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)

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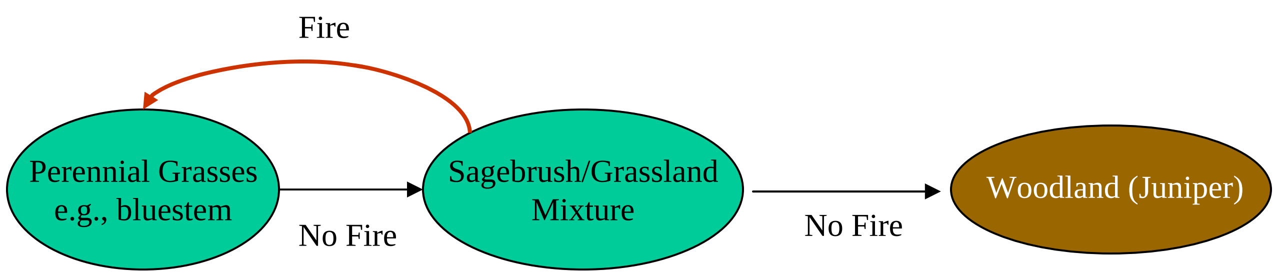
Great Basin Restoration Initiative

- 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

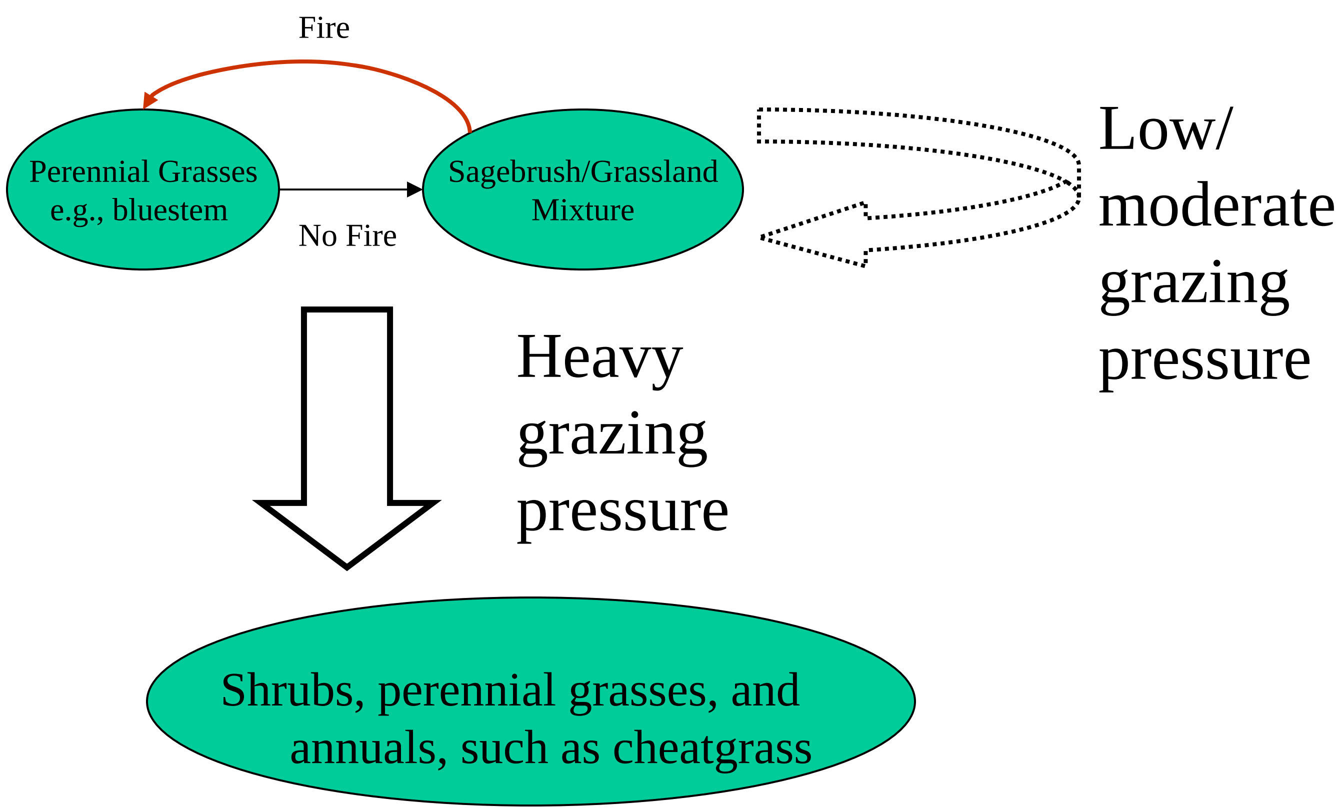
Sagebrush-grassland ecosystem



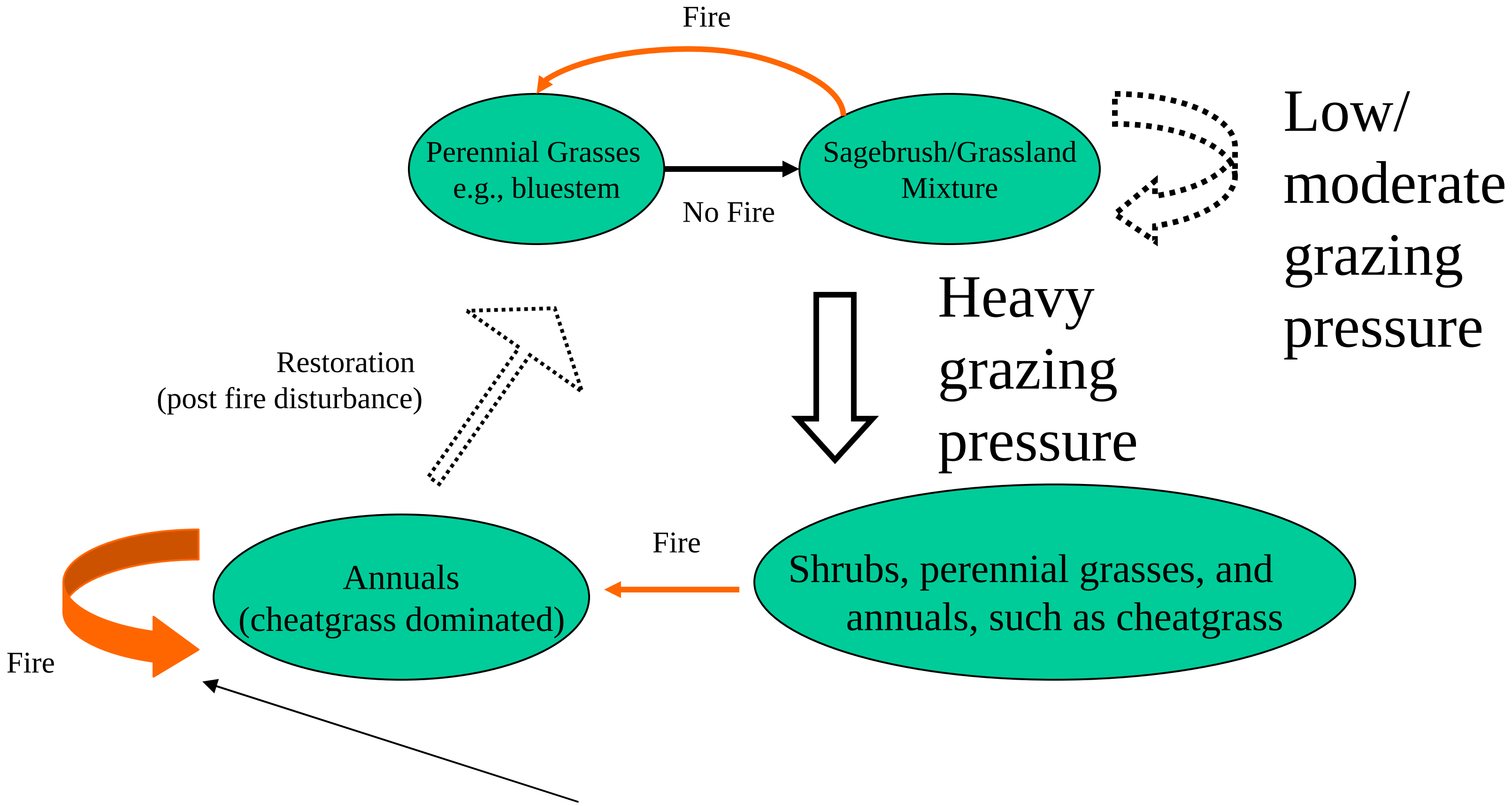
- Fire plays an important role in maintaining balance between grasses (understory of sagebrush) and sagebrush

- Fire return intervals are on average 20-100 years

Sagebrush-grassland ecosystem introducing grazing pressure



Sagebrush-grassland ecosystem with cheatgrass



Fire return interval with cheatgrass is 3-5 years

“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

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

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

Control Variables:

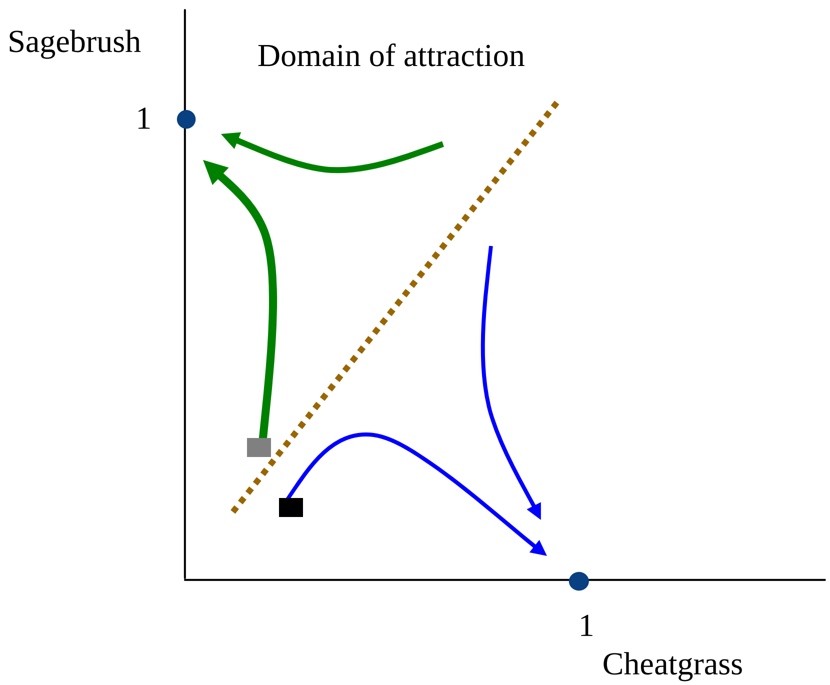
Reseeding: *a*

Grazing intensity: g

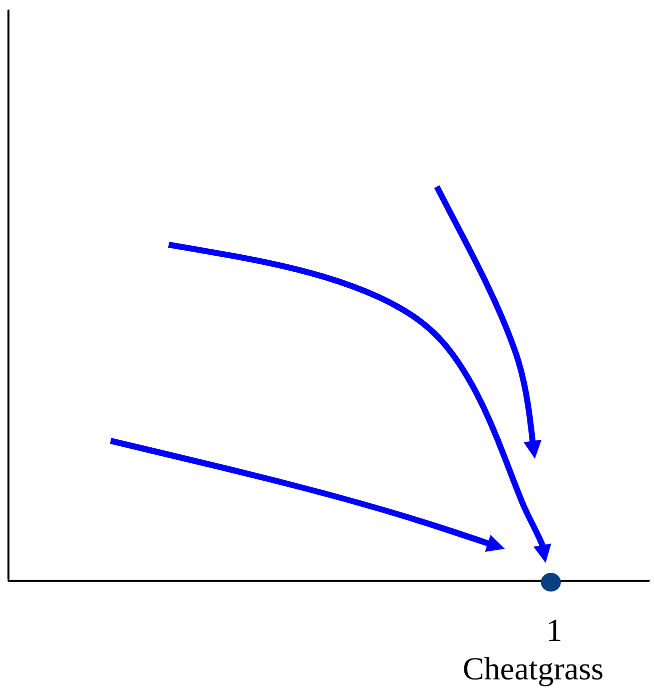
with $u>\mu$

Model predictions

Low grazing



High grazing



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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

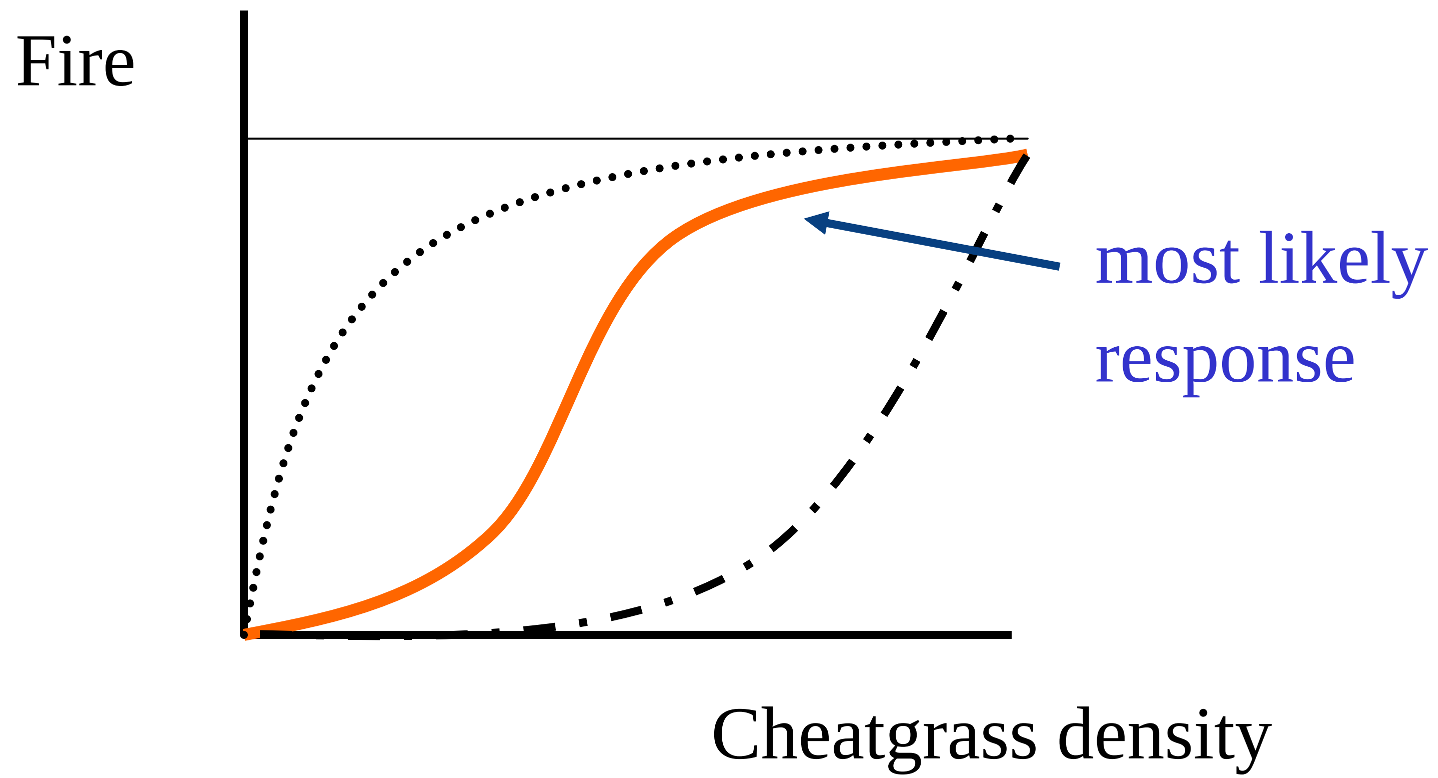
$$F = \rho[\frac{B + C^{\gamma}}{\beta + C^{\gamma}}]$$

$\gamma =$ 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

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

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

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

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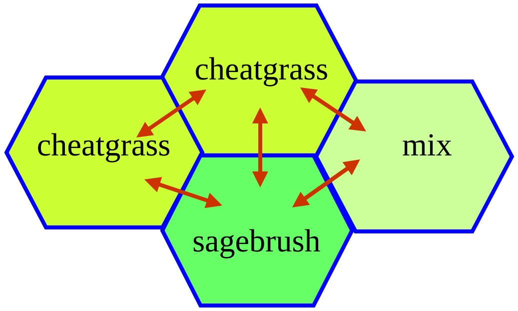
Introducing space (multiple patches)

- 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)



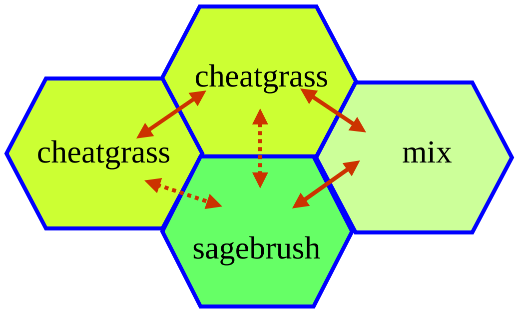
• and fire risk i: $F_i = \rho_i [\frac{B + C_i^{\gamma}}{\beta + C_i^{\gamma}}]$

• 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

$$\rho_i = \sum_{k \in Neighborhood_i} d_k(I_k) C_k$$



- $d_k(I_k)$ 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

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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

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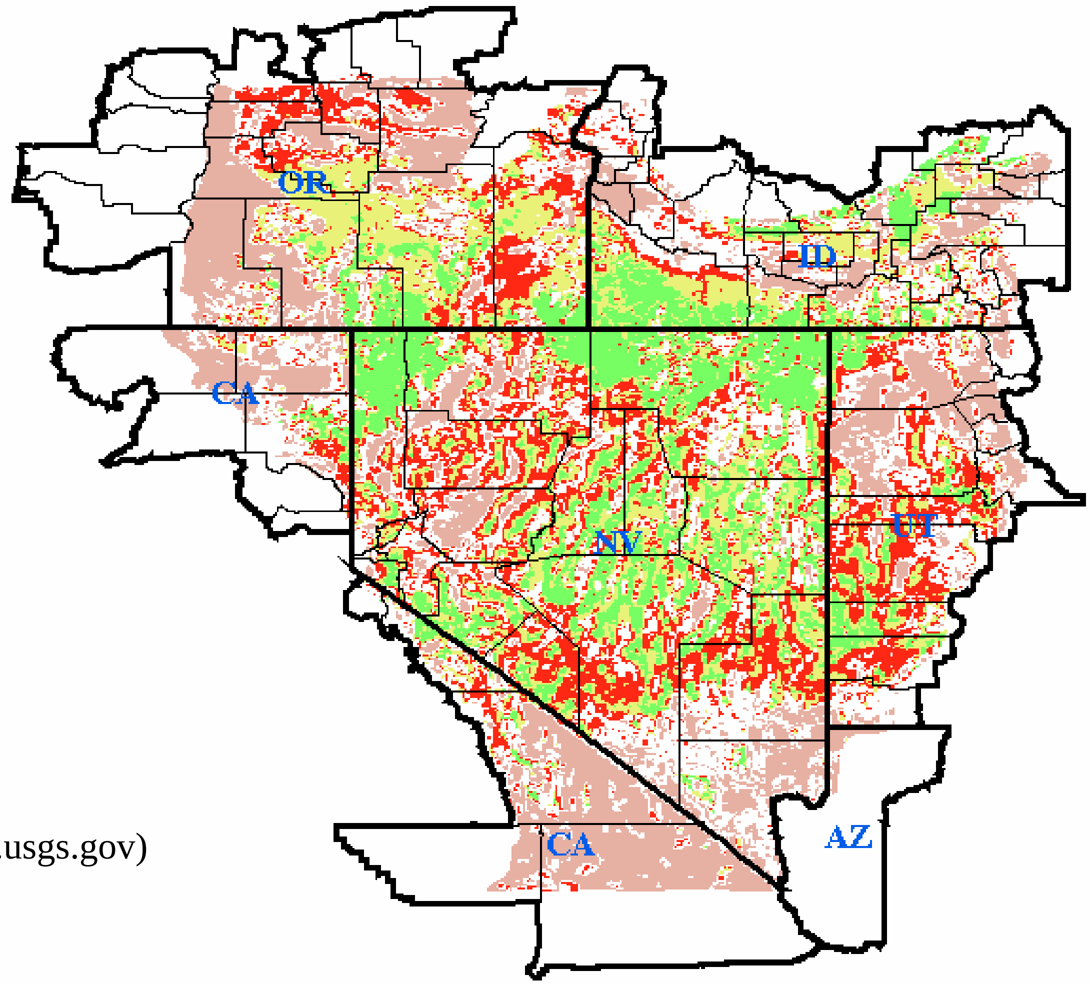
Additional slides

Cheatgrass risk assessment in GB



Risk

Green is low

Yellow is medium

Red is high

(source: SAGEMAP.wr.usgs.gov)

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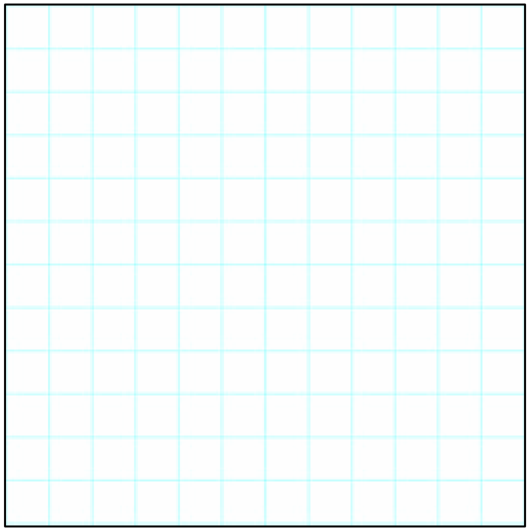
Fire risk correlation

• 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: $F_{ij} = \rho_{ij}[\frac{B + C_{ij}^{\gamma}}{\beta + C_{ij}^{\gamma}}]$

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

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