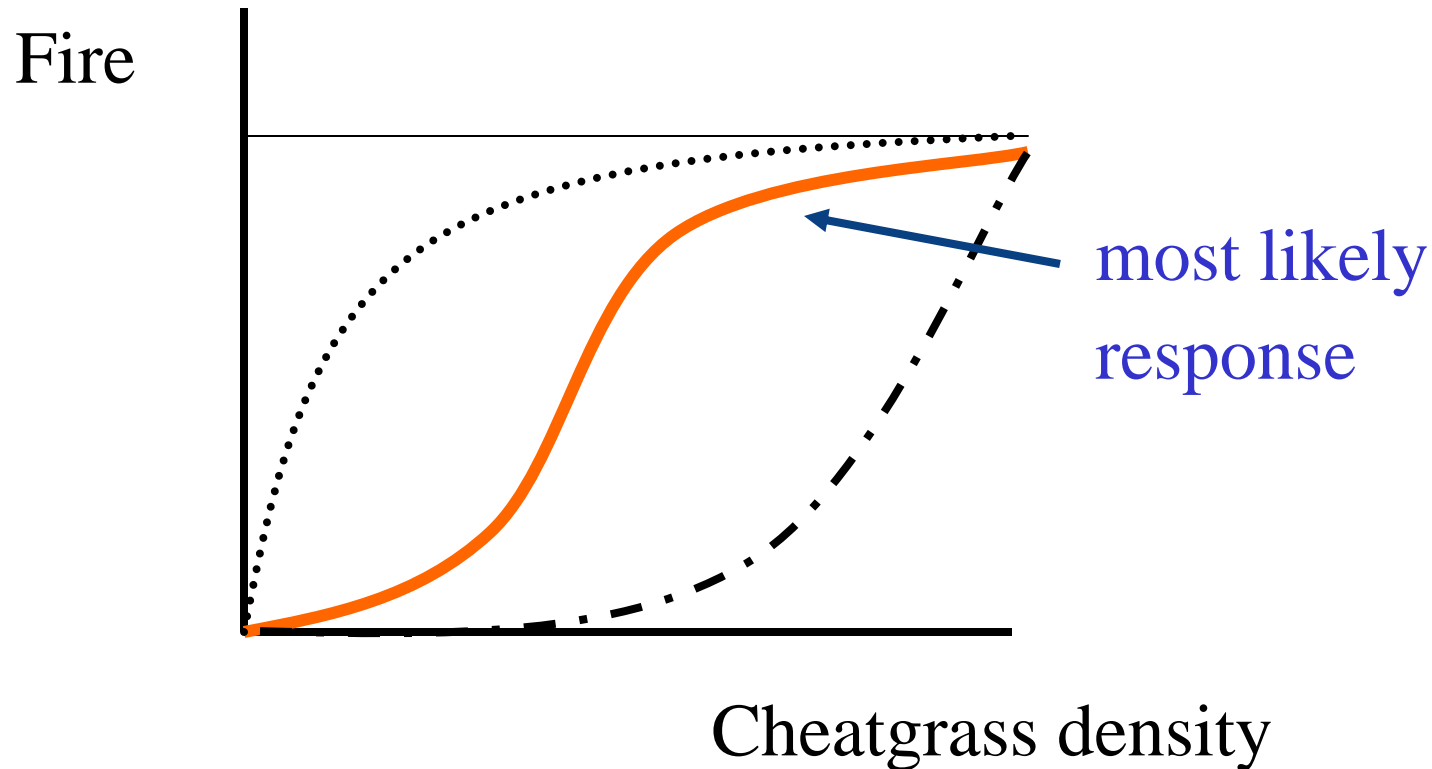
- Following Ludwig, Walker and Holling (1997), let ρ be the fire potential, and F be the fire risk

$$F = \rho \left[\frac{B + C^\gamma}{\beta + C^\gamma} \right]$$

γ = defines sharpness of the increase of fire risk
with increase in cheatgrass density

B, β parameters that define nature of functional response

Fire risk and cheatgrass



- Paul is working on estimating this functional relationship for cheatgrass in GB

Fire and competition

- Greater the fire risk, the more competitive is cheatgrass over sagebrush

$$\text{Sagebrush: } \frac{dS}{dt} = \underbrace{w(S; a)}_{\text{Growth}} - \underbrace{u(F)SC}_{\text{Competition}} - \underbrace{gS}_{\text{Grazing}}$$

$$\text{Cheatgrass: } \frac{dC}{dt} = \underbrace{\omega(C)}_{\text{Growth}} - \underbrace{\mu(F)SC}_{\text{Competition}} - \underbrace{gC}_{\text{Grazing}}$$

where $F \uparrow \Rightarrow u(F) \uparrow$ and $\mu(F) \downarrow$

Introducing space (multiple patches)

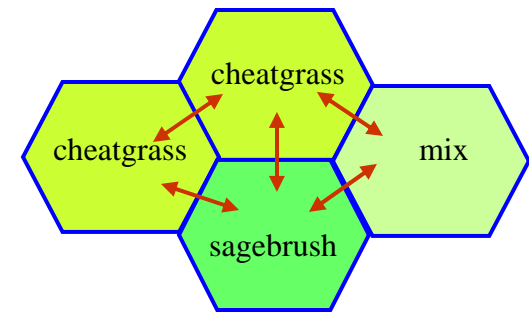
- Key spatial processes
 - Fire risk is correlated across patches
 - Movement of animals (livestock)
 - Cheatgrass seeds easily attach to animal hides
 - Movement of individuals
- Focus today on correlation of fire risk (via spread)

Fire risk correlation

- Suppose, for example, we have the following configuration, where i indicates patch location
- We then have a cheatgrass density and sagebrush density in each patch (C_i, S_i)

- and fire risk i :
$$F_i = \rho_i \left[\frac{B + C_i^\gamma}{\beta + C_i^\gamma} \right]$$

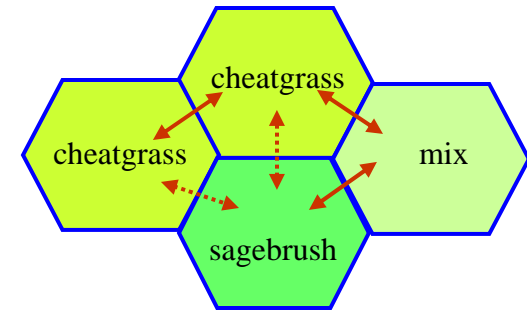
- where ρ_i is the correlated risk adjustment due to the spread of fire (represented by red arrows) and is a function of the cheatgrass density in the neighboring patches



Fire correlation and greenstripping

- We can model the fire correlated risk component in patch i as

$$\rho_i = \sum_{k \in \text{Neighborhood}_i} d_k(I_k) C_k$$



- $d_k(I_k)$ is the weighting function capturing connectivity
- I_k is a spatially-explicit control variable that represents greenstripping
 - Reduce the correlation of fire risk across patches (e.g., $\partial d_k(I_k) / \partial I_k < 0$)
 - What type of patterns of greenstripping are cost-effective?
 - e.g., checkerboards of fire breaks or fire breaks that run perpendicular to prevailing winds

Summary of model features

- Grazing and fire increase the competitive advantage of cheatgrass over sagebrush
- Fire is correlated across patches, and the correlation depends on the cheatgrass density of neighborhood patches
- Threshold in each patch is a function of economic and ecological conditions of patches in the neighborhood and local conditions

Controls for managing cheatgrass

- Grazing intensity
 - lower levels can reduce likelihood of going to cheatgrass dominated state
 - setting grazing intensity to zero in any patch is creating a protected area
- Restoration (reseeding) of sagebrush populations
- Greenstripping (can reduce the risk of fire spreading into neighboring patches)

Year II tasks

- Parameterize model with data from Great Basin (data is already collected)
 - Ecological data
 - cheatgrass risk, cheatgrass population, sagebrush population, habitat types
 - Fire data
 - fire occurrences, fire risk
 - Socioeconomic data
 - land uses, census tract-level demographic and economic information
 - livestock stocking rates, nutritional information on cheatgrass, native perennials
 - costs of different controls (e.g., restoring \$100/acre)

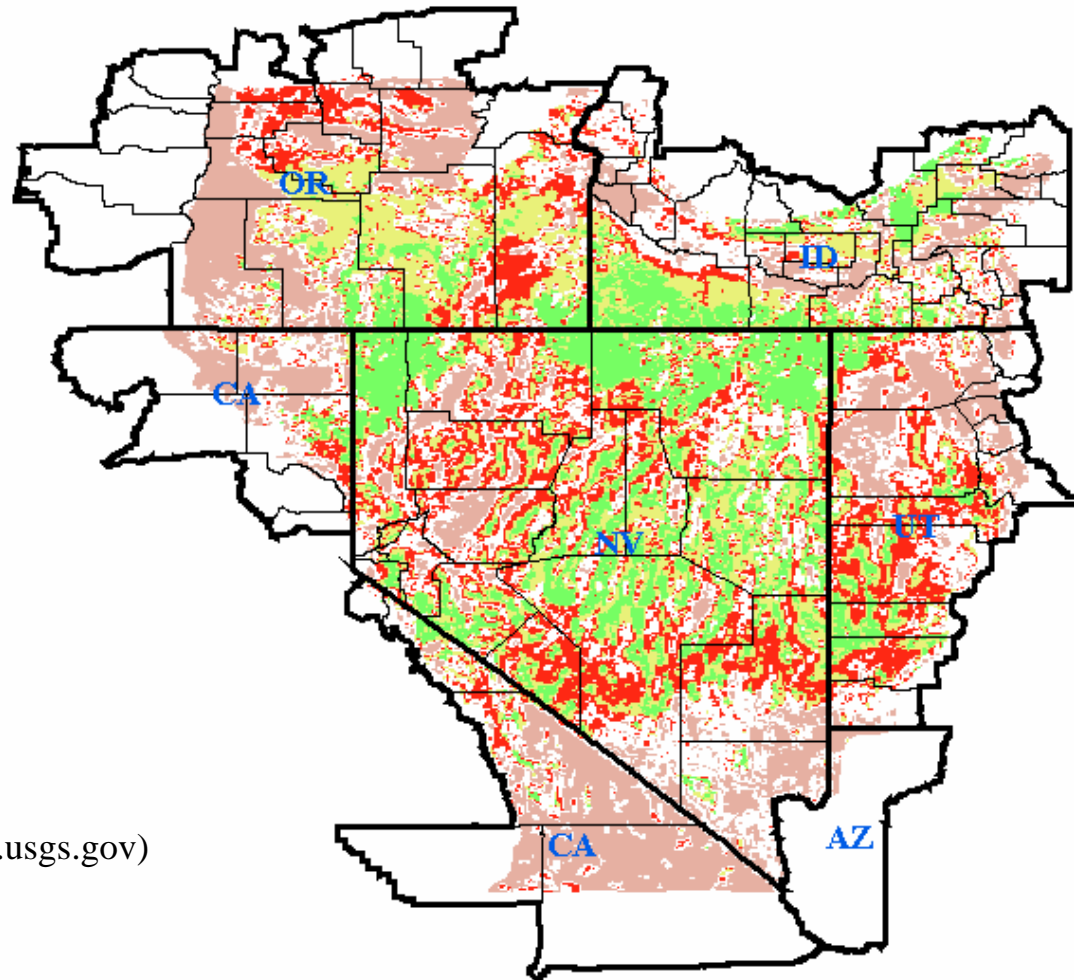
Focus of analysis

- Cost-effective control regimes from perspective of landscape planning
 - Each of the management levers will alter the successional threshold (size of domains)
- Interdependencies between spatial controls (greenstripping) and traditional non-spatial (grazing intensity and restoration)
 - E.g., spatial effects of non-spatial policies



Additional slides

Cheatgrass risk assessment in GB



Risk

Green is low

Yellow is medium

Red is high

(source: SAGEMAP.wr.usgs.gov)

Fire risk correlation

- Suppose, for example, we take a grid and each cell (patch) is referenced by i,j

- We then have a cheatgrass density and sagebrush density in each patch (indexed by i,j).

- and fire risk i,j : $F_{ij} = \rho_{ij} \left[\frac{B + C_{ij}^\gamma}{\beta + C_{ij}^\gamma} \right]$

- where ρ_{ij} is the correlated risk adjustment, which is a function of the cheatgrass density in the neighboring patches (cells)

