Comparing cost-effectiveness of restoration strategies: Cheatgrass case study

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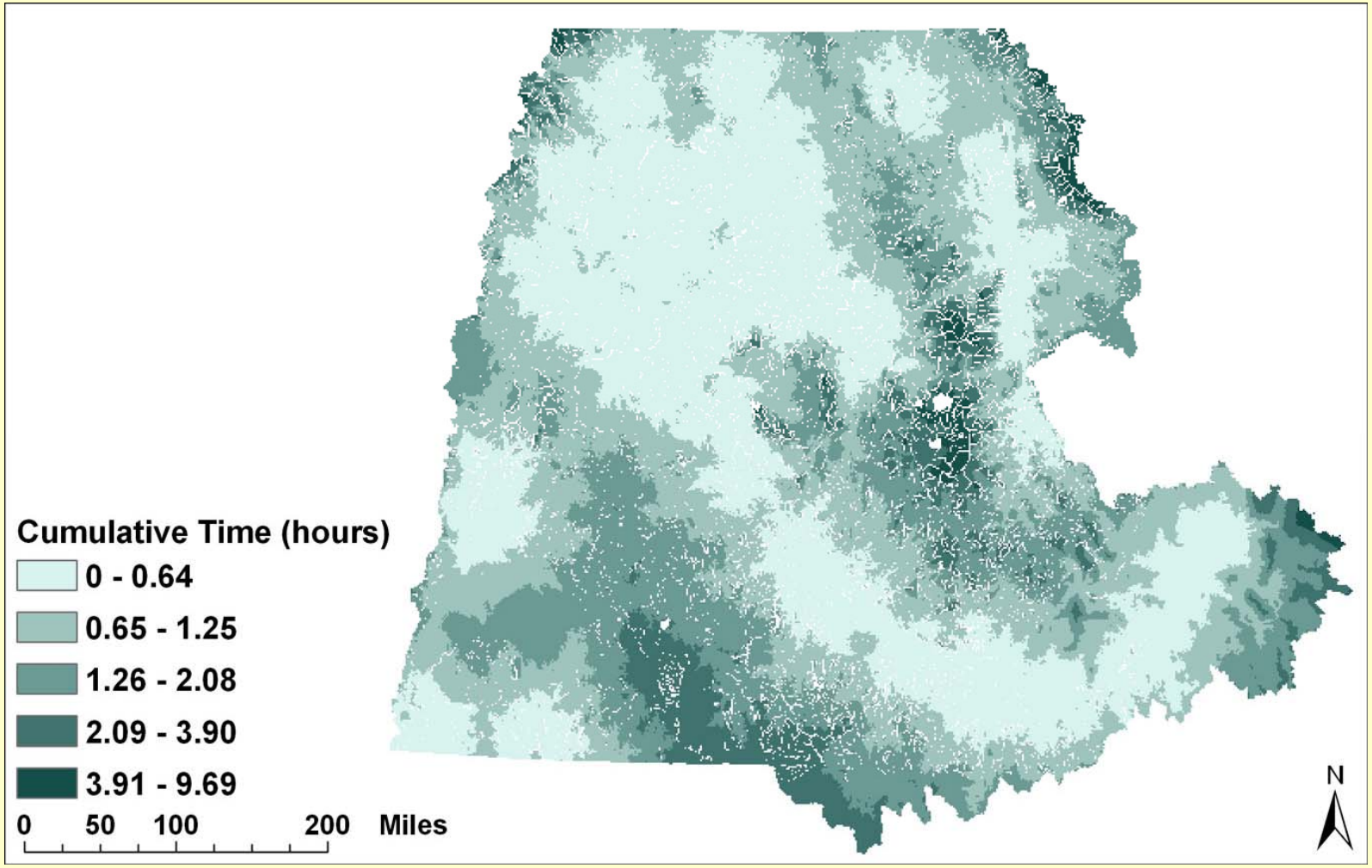
Decision Analysis Components

1. Benefits of Successful Restoration
2. Probability of Successful Restoration
3. Costs of Treatment

In each case evaluating effects of:

- Site characteristics
- Location context
- Scale of treatment
- Intensity of treatment

Columbia River Basin - Cumulative Travel Cost from Contractor Locations



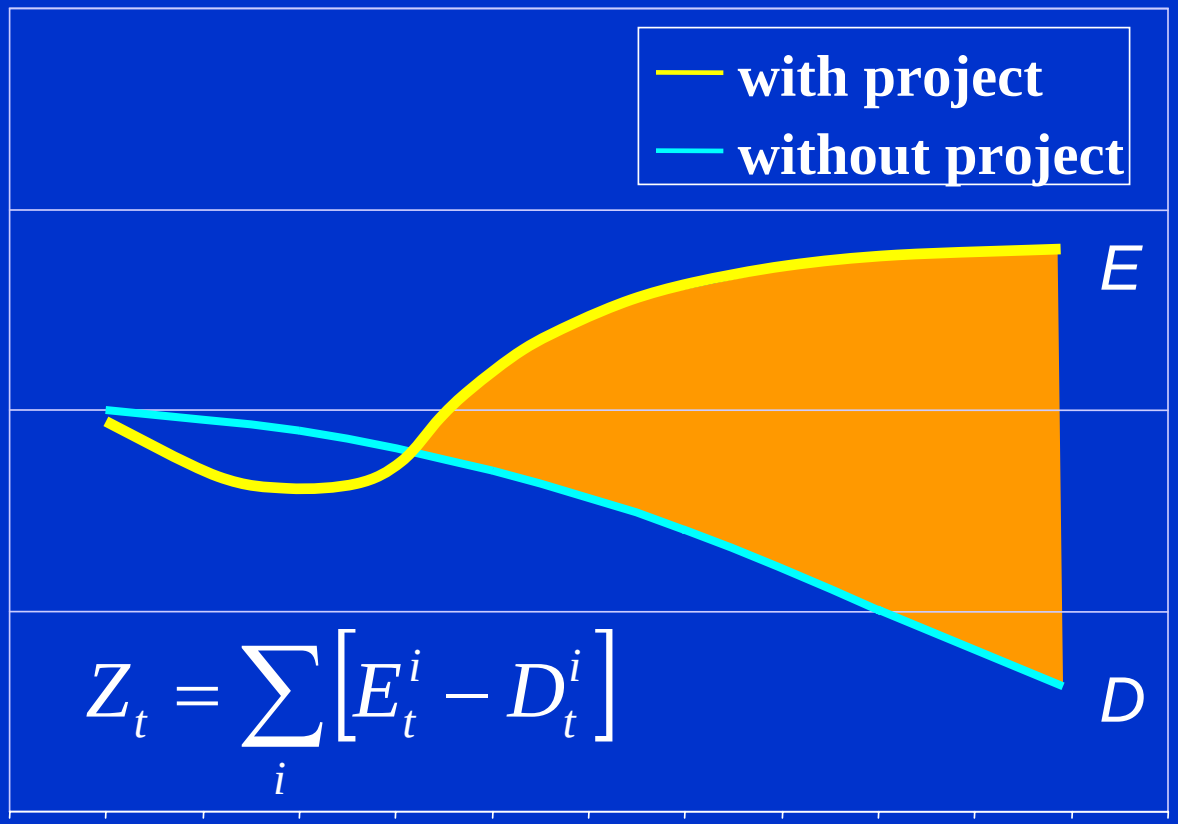
Initial Cheatgrass Benefit-Cost Analysis

Benefits = Costs Avoided

- Identify goods and services at risk
- Identify data & information available to assess impacts
- Estimate impacts
  - Compare to baseline
  - Evaluate changes in welfare considering timing and risk
- Aggregate impacts

Measuring Benefits

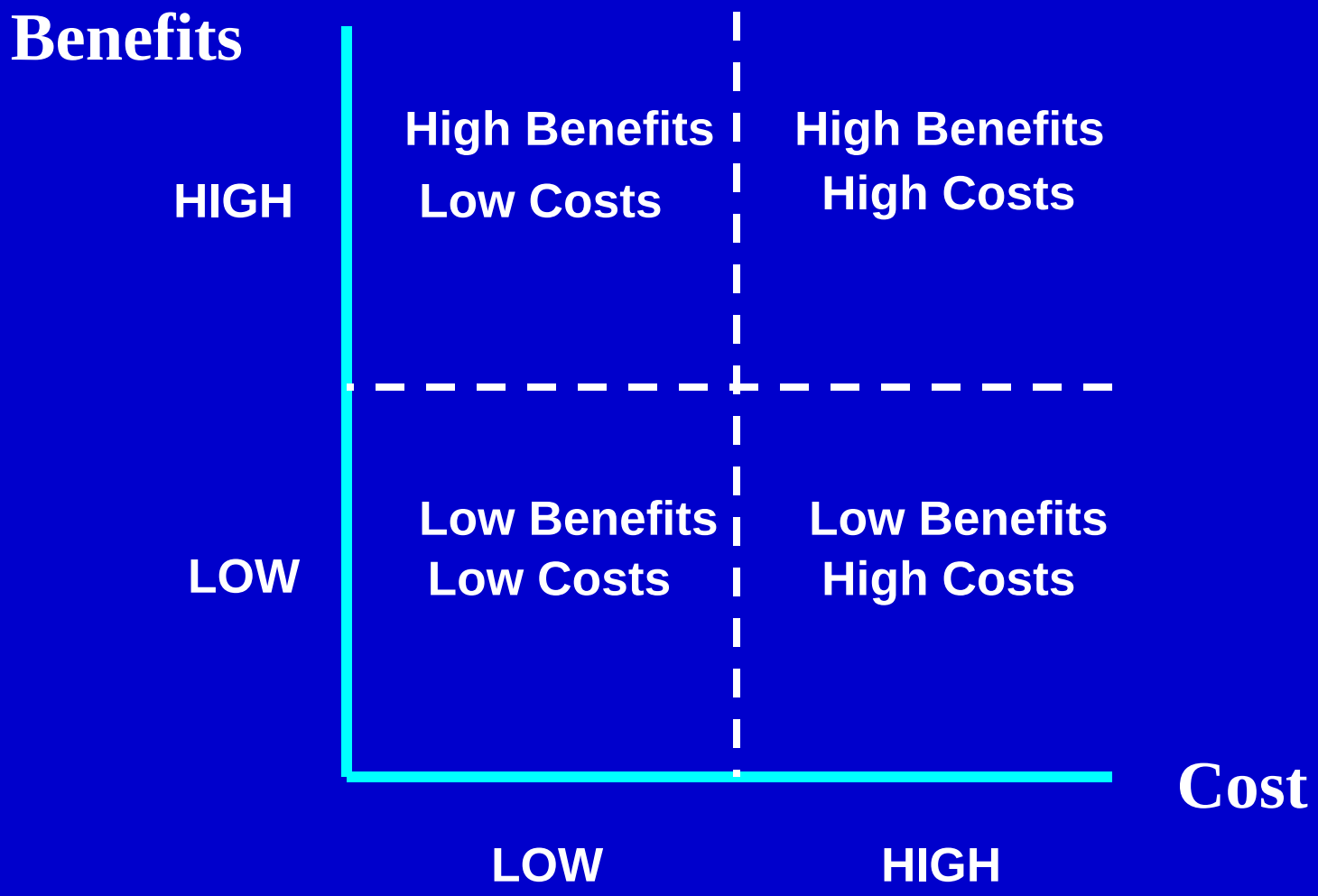
Benefits from Service i



i = service, t = time period

Time

Cost-Effectiveness of Environmental Investments



Types of Uncertainty

Uncertainty over future costs and benefits (with or without restoration)

- Impacts of invasive on service supply and demand
- Substitutability of alternative methods of risk reduction / benefit provision
- Reversibility of environmental damages
- Delayability of action
- Future demand for goods and services
- Intergenerational equity

>> Uncertainty → Rigorous CBA difficult

→ Higher threshold for action

Cost-Benefit Guidance from OMB

Analysis results should:

- Monetize: "…show the type and timing of benefits and costs, and express the estimates in this table in constant, undiscounted dollars…" (discount elsewhere)
- Quantify: "list the benefits and costs you can quantify, but cannot monetize, including their timing"
- Describe: "…benefits and costs you cannot quantify"

-- *OMB Circular A-4, September 2004*

Benefit Indicators

- Proxies for social benefits arising from ecosystem functions
- Developed using conceptual production functions and location theory
- Spatial service use zones are identified, in which supply and demand can be evaluated
- Service-specific and scale with service

Why Develop Benefit Indicators?

- Quantify benefits that cannot be estimated in dollar terms
- Convey economic concepts within a framework typically used by land managers
- Illustrate priorities / trade-offs among options to allow public participation / negotiation
- Can be applied to benefit transfer
- Compare cost-effectiveness among multiple risk reduction options (e.g., off-site mitigation)

Benefits ≈ Fire damage costs avoided

- Cheatgrass control = reduced fire risk (expected damage) now
- Cheatgrass prevention = reduced fire risk (expected damage) in future

Cheatgrass- & Medusahead-Dominated Site

Native-Dominated Site

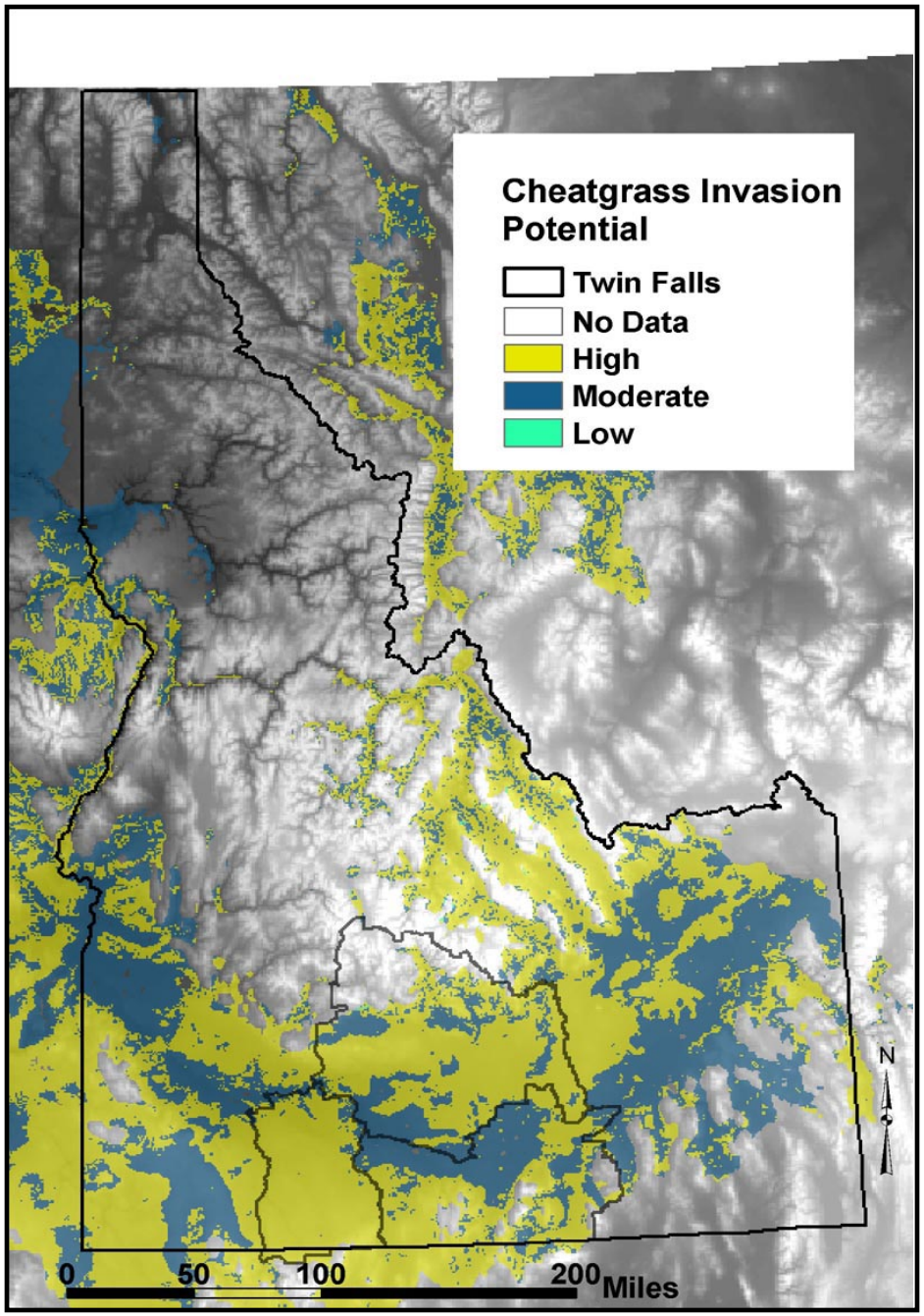
Potential welfare changes in Twin Falls study area

Ecosystem Service	Mechanism
Hunting (esp. sage grouse, deer, antelope)	Increased costs, reduced bag rates, reduced quality of experience. Fires destroy habitat & reduce resilience of herds.
Hiking / Dog Walking	Increased costs, reduced quality of experience. Users avoid infested/burned areas.
All terrain vehicle use	Reduced costs of activity (?) Avoid when fire-prone, but once burned are preferred.
Property protection	Private & public costs w/ fire prevention, property replacement, insurance rates.
Place-based aesthetics	Sage / sage grouse are characteristic species at risk, fires cause undesirable air quality effects / health risks, burned areas degrade views.
Rancher incomes (lost use of rangeland)	Lost profits – if no land substitute, reduces productivity and/or increases costs. Fires & BLM policies force ranchers off allotments.

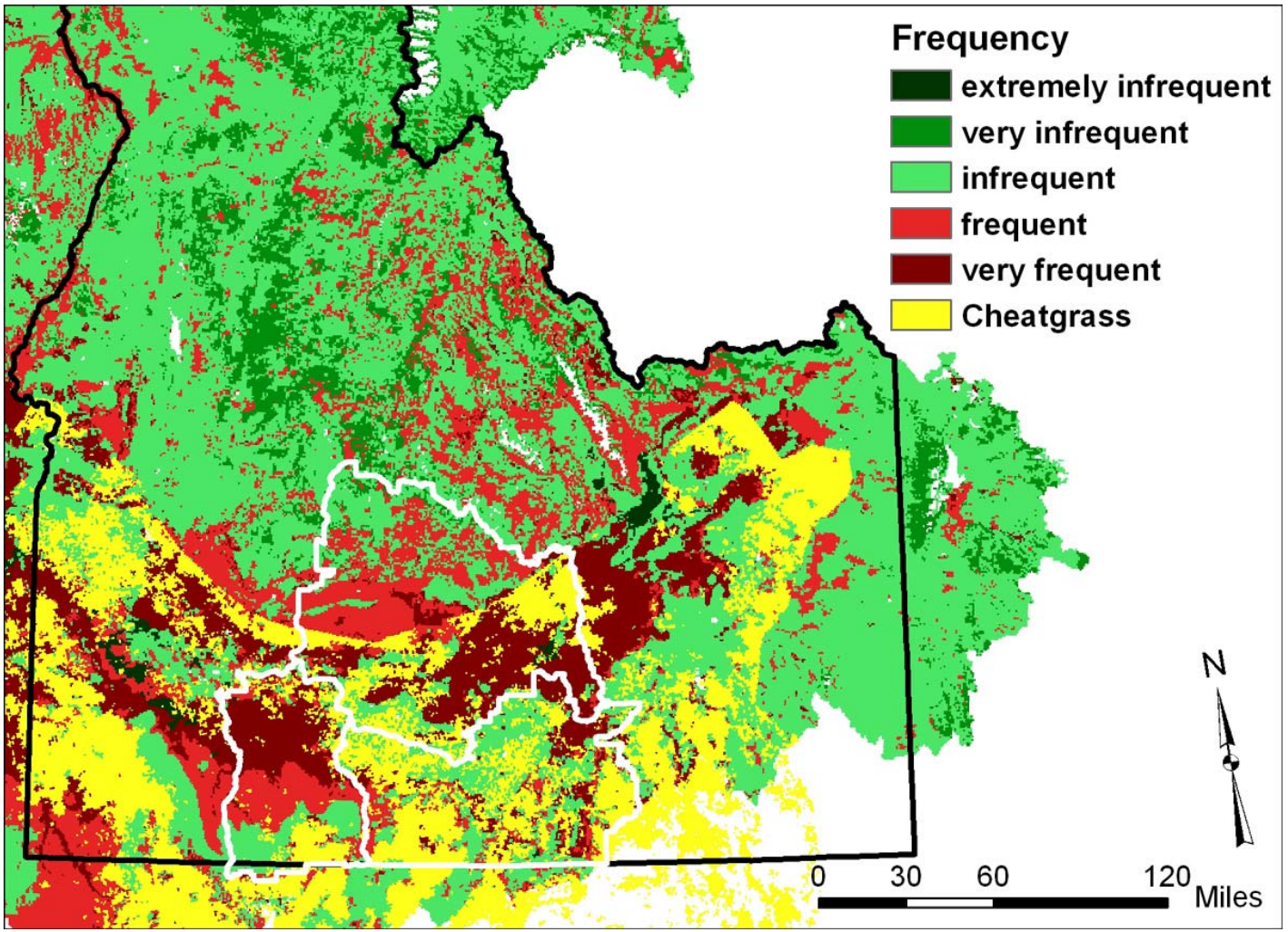
Long-term Baseline Fire Potential

Measure	Proxy for
Fire Condition Class	Enhanced fire risk due to cheatgrass on site
ATV use	Risk of Human-caused ignition
Contiguity of cheatgrass	Potential for widespread fire

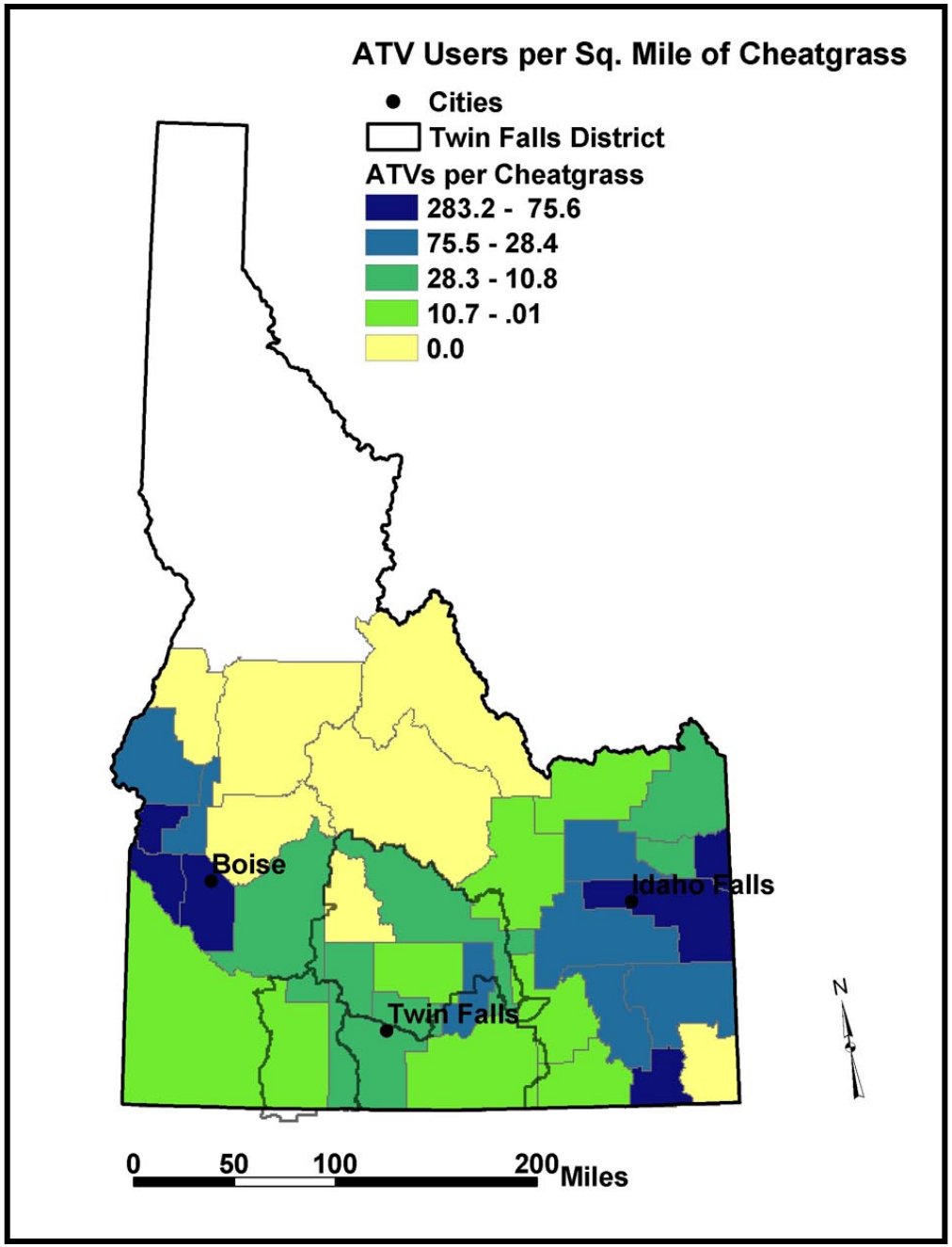
No Action Baseline: Cheatgrass Invasion Potential



Enhanced Fire Risk Due to Cheatgrass



Human-caused fire ignition risk factor: ATVs per sq. mile of cheatgrass



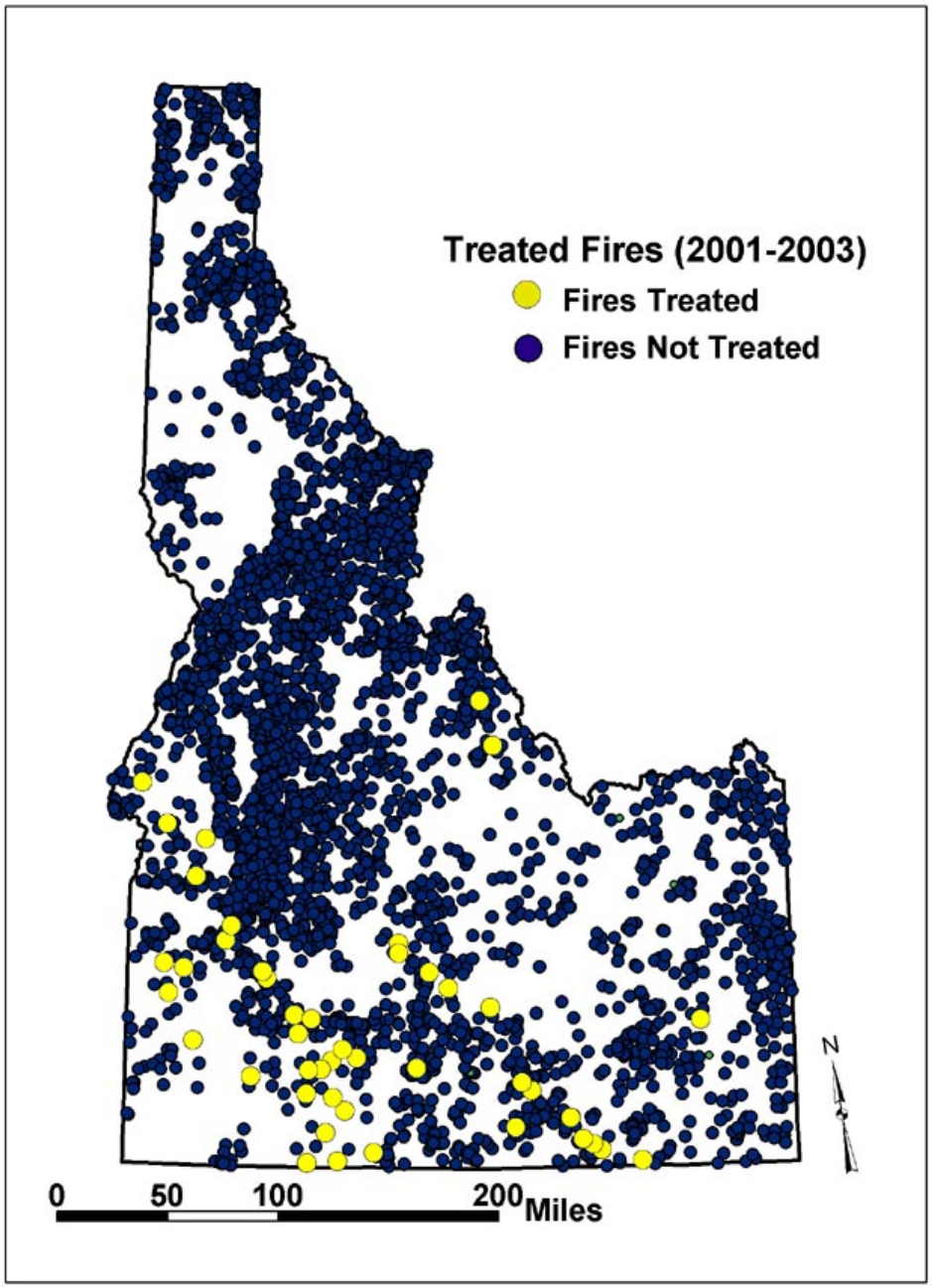
Programs Funding Restoration

- National Fire Plan
  - Hazardous Fuel Reduction Projects on federal lands
  - Hazardous Fuel Reduction Projects in Wildland-Urban Interface (collaborations with counties)
- Burned Area Rehabilitation

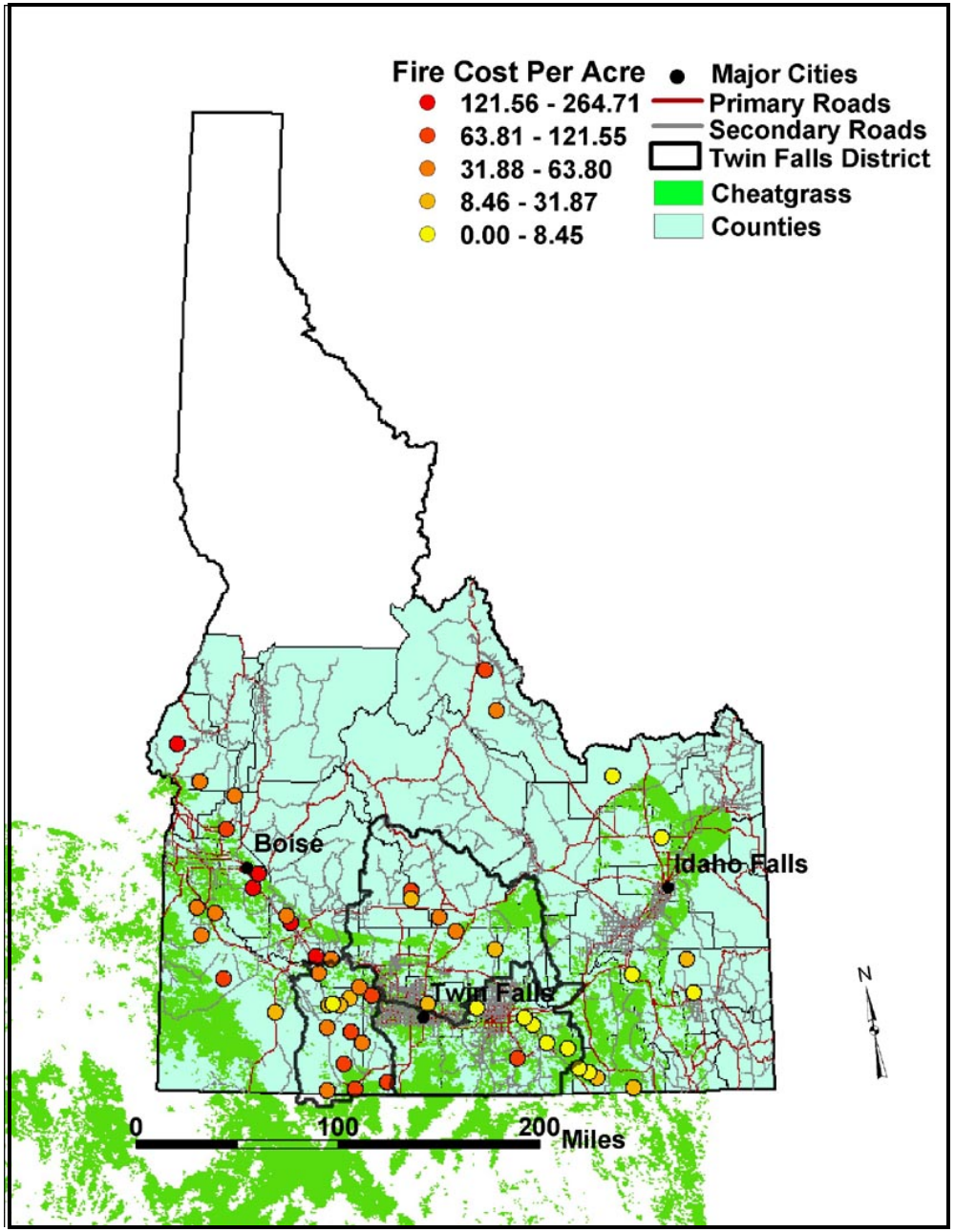
Risk Reduction Strategies

- Directly control cheatgrass in strategic locations
- Prevent cheatgrass becoming dominant in burned areas
- Prevent cheatgrass re-establishment following fire
- Create fire breaks using “green-strips”

2001-2003 Fires Treated & Untreated in Idaho



Fire Cost by Location



Spatial Benefit Analysis

- Hierarchical approach
  - Regional screening (ranked zones)
  - Site-specific screening (ranked sites)
- Service specific scales
- Adjust for restorability and delayability

Recreation Demand

Aggregate recreation demand:

$$E(x) = f(p, Q, y)$$

E(x) = expected number of trips to recreation sites

p = *travel costs*

Q = *site-specific characteristics*

y = *demographics of source population (income, education)*

Recreation Demand by Location

Preference for sites is based on:

- Cost of use
- Site quality for intended activities (e.g., probability of hunting success)
- Ancillary qualities (e.g., wildlife viewing opportunities, quality of wilderness experience)
- Complementary goods (e.g., proximity to developed campsites)

Assume: Degree of preference for a site is proportional to consumer's willingness-to-pay for protection / restoration of site

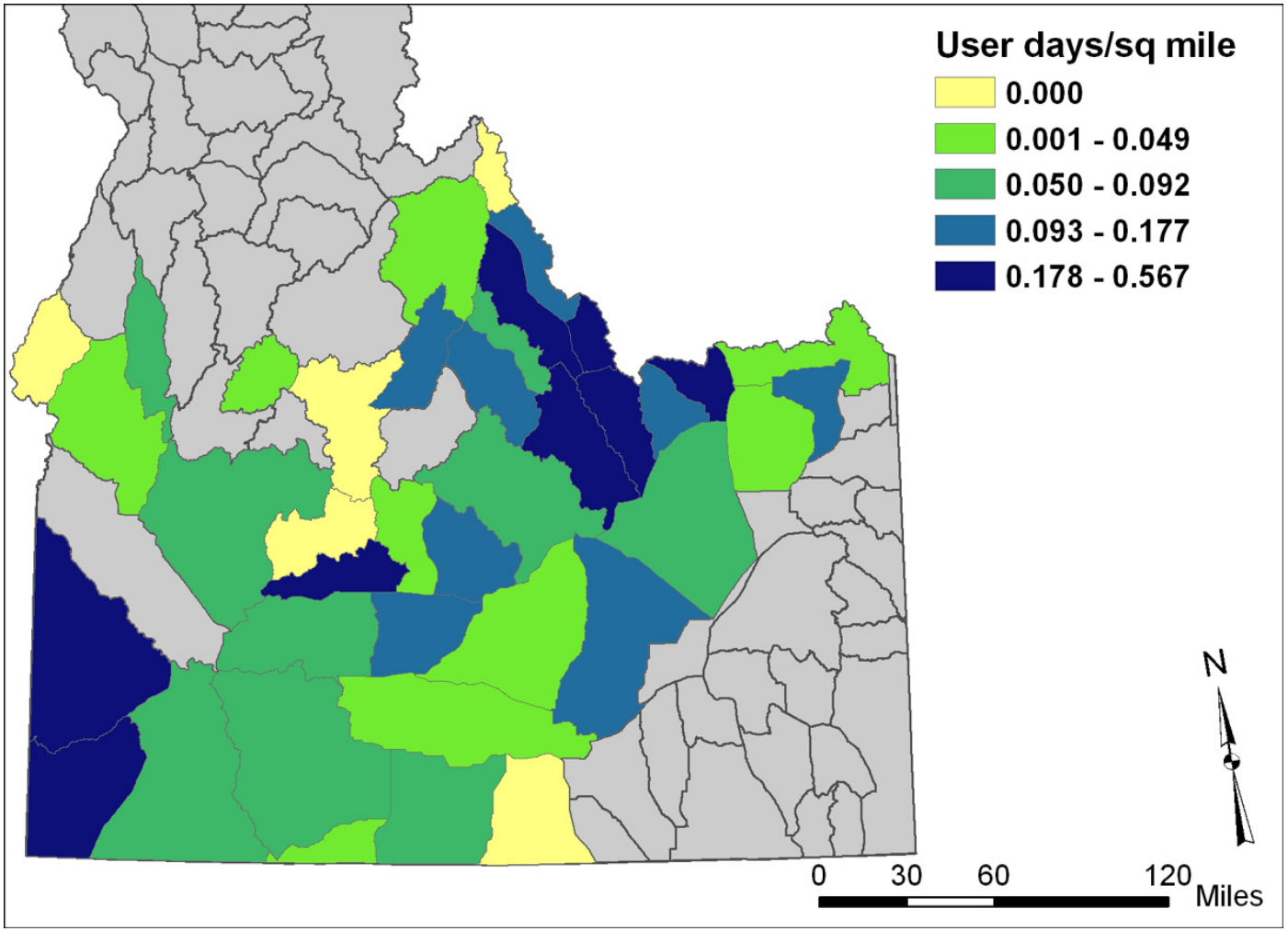
Components of Site Value

Site Quality	How well does this site provide biophysical *functions* necessary to the service?
Service Opportunity	What features of this site make this *service* available and valuable at this location?
Service Scarcity	How rare is this service in the user area?
Service Loss Risk	Is this service likely to be lost or impaired from uncontrollable forces?

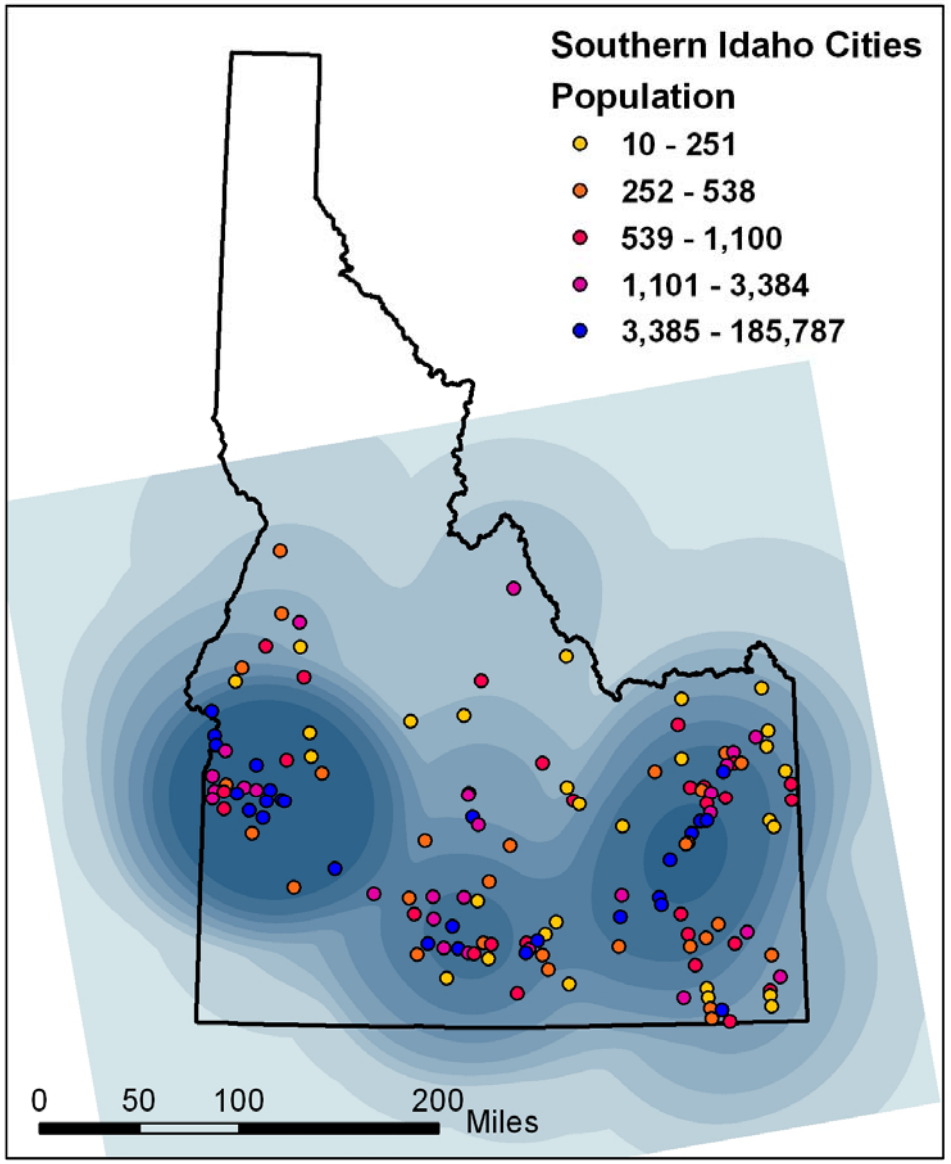
Measurable Indicators: Relative Hunting Benefits by Location

Type	Measure	Proxy for
Site biophysical quality	Habitat quality (e.g., % native cover) within hunting areas	Hunting availability (species presence, alt. viewing opportunities)
Site Opportunity	User day density by hunting unit	Quality + Cost of Access
	Trip density	Cost of Access
	Camping capacity	Complementary input

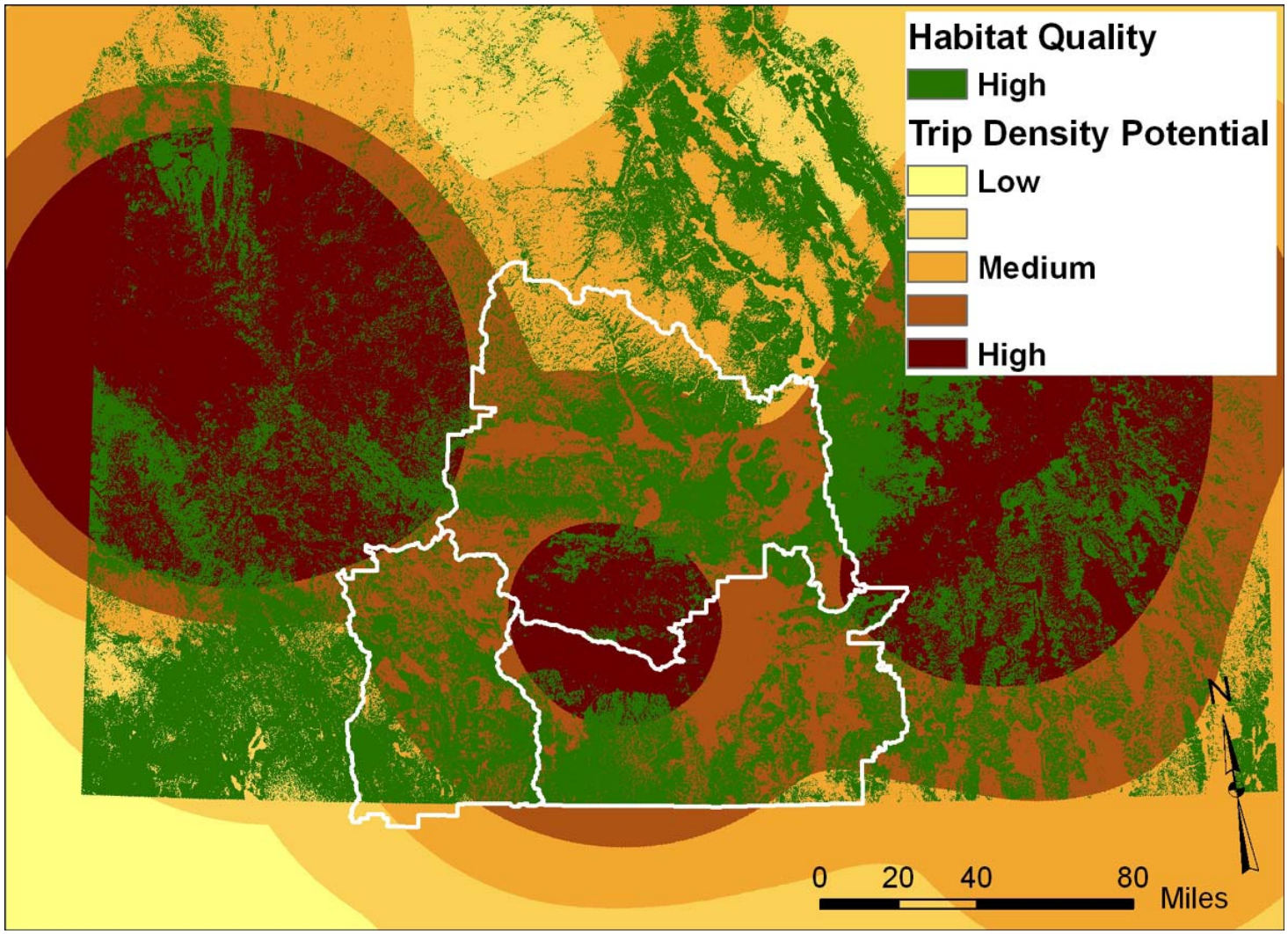
Antelope Rifle Hunting
User Day Density



Trip Density



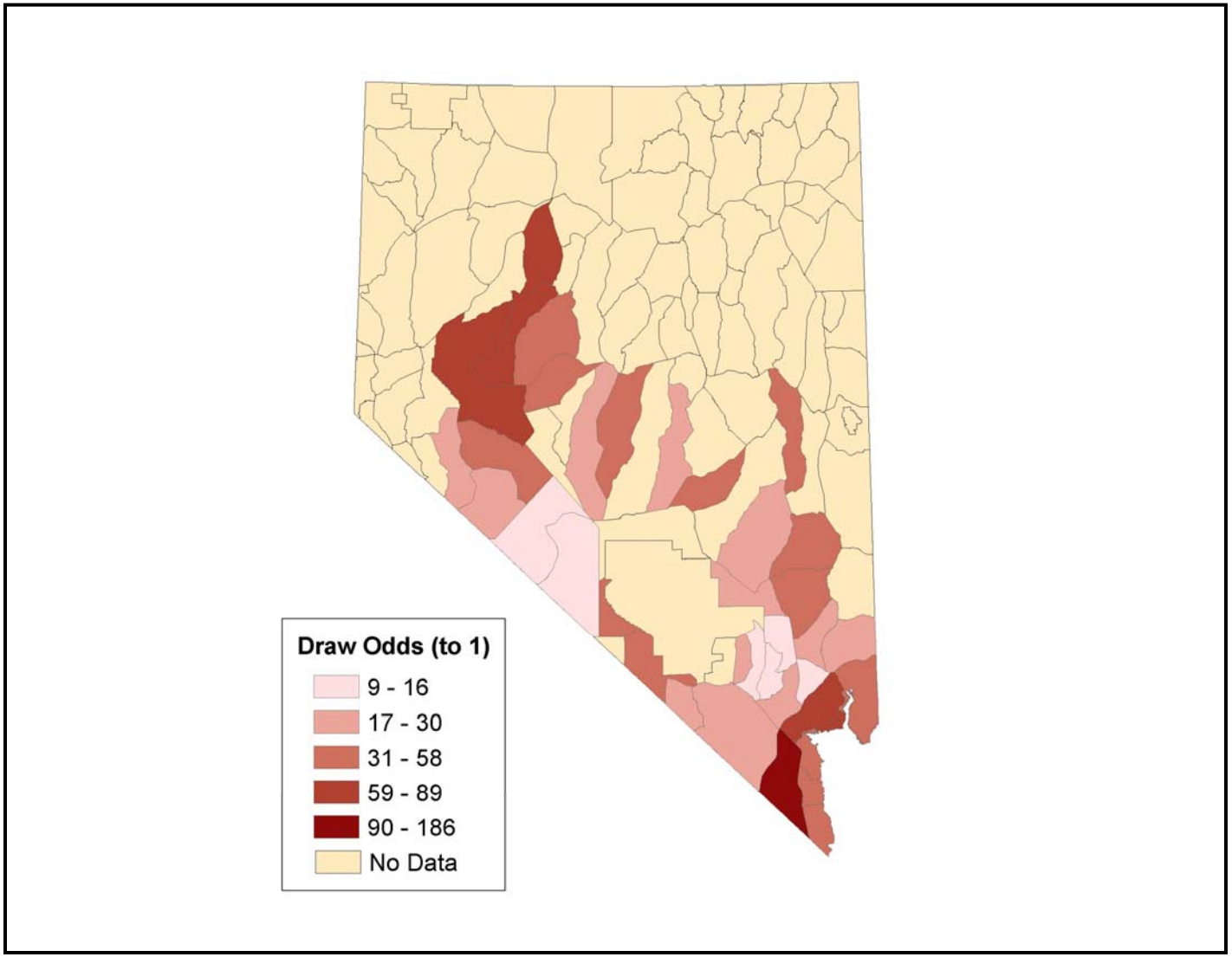
Site Quality X Trip Density



Measurable Indicators: Relative Hunting Benefits by Location (cont.)

Type	Measure	Proxy for
Scarcity / Substitutability – Screening level	% hunting unit with high risk of burning	Substitutability within hunting area
	Draw odds	Scarcity (Demand:Supply)
Scarcity / Substitutability – Site level	Acres of alternative hunting areas of equal or better quality within equivalent density zone	Substitutability holding quality and cost constant
Service Loss Risk	Presence of other invasives not controlled by treatment	Uncontrollable forces

2003 Permit Odds for Bighorn Sheep Hunt



Source Data: Nevada Department of Wildlife

Aggregating Indicators

- Implied production function
- Can assign functional forms for select indicators (e.g., species-area relationships)
- With mixed units for multiple services, need weighting scheme
- Can assign relative values with MCDA
  (e.g., critical life requisites)
- Scores/Functions can feed into an optimization

Adjusting Benefits by Treatment Risk

- Identify appropriate treatments
- Evaluate likely success rate(s) based on site characteristics
- Weight benefit indicators by probability of different outcomes

Treatment Options Evaluated

1. No action - Allow site to recover/degrade
2. Preventive reseeding following fire
3. Fire-Herbicide-Reseed regime
4. Grazing management options

Risk-Weighted Outcomes

$$E = [f(s_r, l_r) * p] + [f(s_d, l_d) * (1 - p)]$$

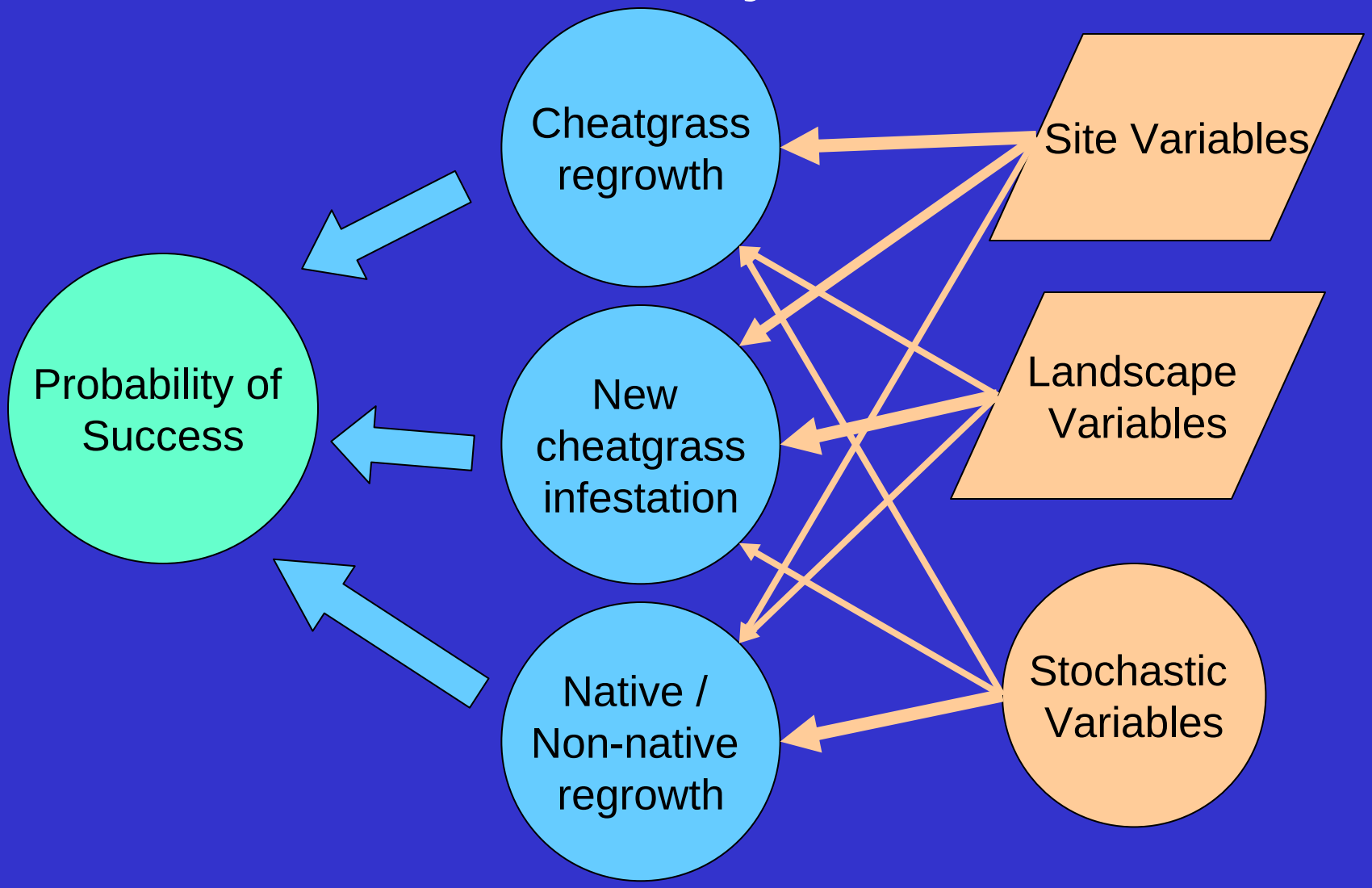
E = expected value

s = site qualities; l = location factors

r = restored conditions; d = degraded conditions

p = probability of restoring service

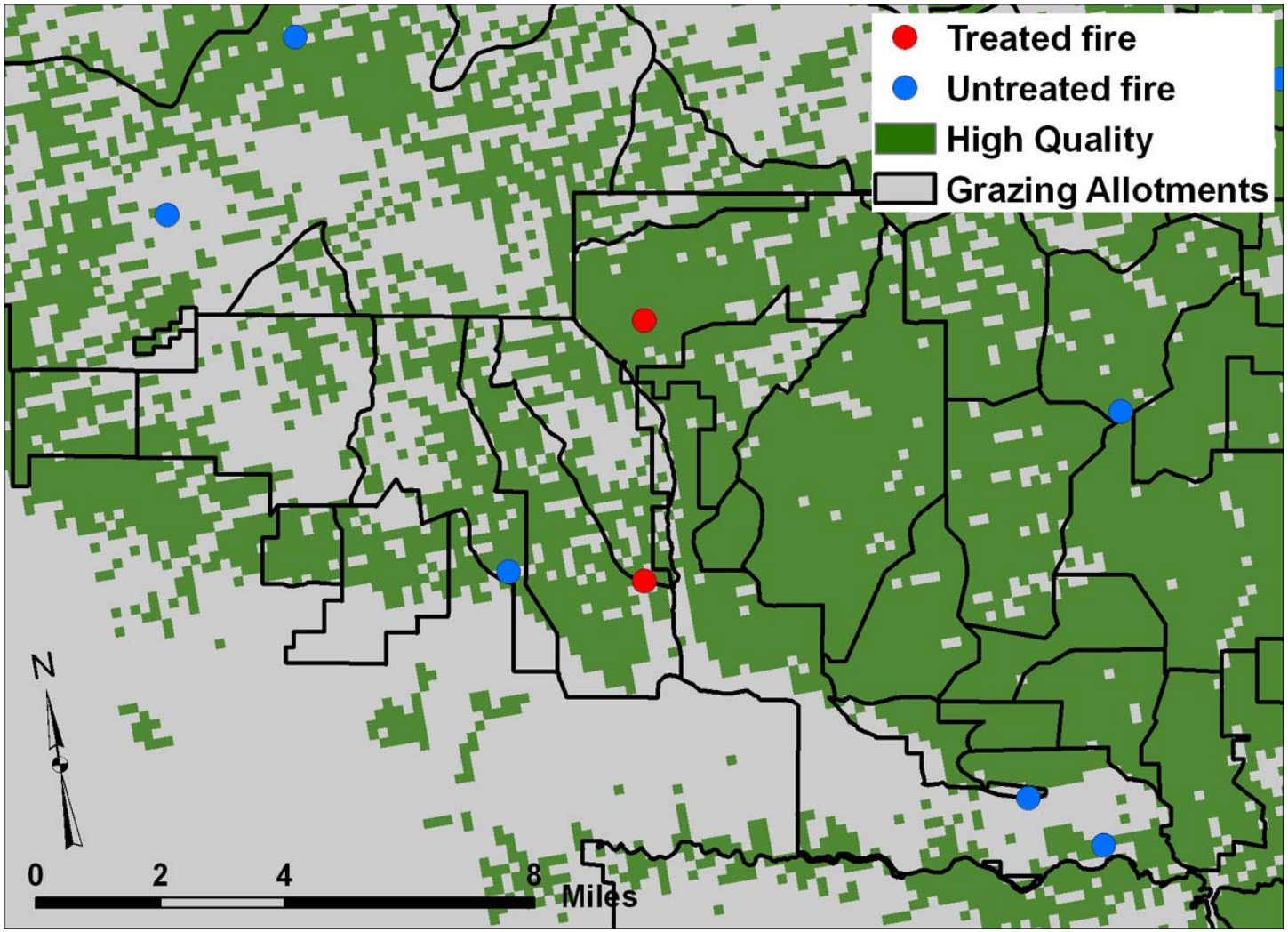
Restorability Model



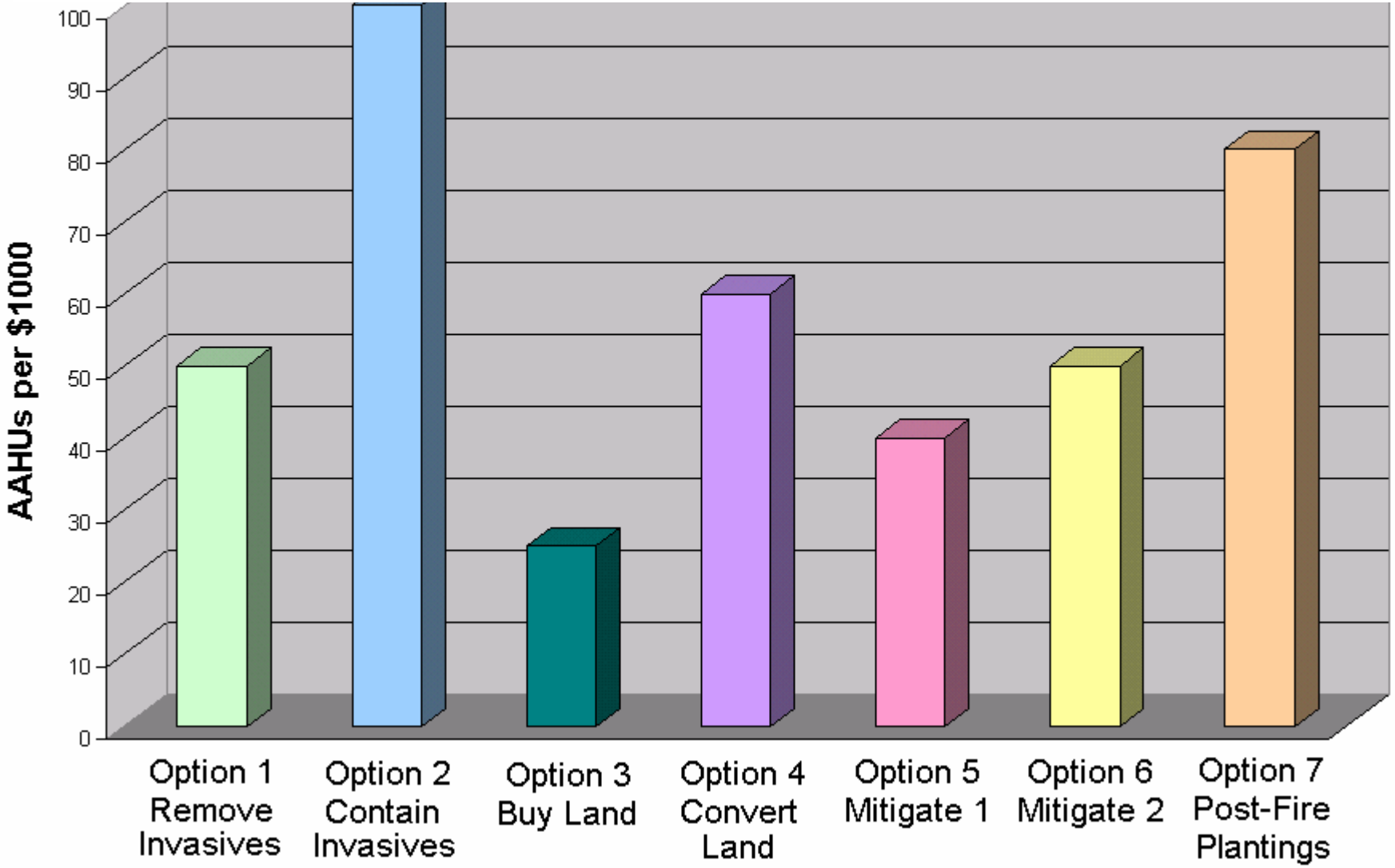
Possible Decision Rules
(with Fixed Budget)

1. Maximize plants killed (intensive)
2. Maximize area treated (extensive)
3. Maximize short-term benefit response from treatment (landowner perspective)
4. Maximize prevention of future harms (social planner perspective)

Decisions at Multiple Scales



Establish Least Cost Method to Achieve Benefits



Summary - Tool Disadvantages

- Data intensive
- Not all factors can be represented spatially
- Cannot be used to justify any given level of spending

Summary - Tool Advantages

- Both supply and demand-based indicators are used to evaluate the ability of assets to produce a stream of services over time
- Benefits measured at multiple scales to incorporate off-site and ancillary benefits of treatment
- Treatment risk is used to explicitly weight benefits to help managers understand trade-offs
- Costs are represented spatially to help managers understand effect of location on treatment cost including “hidden” costs of employee time visiting sites
- Costs and Benefits of intensive vs. extensive options & economies of scale can be evaluated
- Risk of supply or demand disruptions is incorporated into expected outcomes of alternative actions