Evaluating the Costs and Benefits of Alternative Weed Management Strategies for Three Montana Landscapes

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Protecting nature. Preserving life.™

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ESSA

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After about five decades of chemical weed control, invasive plants infest an estimated 40.5 million ha in the United States (NISC 2001) and continue to spread at nearly 14% per year (Westbrooks 1998).

- Sheley and Krueger-Mangold 2003

Current Weed Management Paradigm

We know what to do

Small-scale success!!!

Short-term success!!!

Large-scale success???

Long-term success???

Unmanageable infestations…

Inconsistent effort…

COSTS!!!

Are efforts sustainable?

Are efforts meaningful?

Weeds are increasing!!!

Applying adaptive management to invasive species at the landscape level requires us to test strategies rather than simply:

- Working harder at applying the same strategy
- Perfecting treatment techniques
- Assuming small-scale success = large-scale success
- Assuming short-term success = long-term success

Strategies need a clear forecast for success

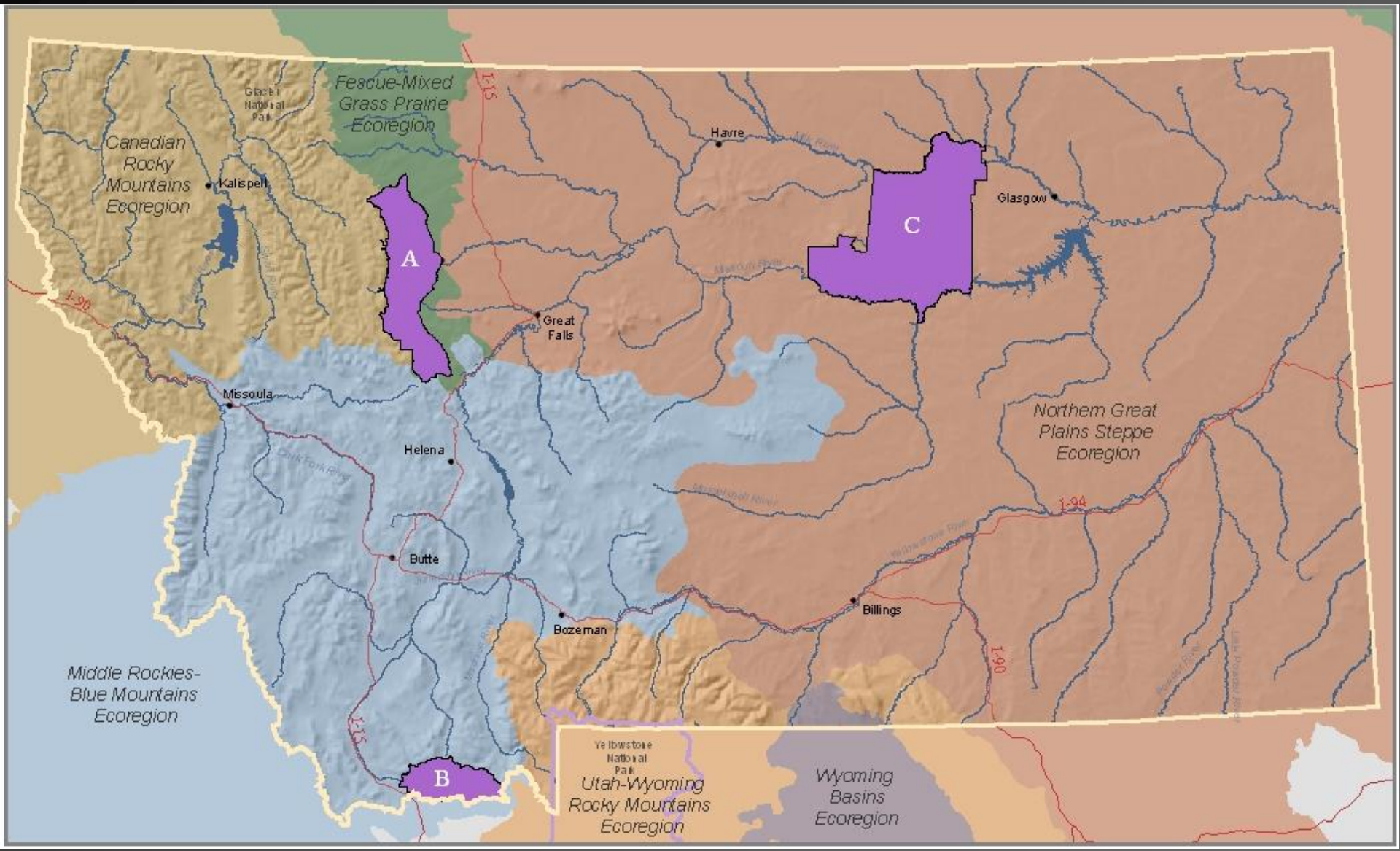
Insanity: Doing the same things over and over again and expecting a different result

- variously attributed

Weed Management Progression

- Prevention
- Eradication
- Control
- Containment
- Restoration/Management

What Is Best Management Strategy?
What Is Possible?


Fescue-Mixed Grass Prairie Ecoregion
Canadian Rocky Mountains Ecoregion
Glacier National Park
Kalispell
Havre
Glasgow
A
C
Great Falls
Missoula
Helena
Butte
Bozeman
Billings
Northern Great Plains Steppe Ecoregion
Middle Rockies-Blue Mountains Ecoregion
Yellowstone National Park
Utah-Wyoming Rocky Mountains Ecoregion
Wyoming Basins Ecoregion
B
I-15
I-90
I-94

Modeling Tools:

- State and transition models using the Vegetation Dynamics Development Tool (VDDT).
- Spatial simulations using the Tool for Exploratory Landscape Scenario Analyses (TELSA).

Available from:

ESSA Technologies

essa.com

Modeling Objectives:

- Understand weed spread at the landscape scale
- Compare effectiveness of various management strategies
- Understand economic costs and impacts of various management strategies

Species Modeled:

- Spotted Knapweed
- Leafy Spurge

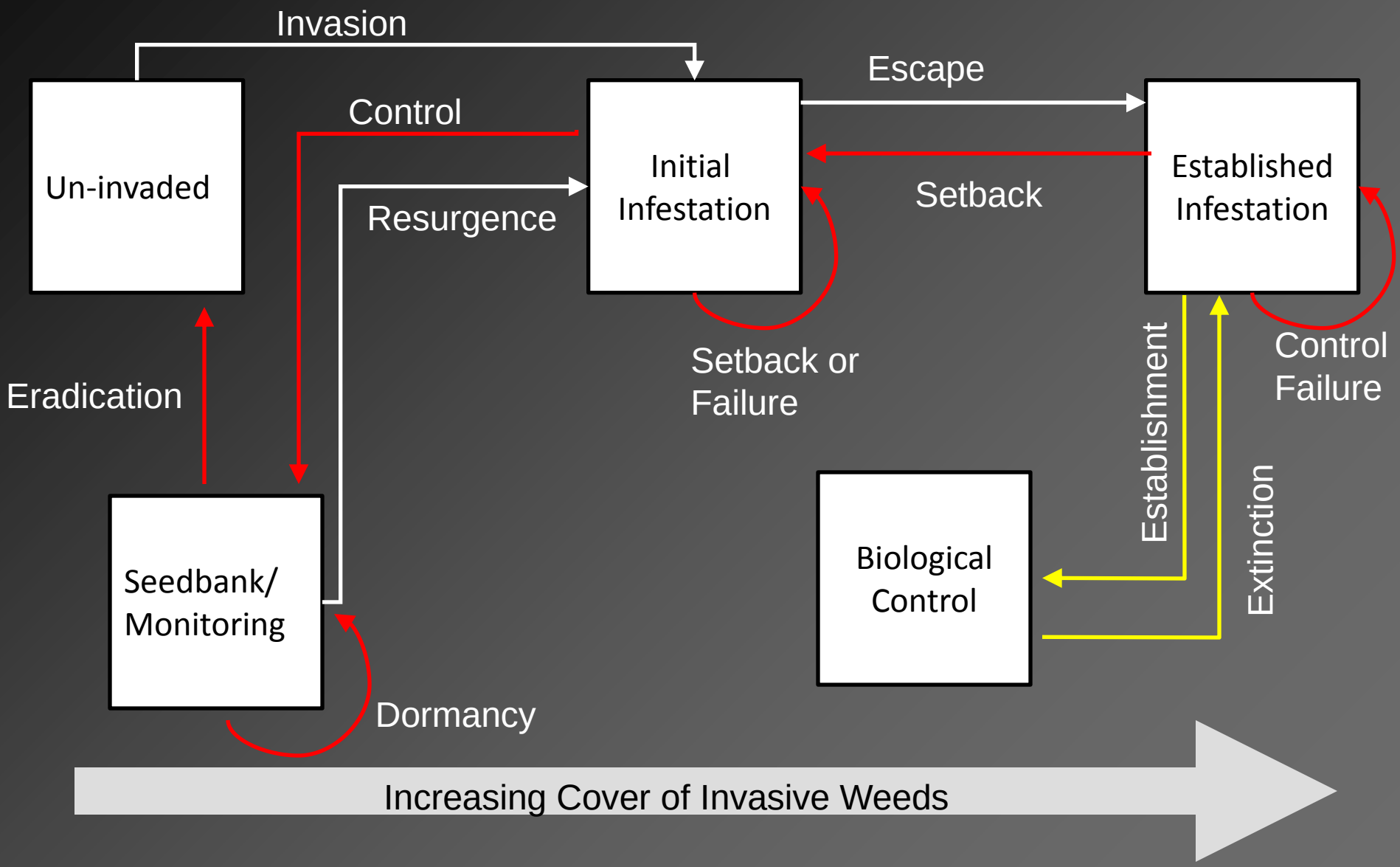
Overview of How the Model Works

Based on vegetation – divides study area into polygons about 2½ ac in size

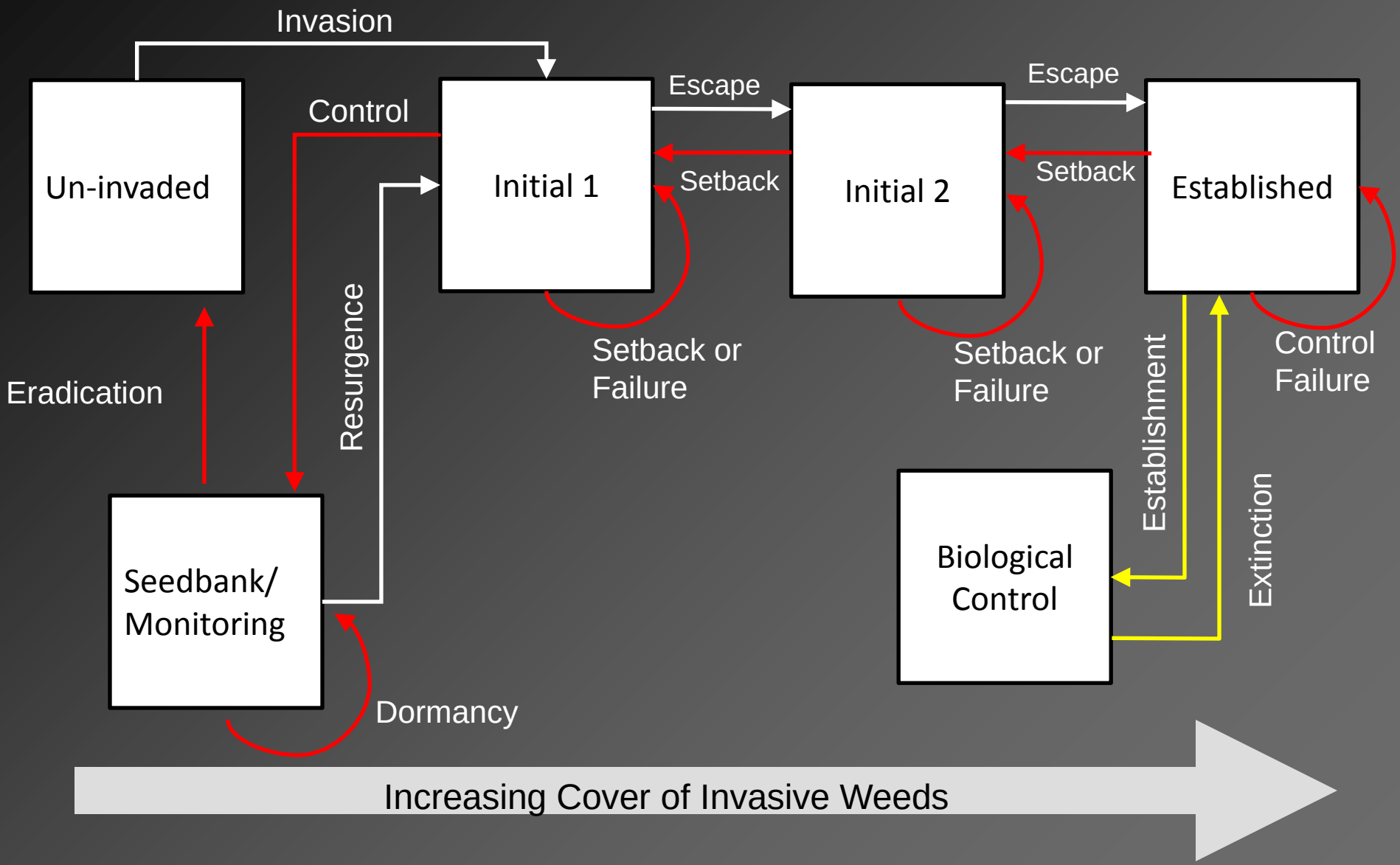
Add data and “rules” to model to give it direction

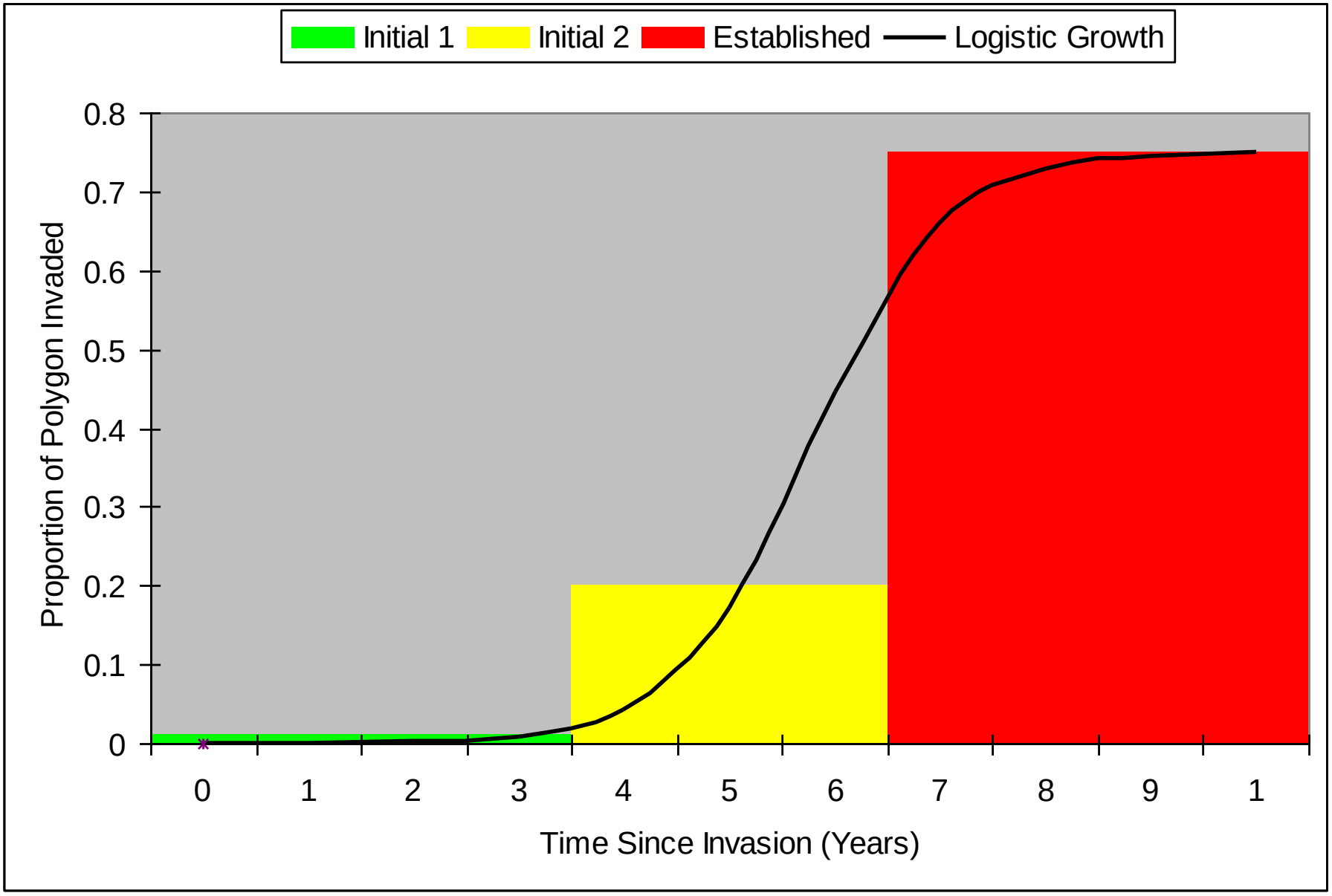
Model runs simulations to predict weed distribution based on data and rules

State and Transition Model



State and Transition Model

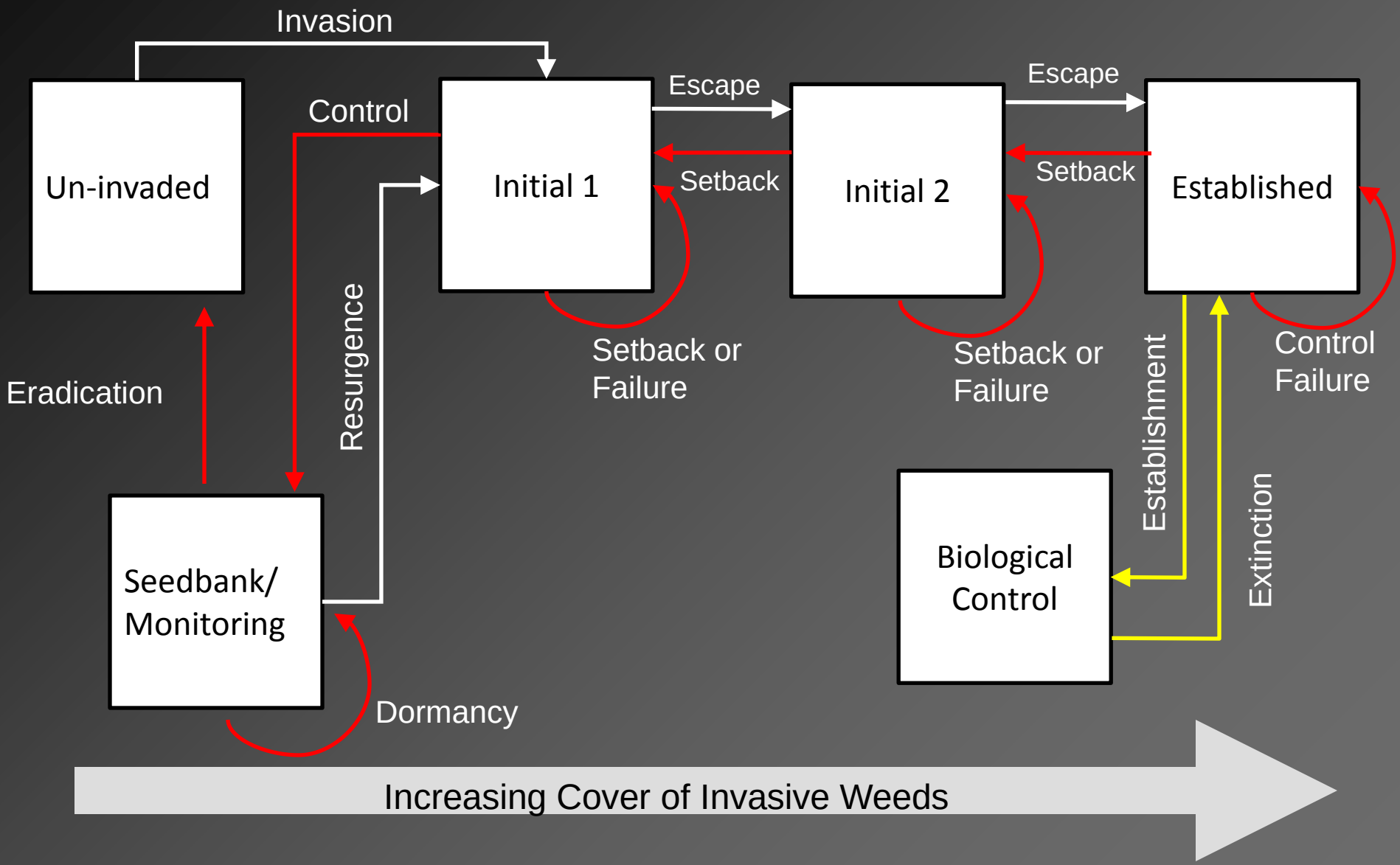



Initial 1
Initial 2
Established
Logistic Growth
Proportion of Polygon Invaded
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
1
Time Since Invasion (Years)

Model Parameters

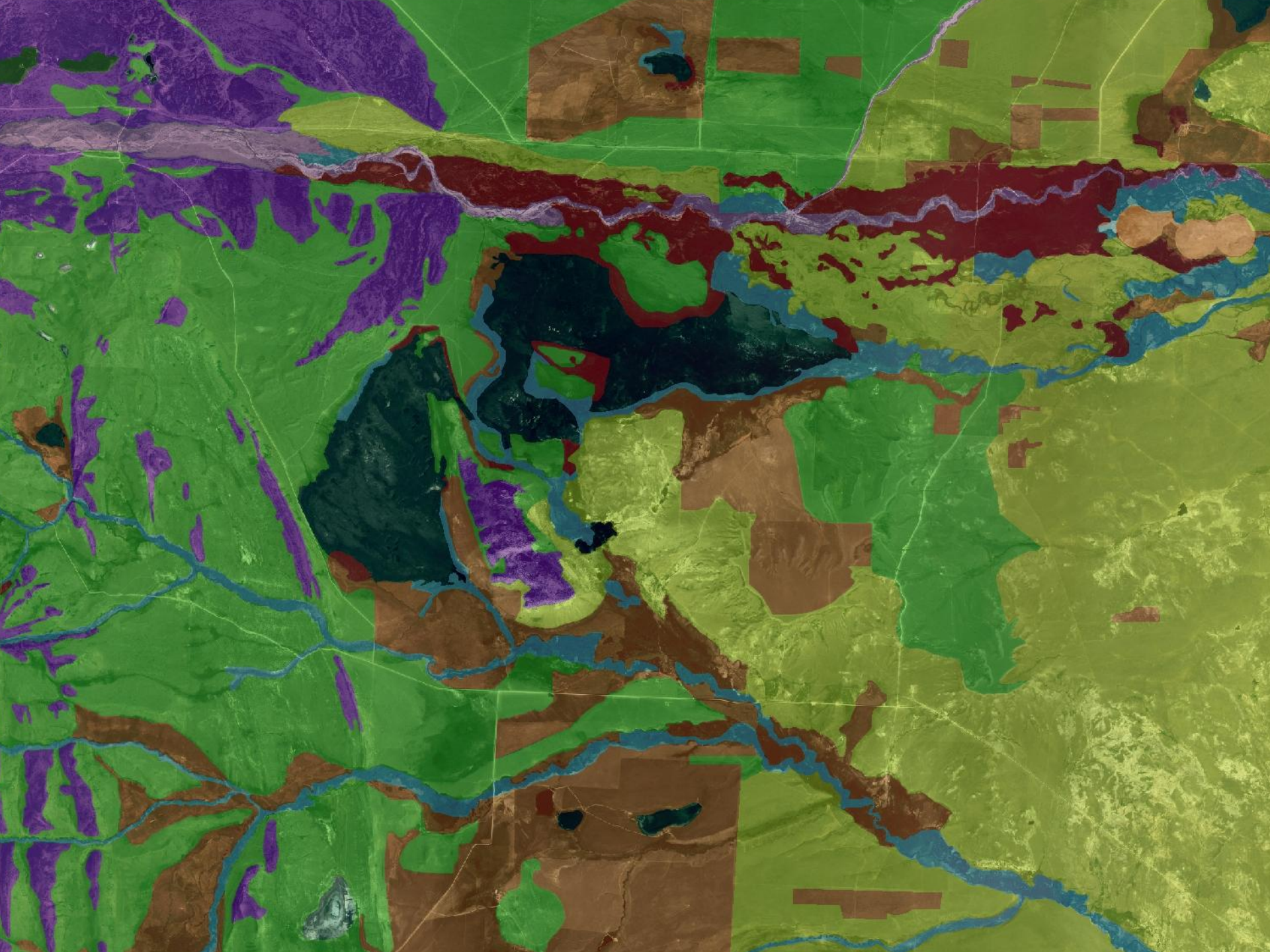
- Spread Rates
- Control Effectiveness
- Factors that affect Spread Rates
  - Vegetation Susceptibility
  - Spread Vectors
- Biocontrol Establishment, Spread, and Extinction Rates

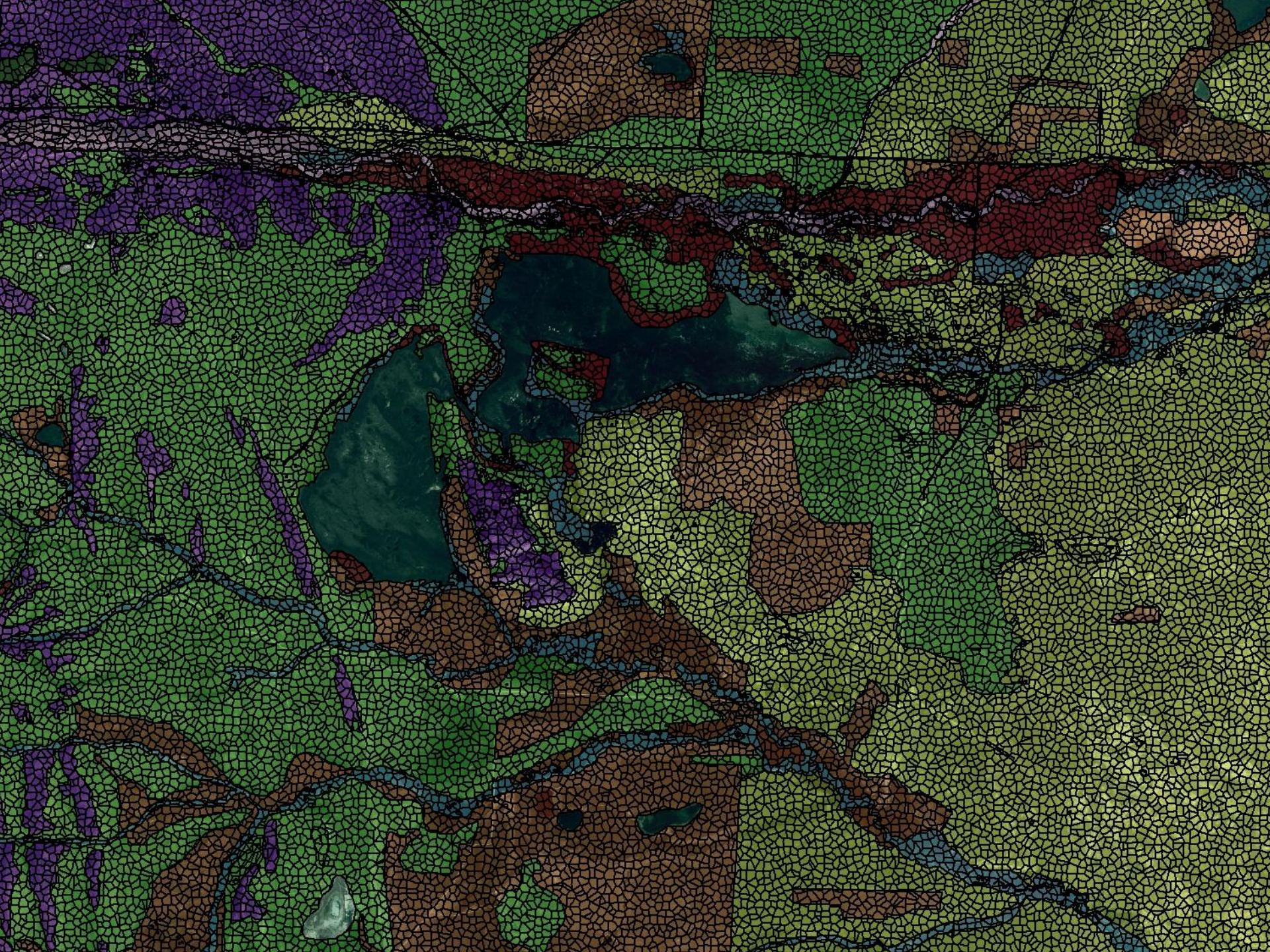
State and Transition Model

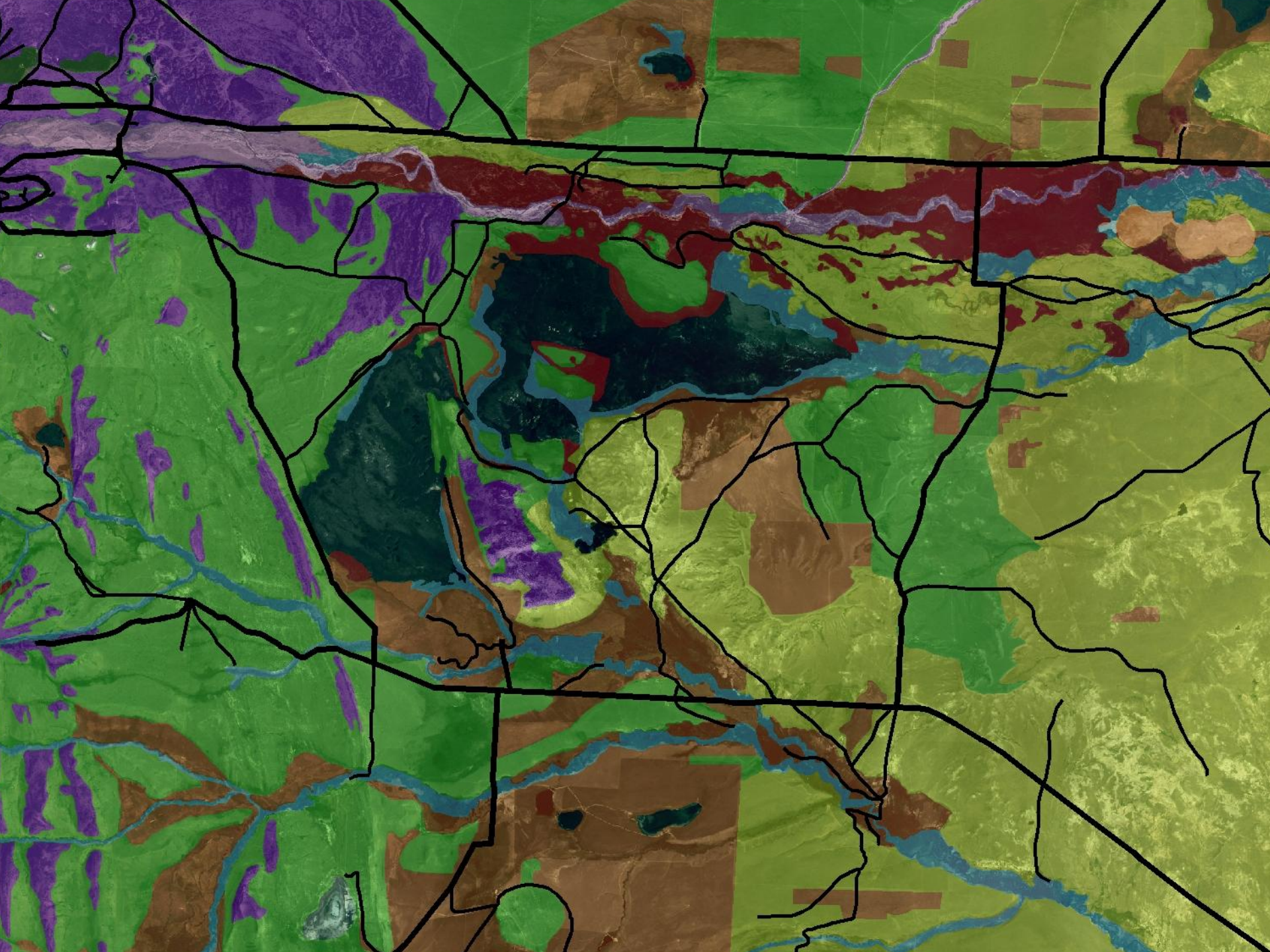


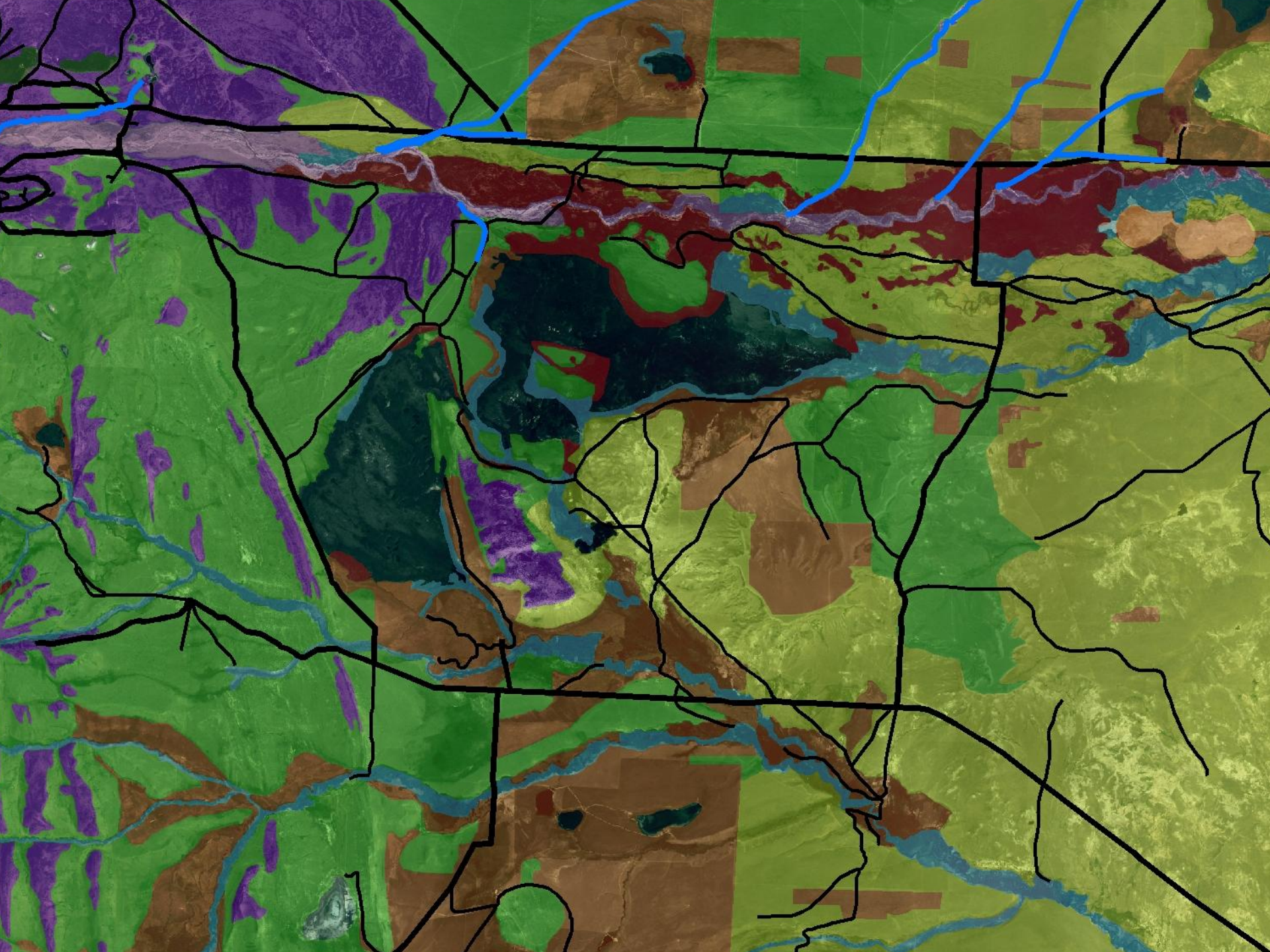
Spatial Inputs

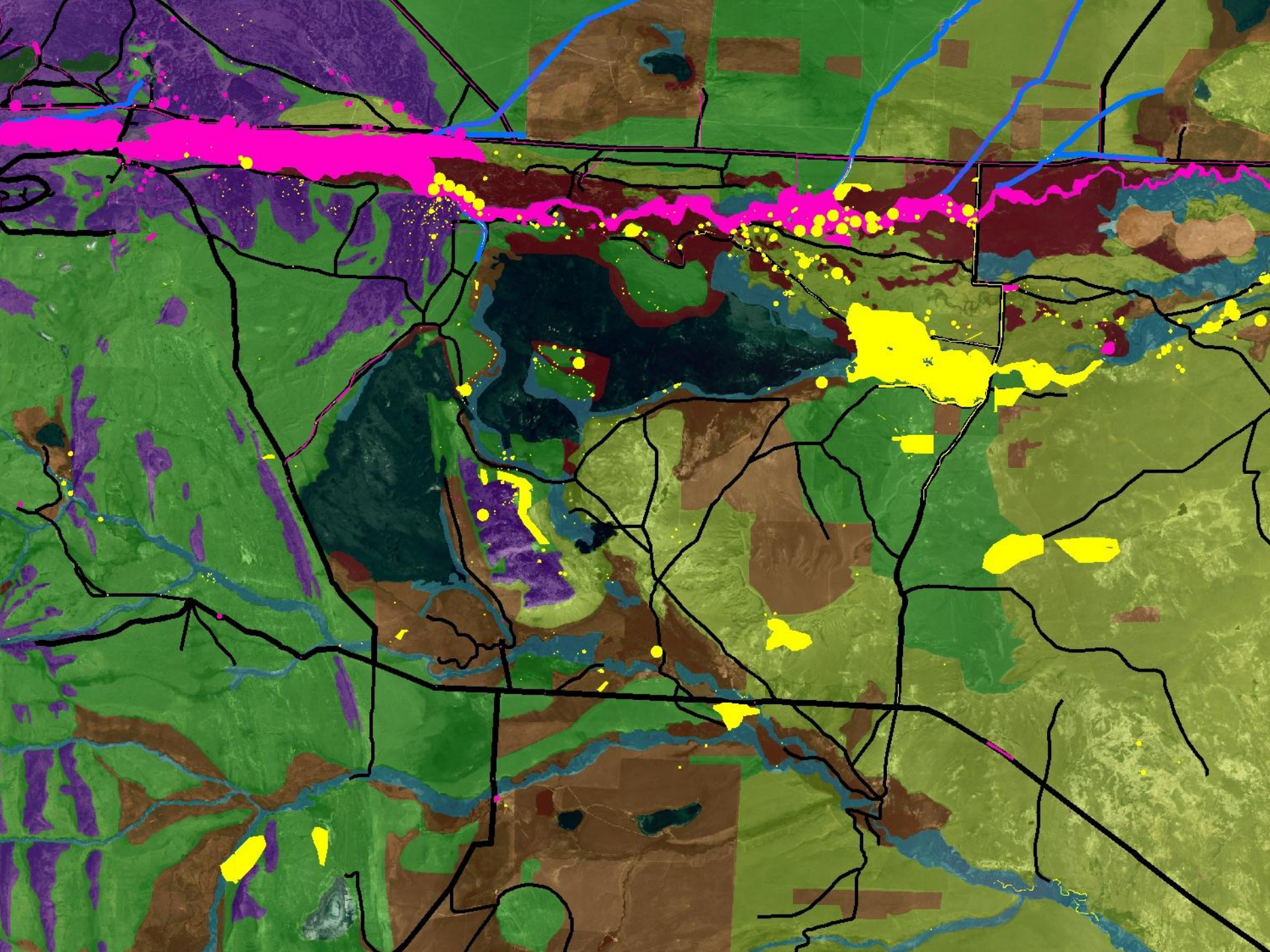
- Weeds
- Biocontrol
- Vegetation Types
- Features that affect spread – roads, ditches, trailheads, etc.
- Tessellation

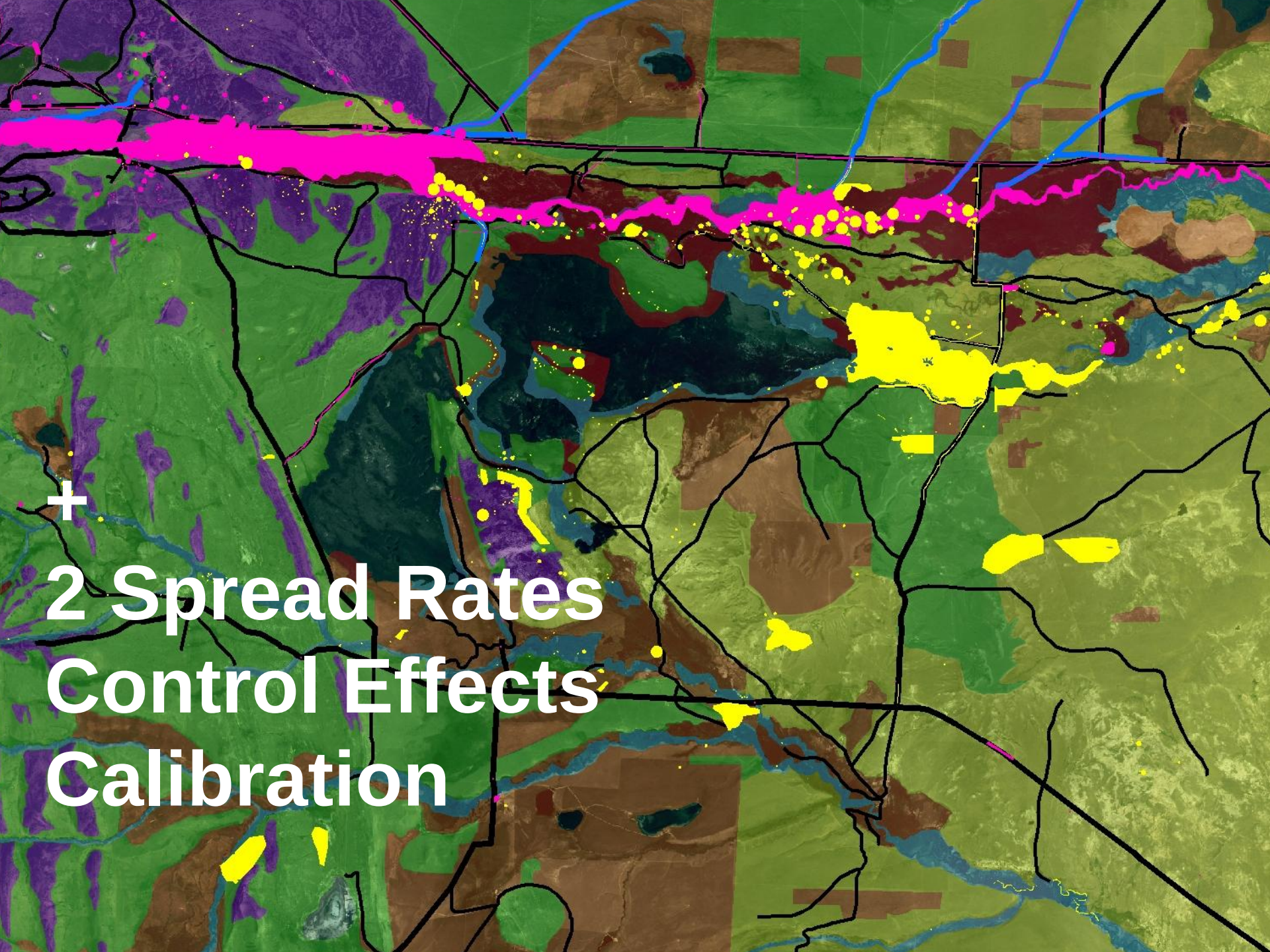






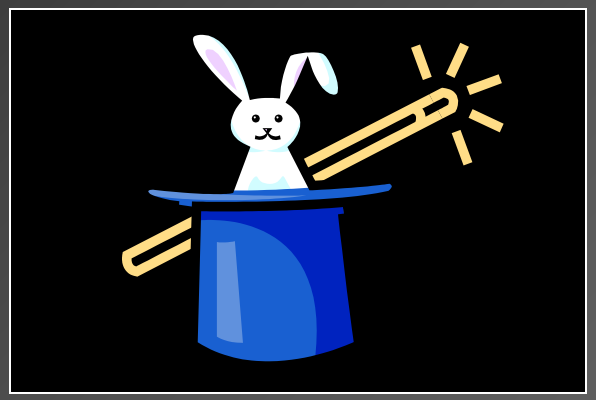


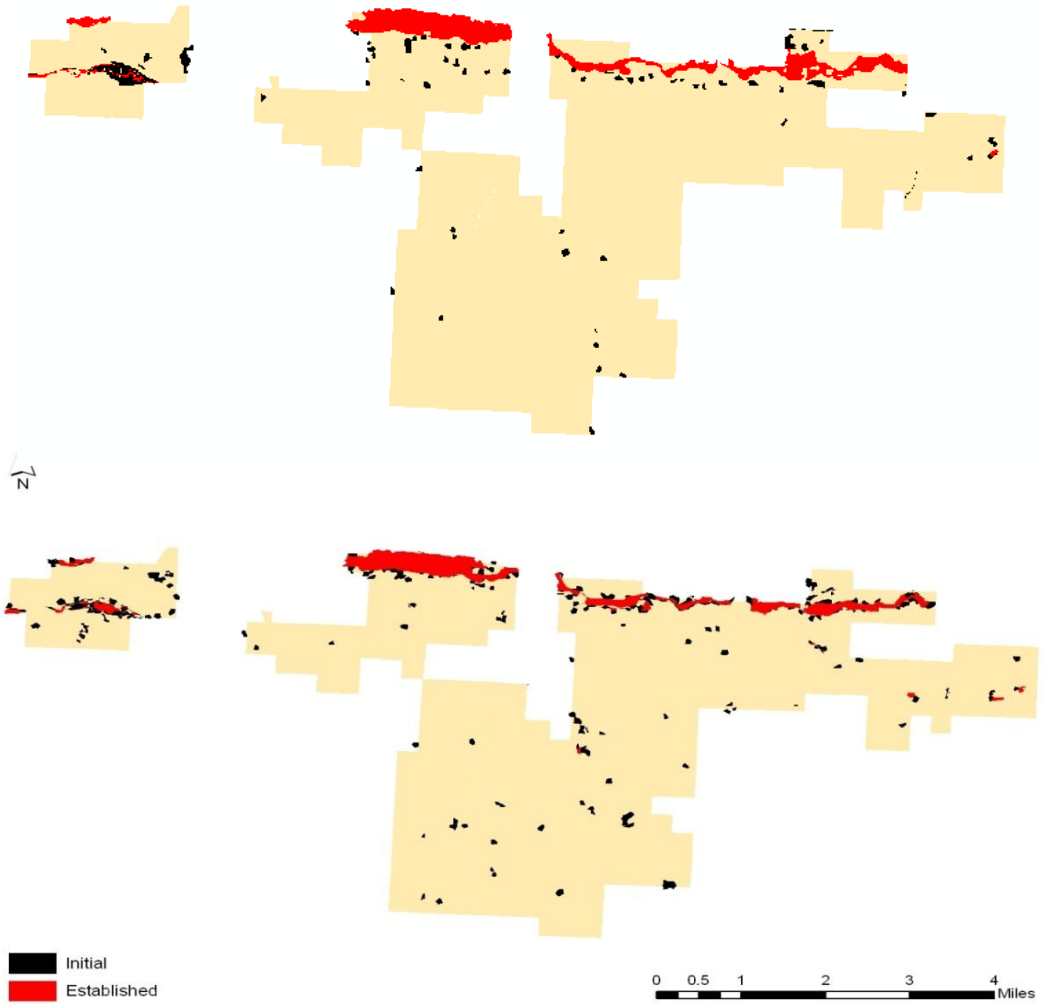



+
2 Spread Rates
Control Effects
Calibration

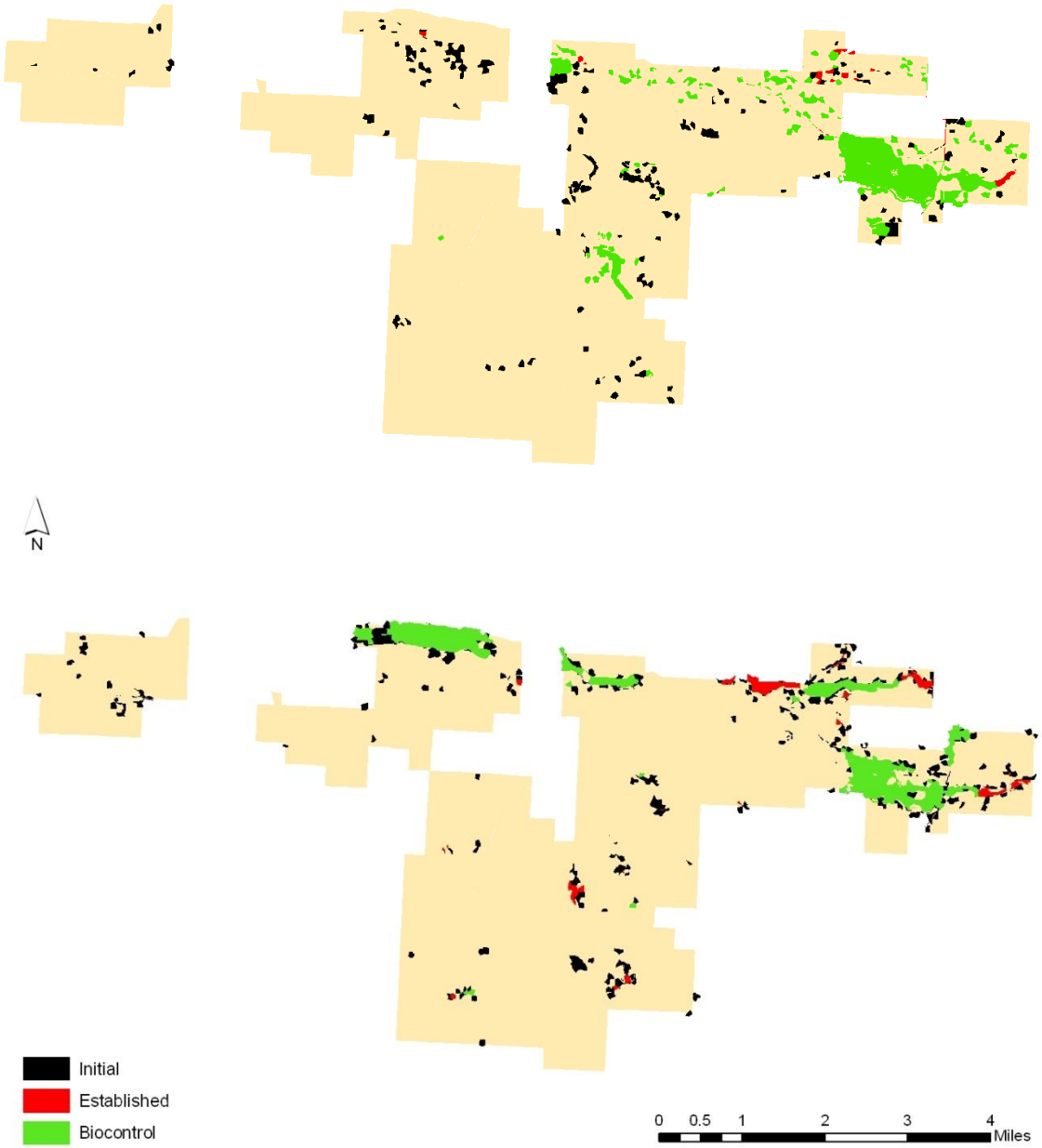
Reality Check

Not a Magic Black Box!

Data →  → **Truth**

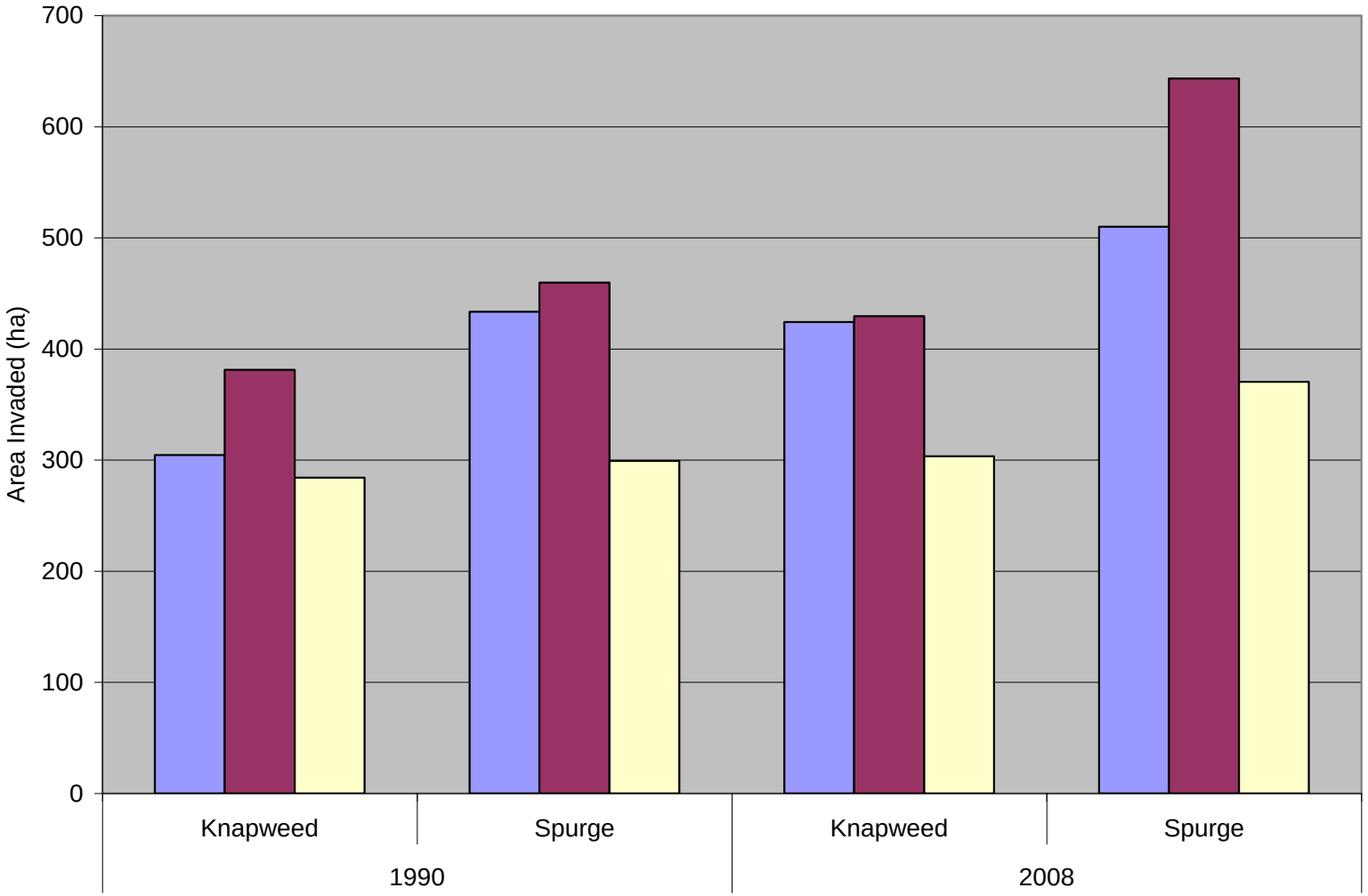


Knapweed Calibration



Spurge Calibration

Calibration Results

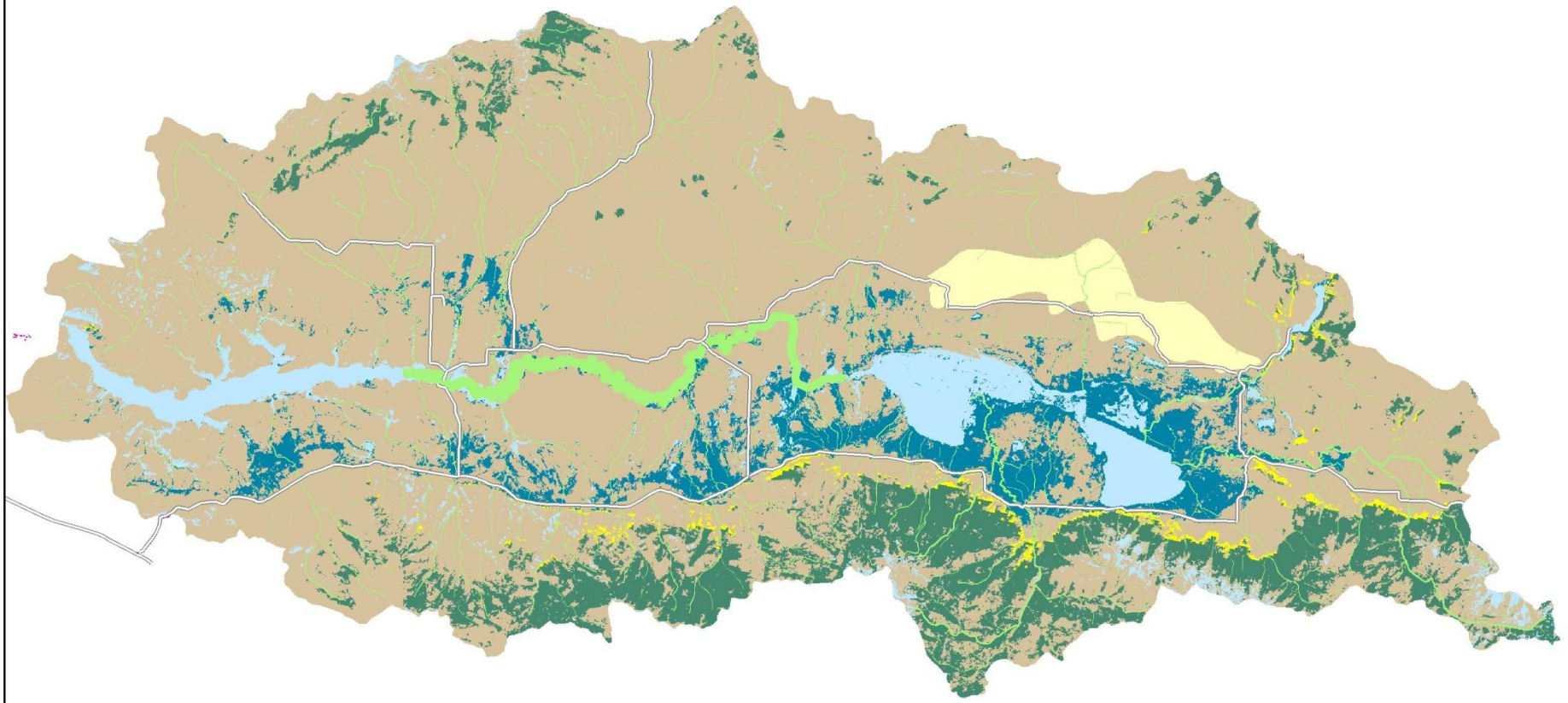


Sample Management Scenarios

- No management
- No constraints
- Blocked
- Delay
- Small patch
- Large patch

Centennial Valley - TELSA Weed Model

Vegetation Types



Potential Vegetation Types

- Sagebrush
- Sandhills
- Water/Wetland
- Wet Meadow
- Aspen
- Riparian
- Conifer
- Unprojectable

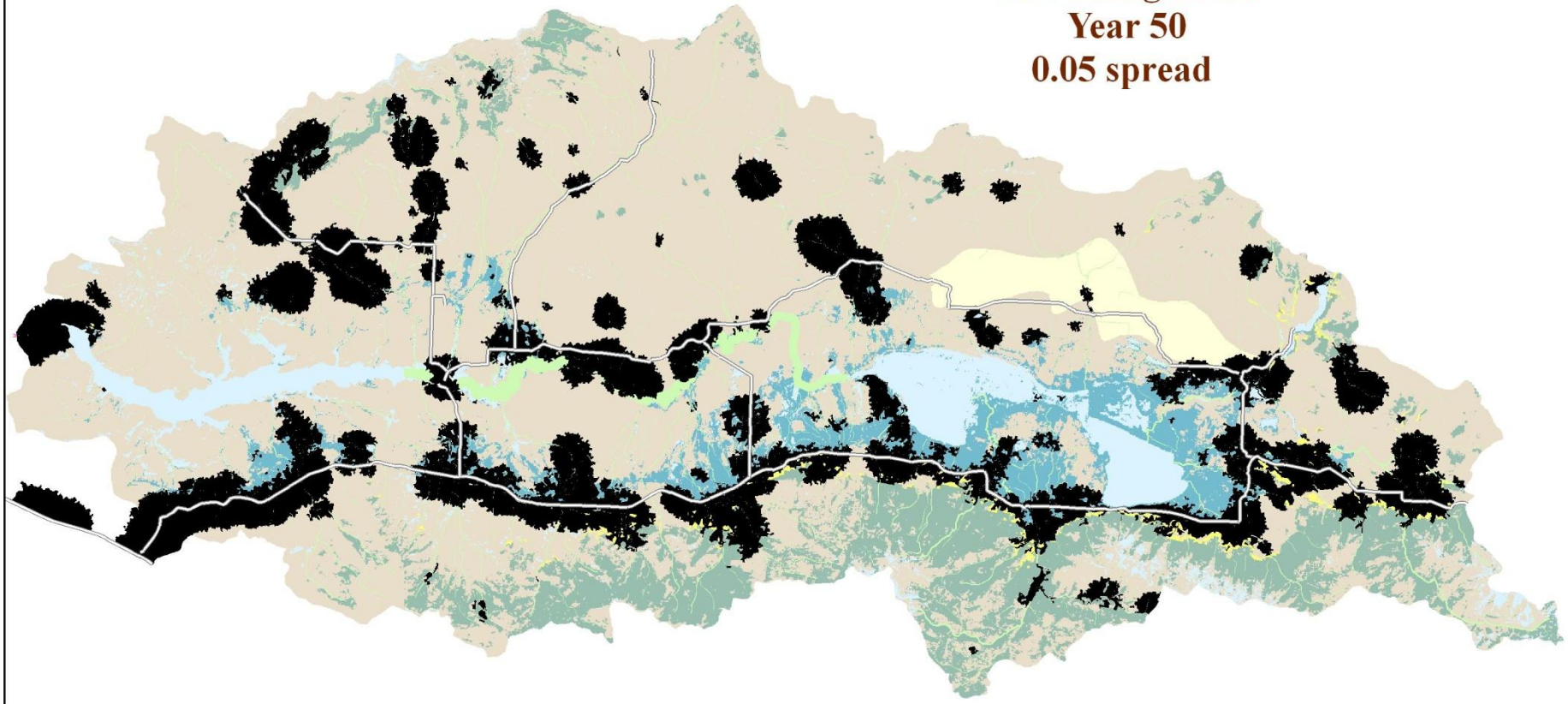
0 2.5 5 10 Kilometers

0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Initial & Established Knapweed
-- No Management --
Year 50
0.05 spread



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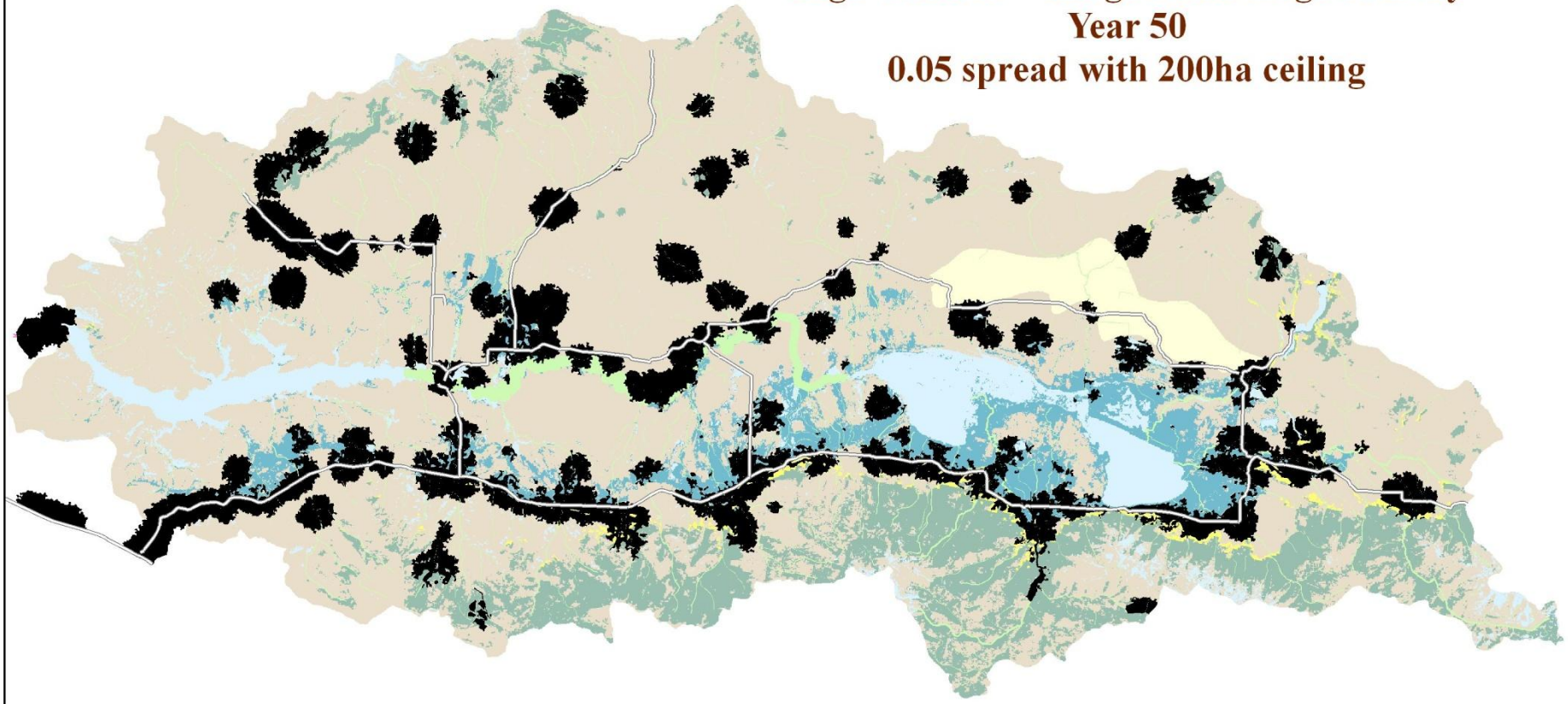
Centennial Valley - TELSA Weed Model

Seedbank, Initial & Established Knapweed
-- High Control -- Large Patch Edge Priority --
Year 50
0.05 spread with 200ha ceiling



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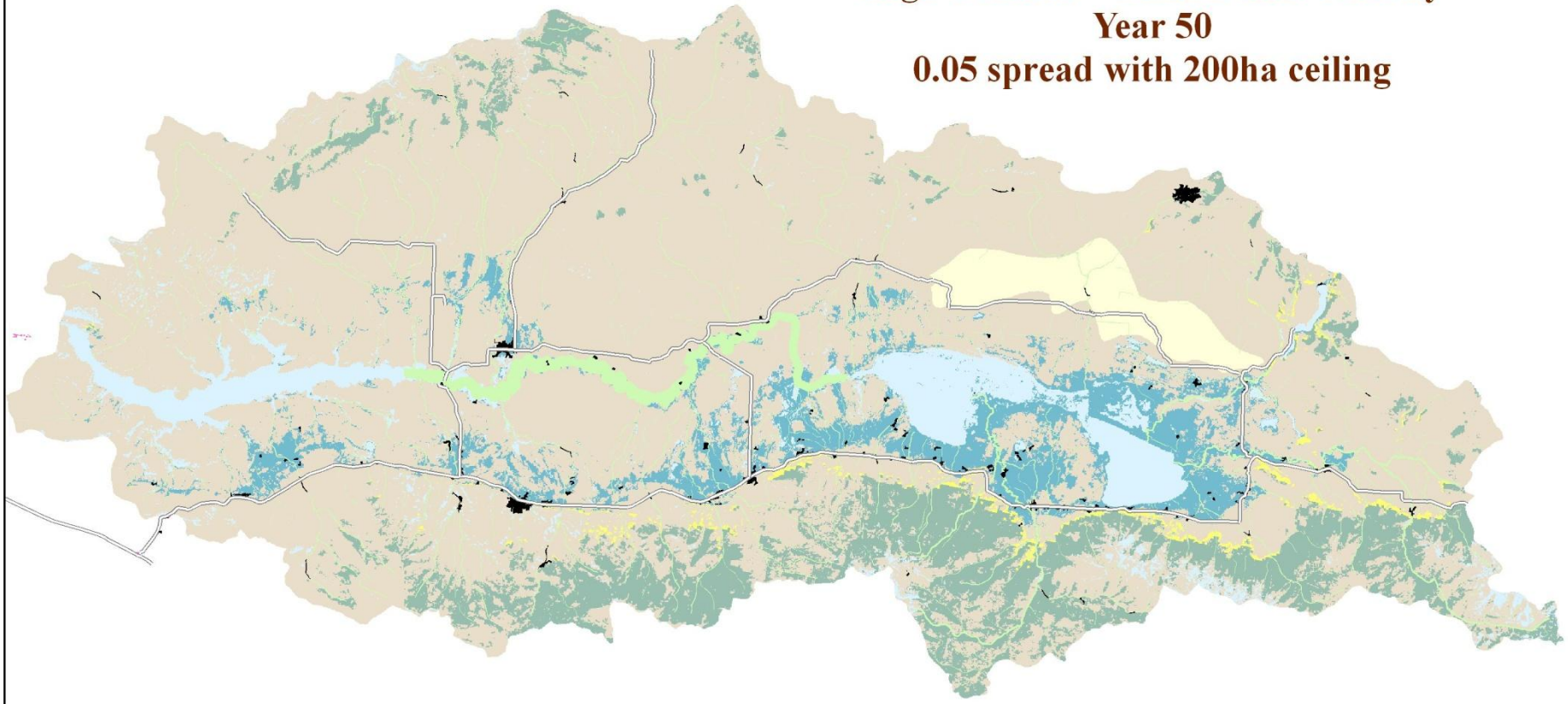
0 2.5 5 10 Kilometers

0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Seedbank, Initial & Established Knapweed
-- High Control -- Small Patch Priority --
Year 50
0.05 spread with 200ha ceiling



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- Conifer
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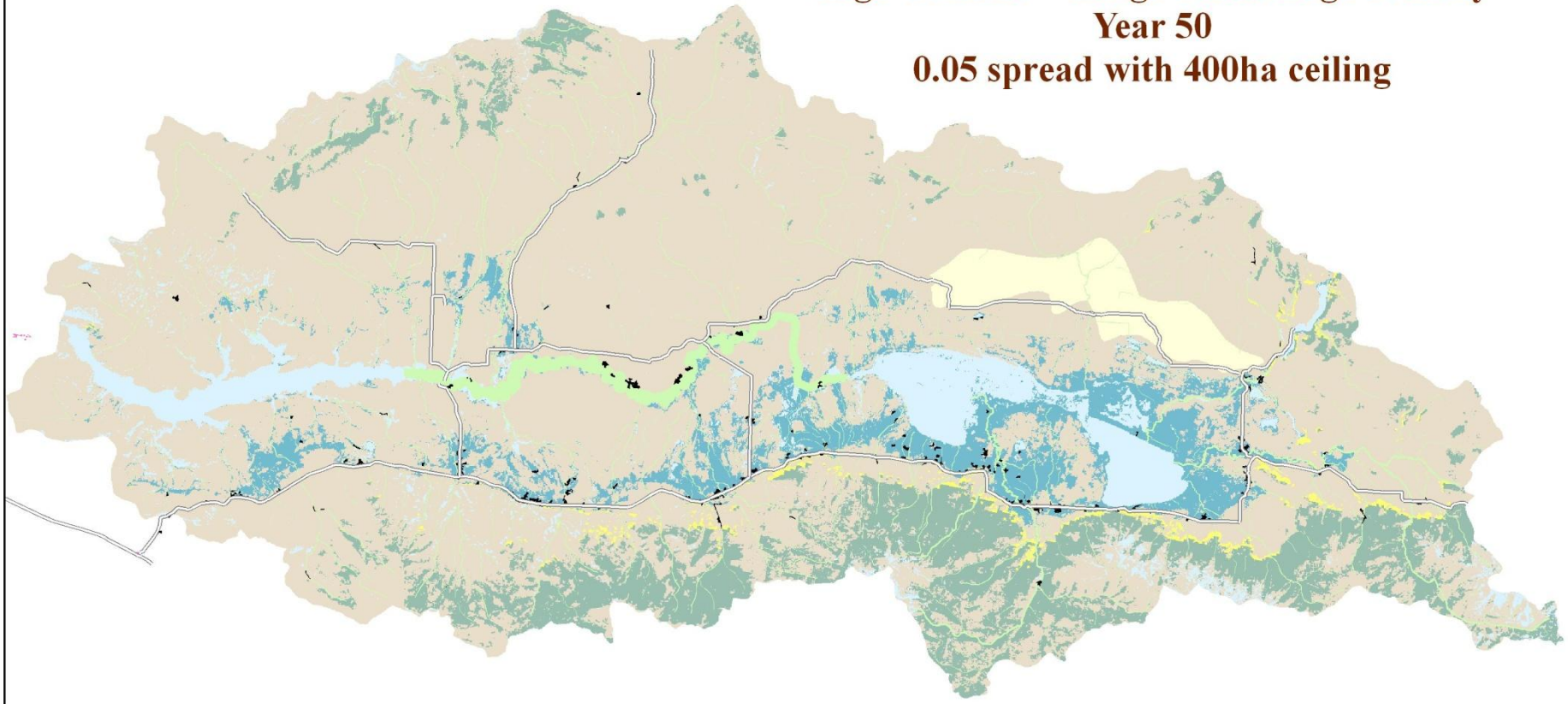
0 2.5 5 10 Kilometers

0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Seedbank & Initial Knapweed
-- High Control -- Large Patch Edge Priority --
Year 50
0.05 spread with 400ha ceiling



Potential Vegetation Types

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- Sandhills
- Water/Wetland
- Wet Meadow
- Aspen
- Riparian
- Conifer
- Unprojectable

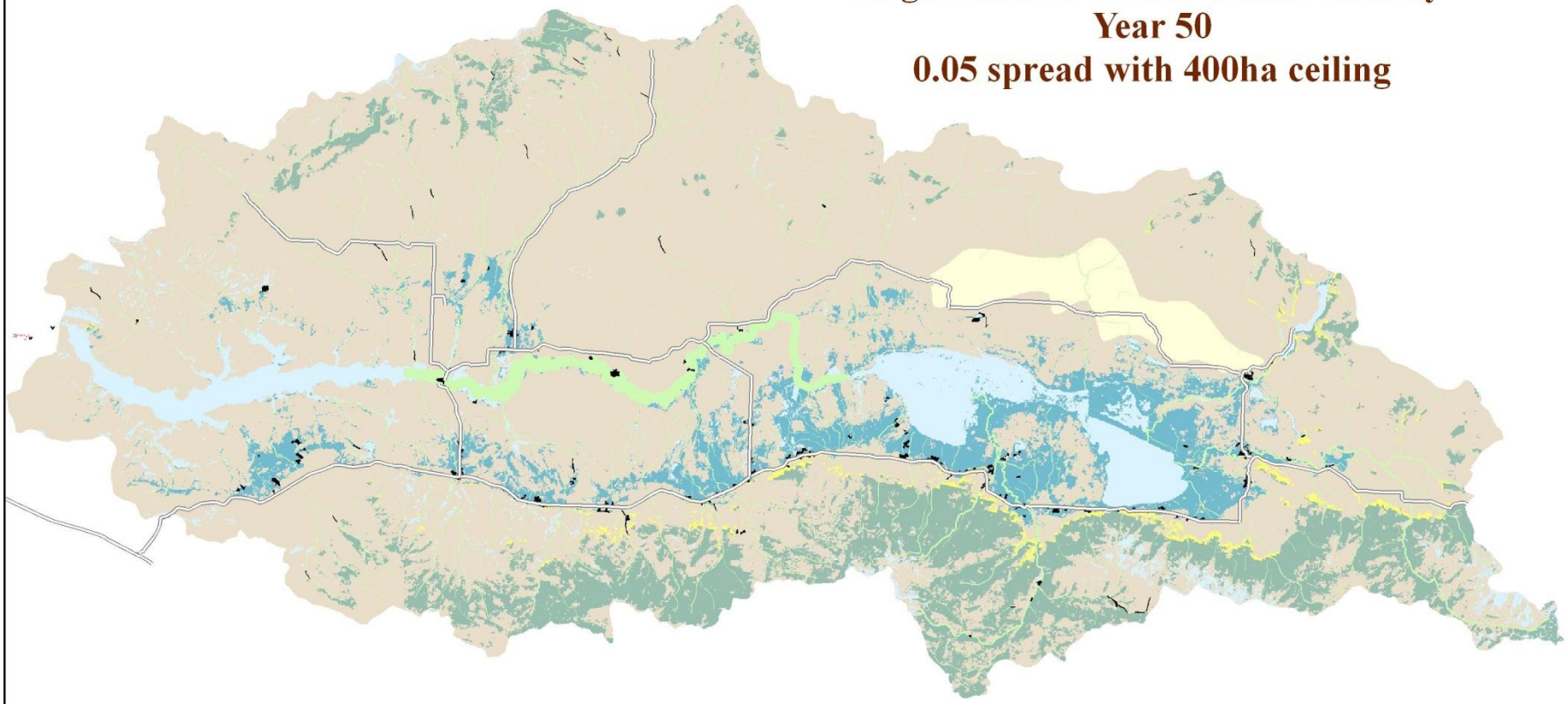
0 2.5 5 10 Kilometers

0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Seedbank & Initial Knapweed
-- High Control -- Small Patch Priority --
Year 50
0.05 spread with 400ha ceiling



Potential Vegetation Types

- Sagebrush
- Sandhills
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- Aspen
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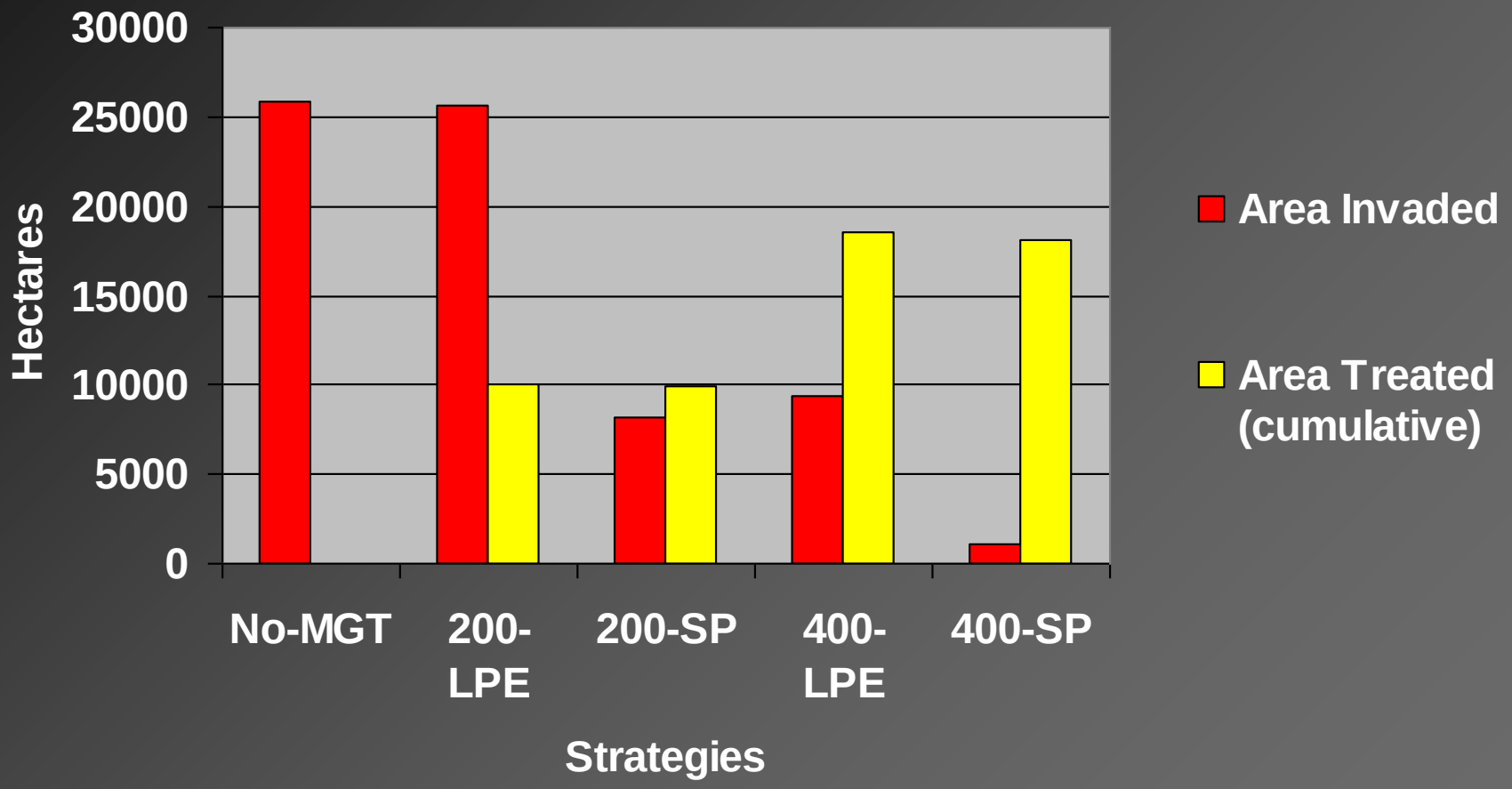
- Unprojectable

0 2.5 5 10 Kilometers

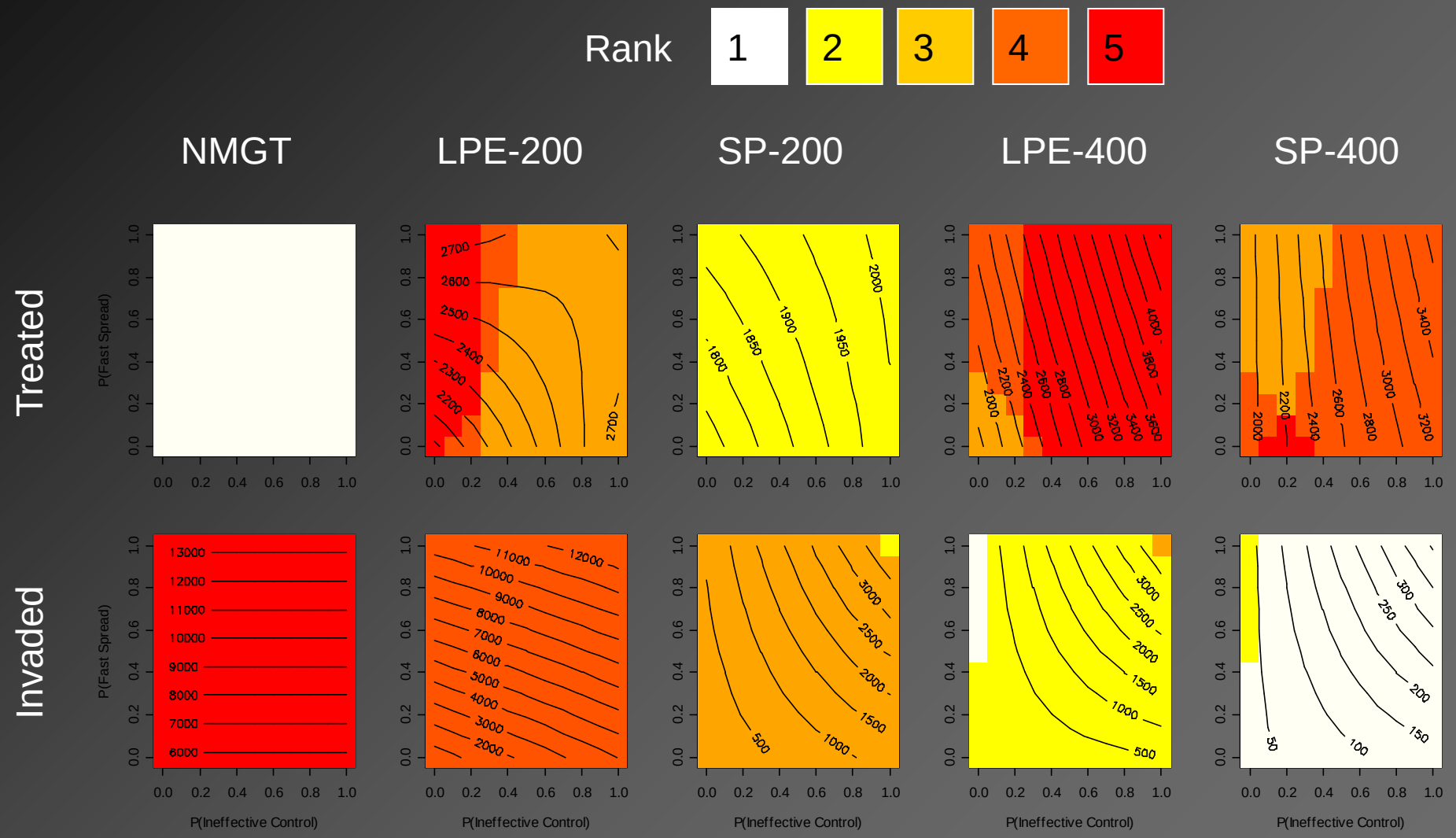
0 2.5 5 10 Miles

N

Area Invaded and Treated After 50 Years
Centennial Valley
Spotted Knapweed - High Spread/Low Control



Sensitivity Analysis: Area Invaded or Treated by Strategy After 50 Years



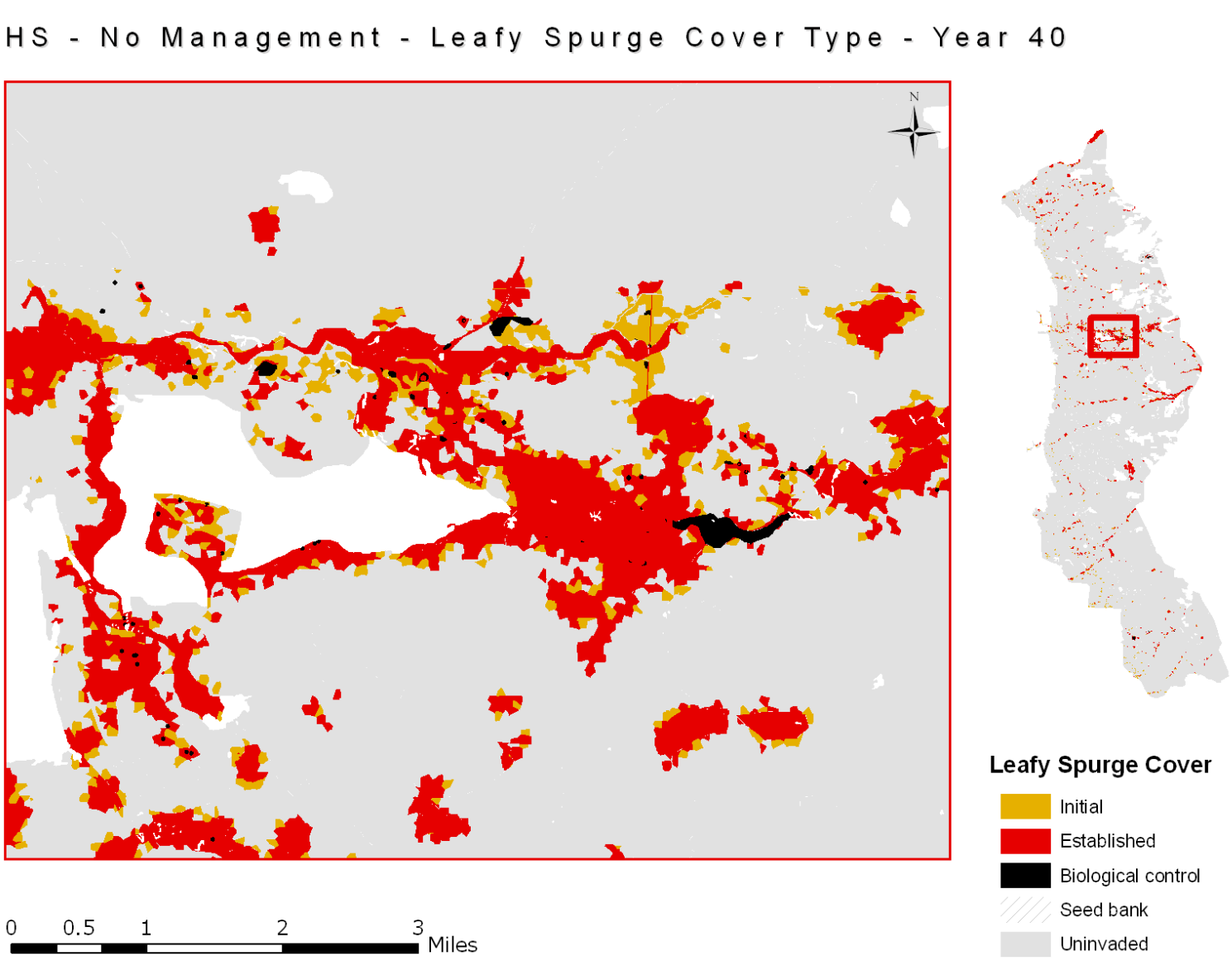
Initial Results - Centennial

- Early detection and control best strategy
- For relatively uninvaded landscape like Centennial maintaining weeds at less than 1% of landscape with annual treatments of 0.2% of landscape a reasonable goal
- Consistency of effort over time more important than quality of effort
- Waiting to implement management greatly increases required long-term management effort

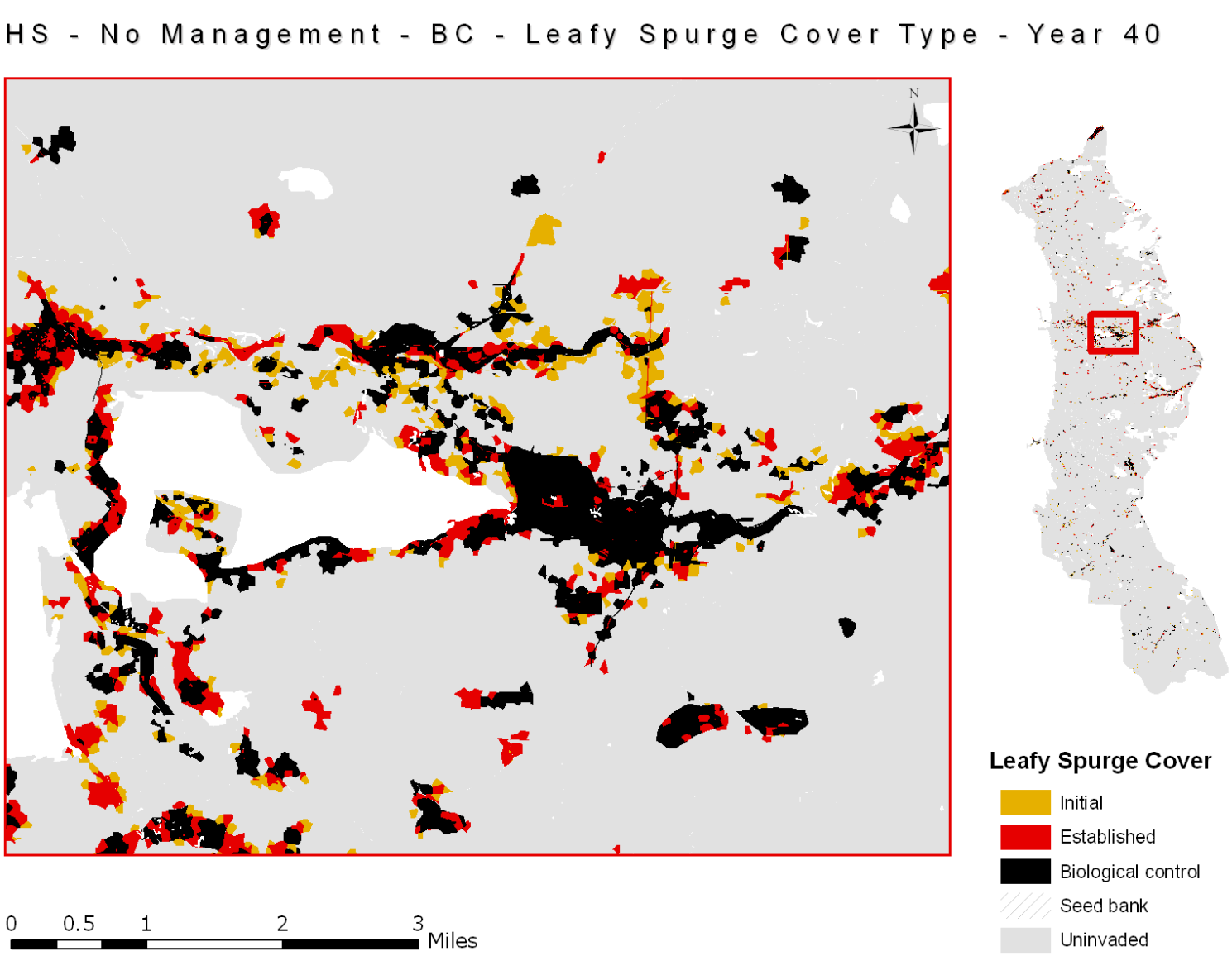
Initial Results - RMF

- Doing nothing = 5-10x more weeds in 40 years
- Treating only small patches and edges of large patches just as effective as treating everything but at less cost
- Highly susceptible habitats are (like gravel riparian) are tough to manage – either already invaded to likely to become so
- Can stay ahead of weeds in other vegetation types
- Consistent management across landscape is important (20% non-participation doubles the amount of weeds)

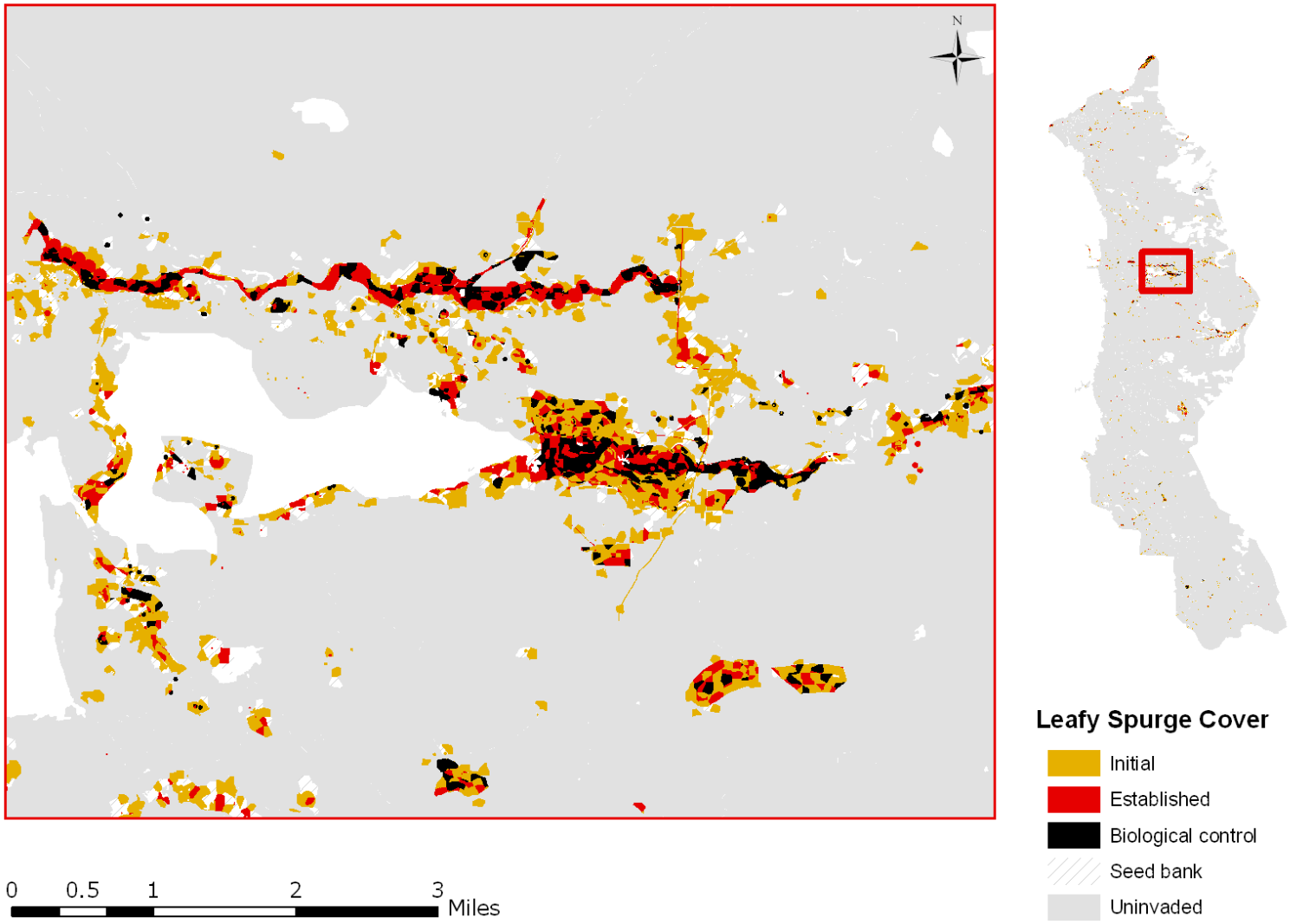
No Management – No Biocontrol



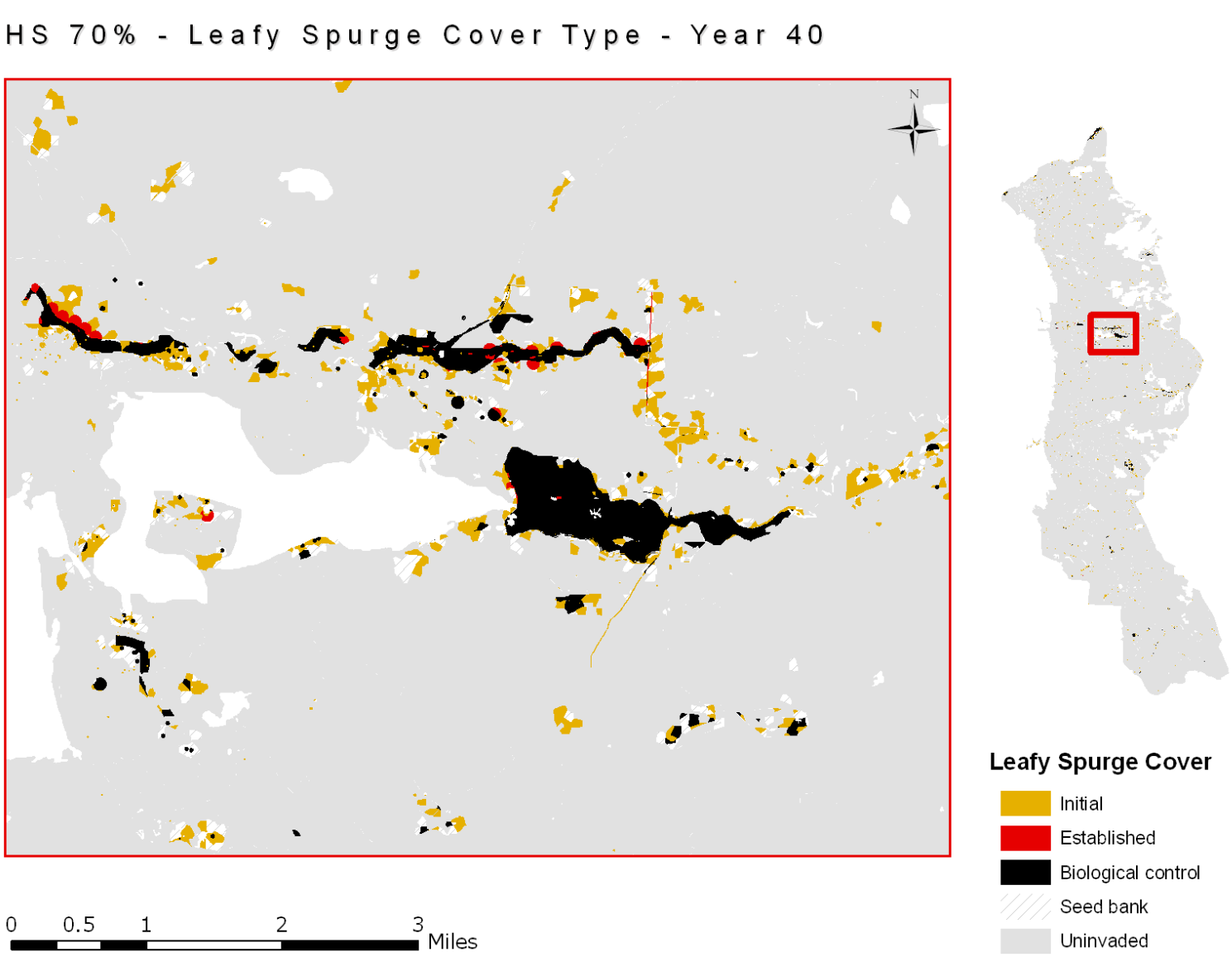
No Management except Biocontrol



Chemical Management – No Biocontrol



Chemical Management and Biocontrol



Initial Results - Biocontrol

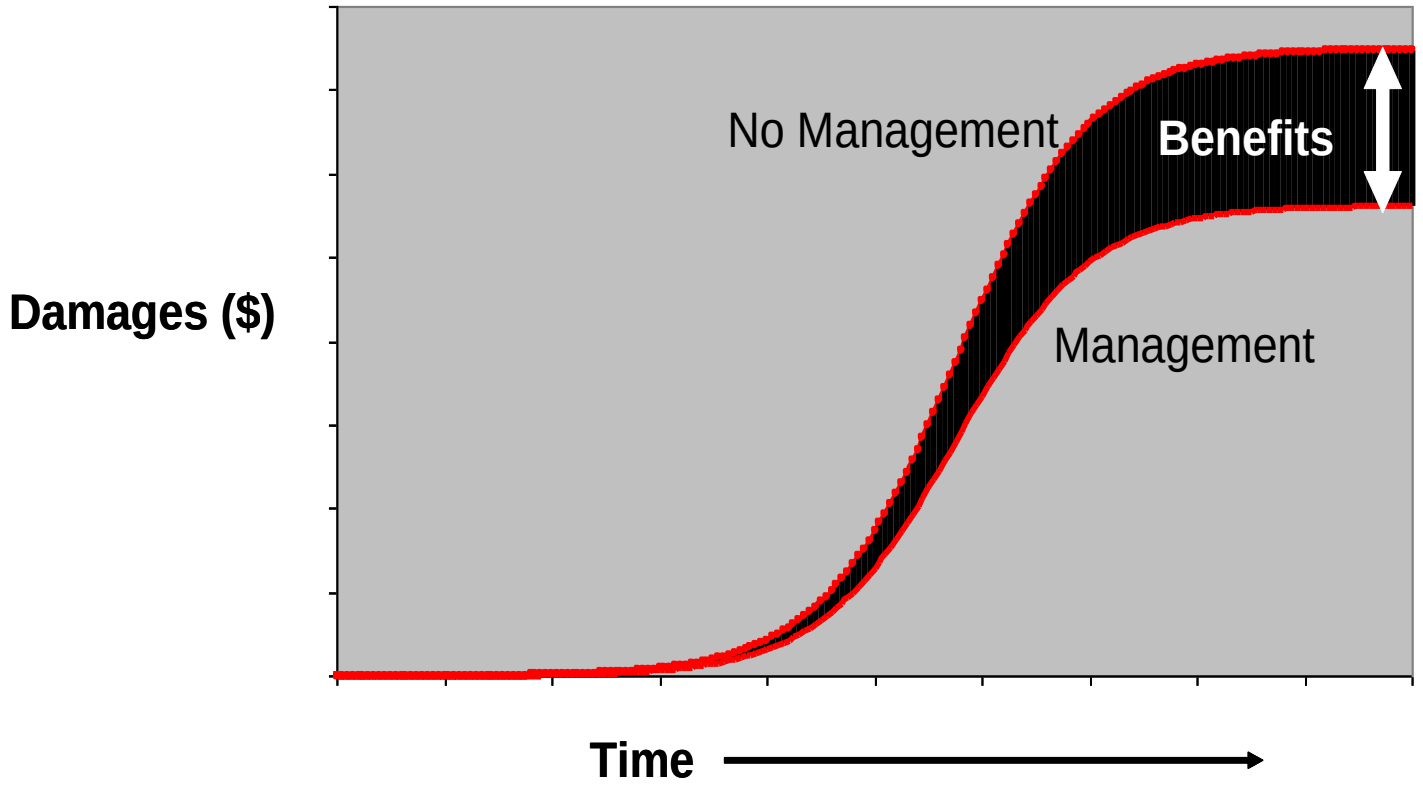
- **Biocontrol is a key component of integrated management, especially within landscapes with large infestations where chemical control is not cost effective**

- **Integration of biocontrol into management program can reduce area invaded by 1/3 at ½ the cost of chemical only management**

Measures

- **What is most effective strategy?**
  - **Total Area Invaded**
  - **Cumulative area treated**
- **Economic analysis**
  - **Treatment cost**
  - **Grazing value**

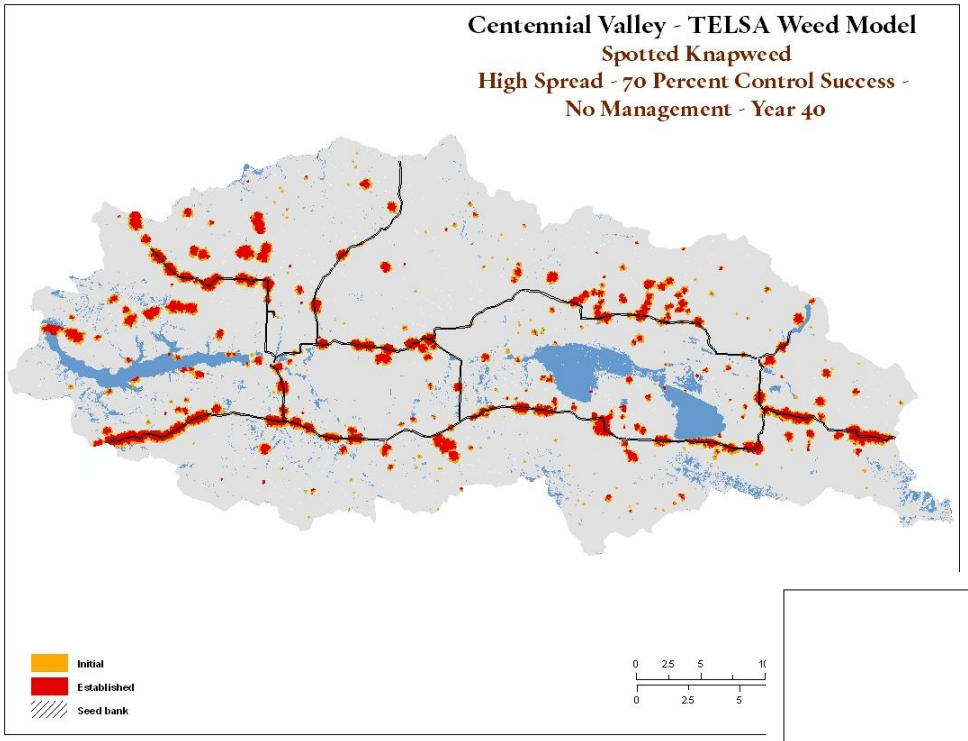
Estimating Economic Benefits and Costs

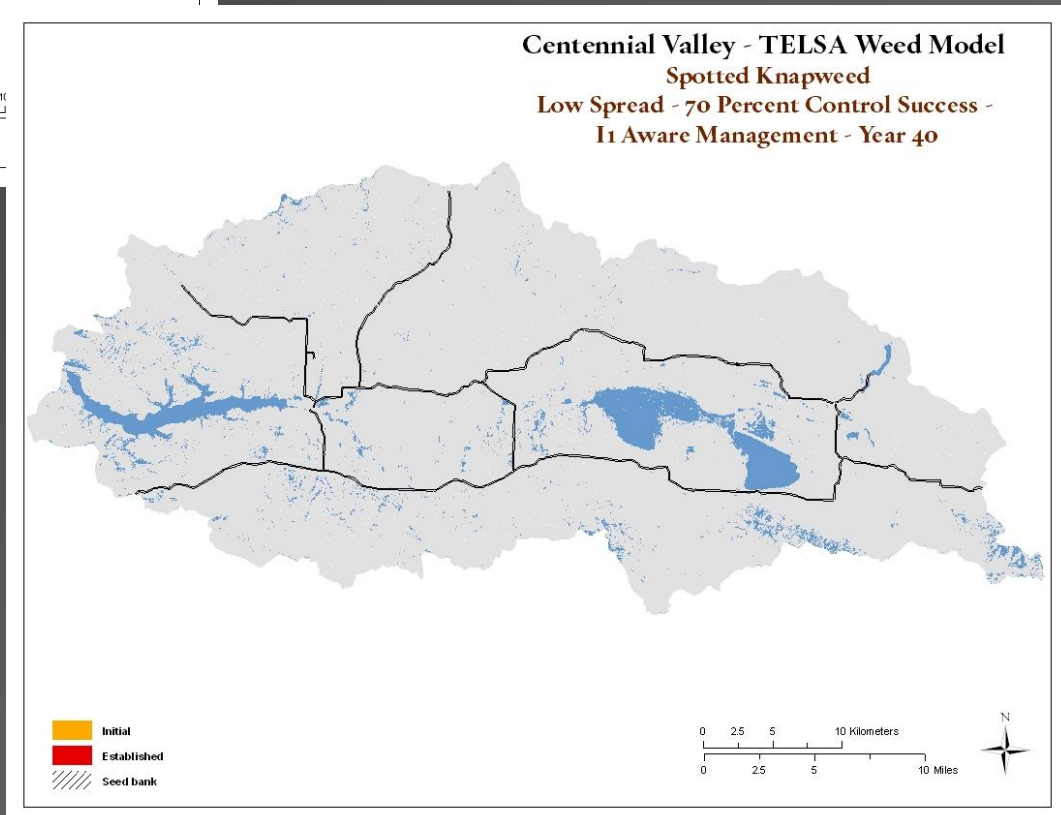


- Only single direct costs considered: ranching
- No indirect costs or non-use values included
- NPV = Benefits – treatments costs
- Results in 2008 dollars using a 2.7% discount rate

Economic Inputs

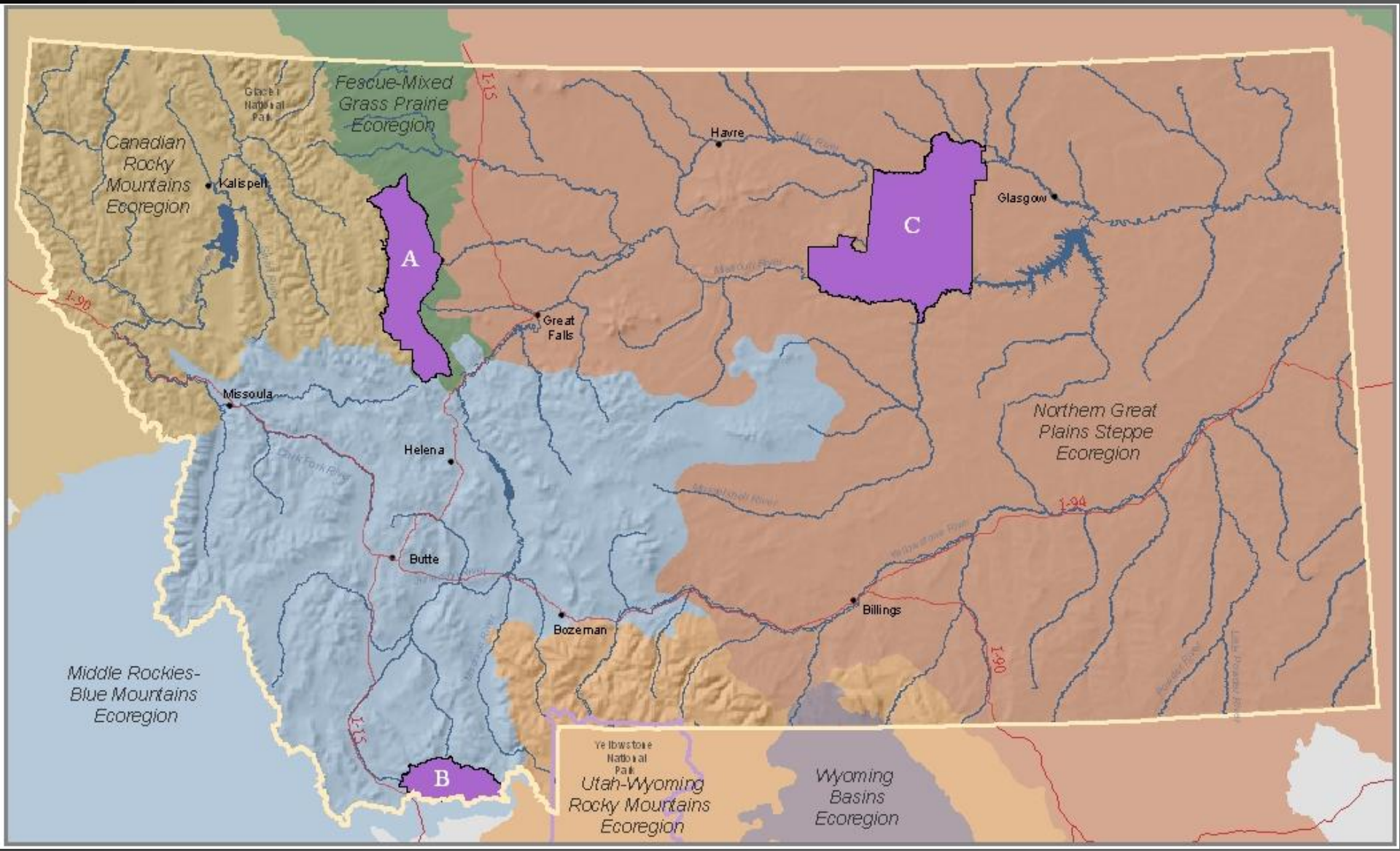
- **Grazing Value:**
  - Average AUM rate for 2008 - $18.10
  - Carrying Capacity from NRCS county estimates (RMF – 0.26, CV – 0.28, MGP – 0.21)
- **Treatment costs:**
  - Established - $40/acre
  - Initial 2 - $85/acre
  - Initial 1 - $225/acre
- **Discount rate: 2.7%**


Centennial Valley - TELSA Weed Model
Spotted Knapweed
High Spread - 70 Percent Control Success -
No Management - Year 40
Initial
Established
Seed bank
0 2.5 5
0 2.5 5


Centennial Valley - TELSA Weed Model
Spotted Knapweed
Low Spread - 70 Percent Control Success -
I1 Aware Management - Year 40
Initial
Established
Seed bank
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles
N

Management Scenarios

- **Standard – Small patch priority, 70% treatment success rates**
  - **Range of treatment ceilings**
- **Large patch priority**
- **I1 Aware**
- **95% treatment success**
- **Roaming**


Fescue-Mixed Grass Prairie Ecoregion
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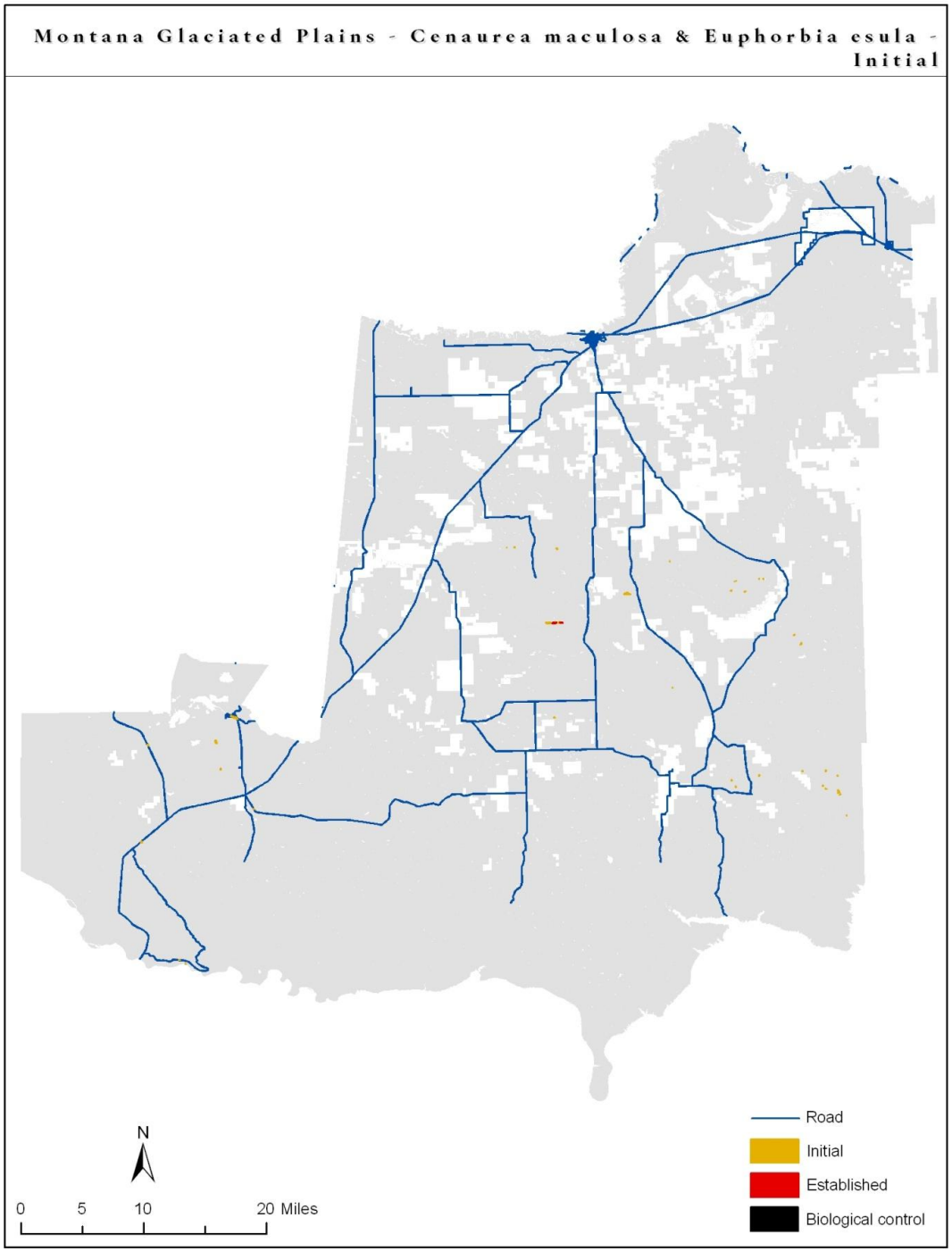
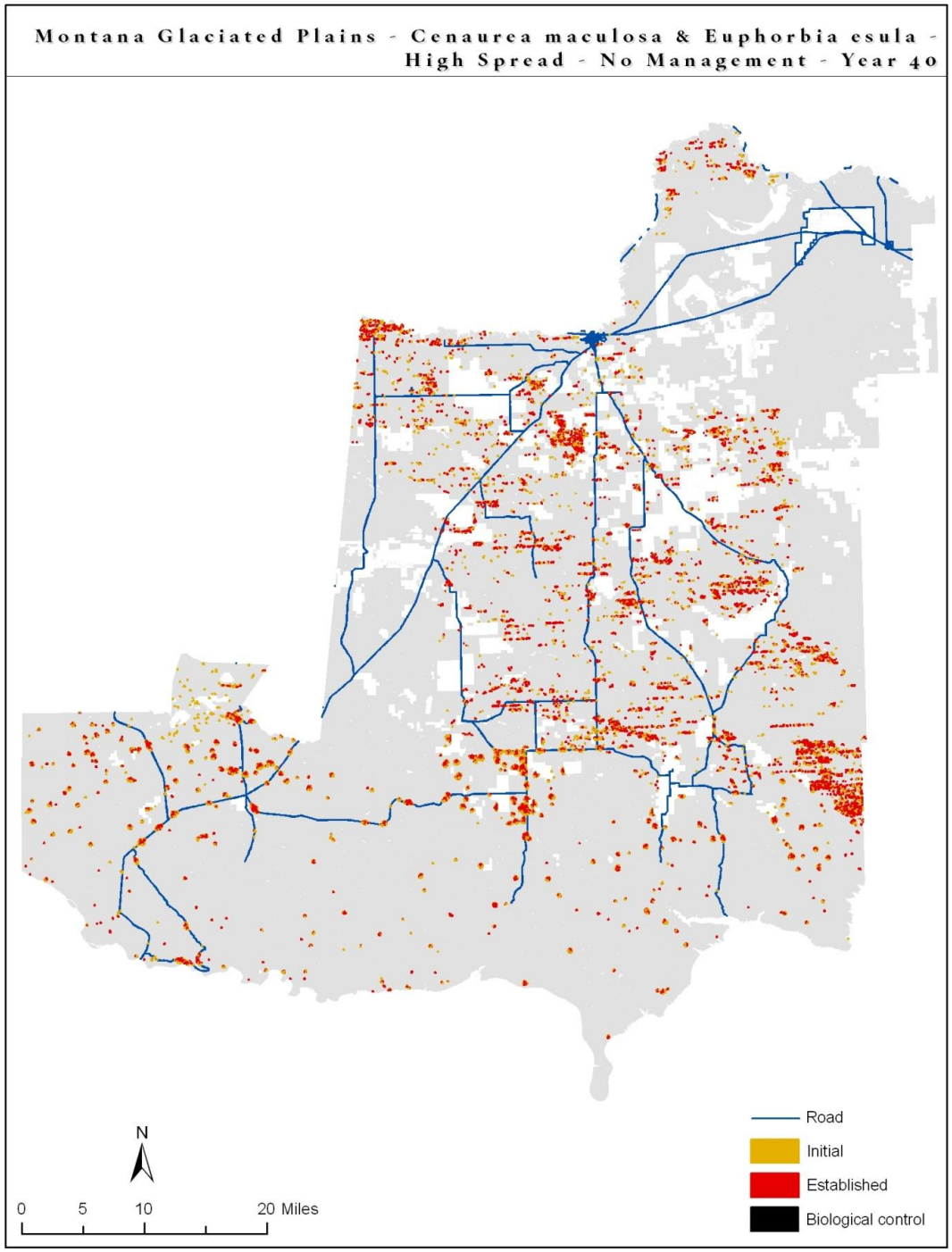
Wyoming Basins Ecoregion
B
I-15
I-90
I-94

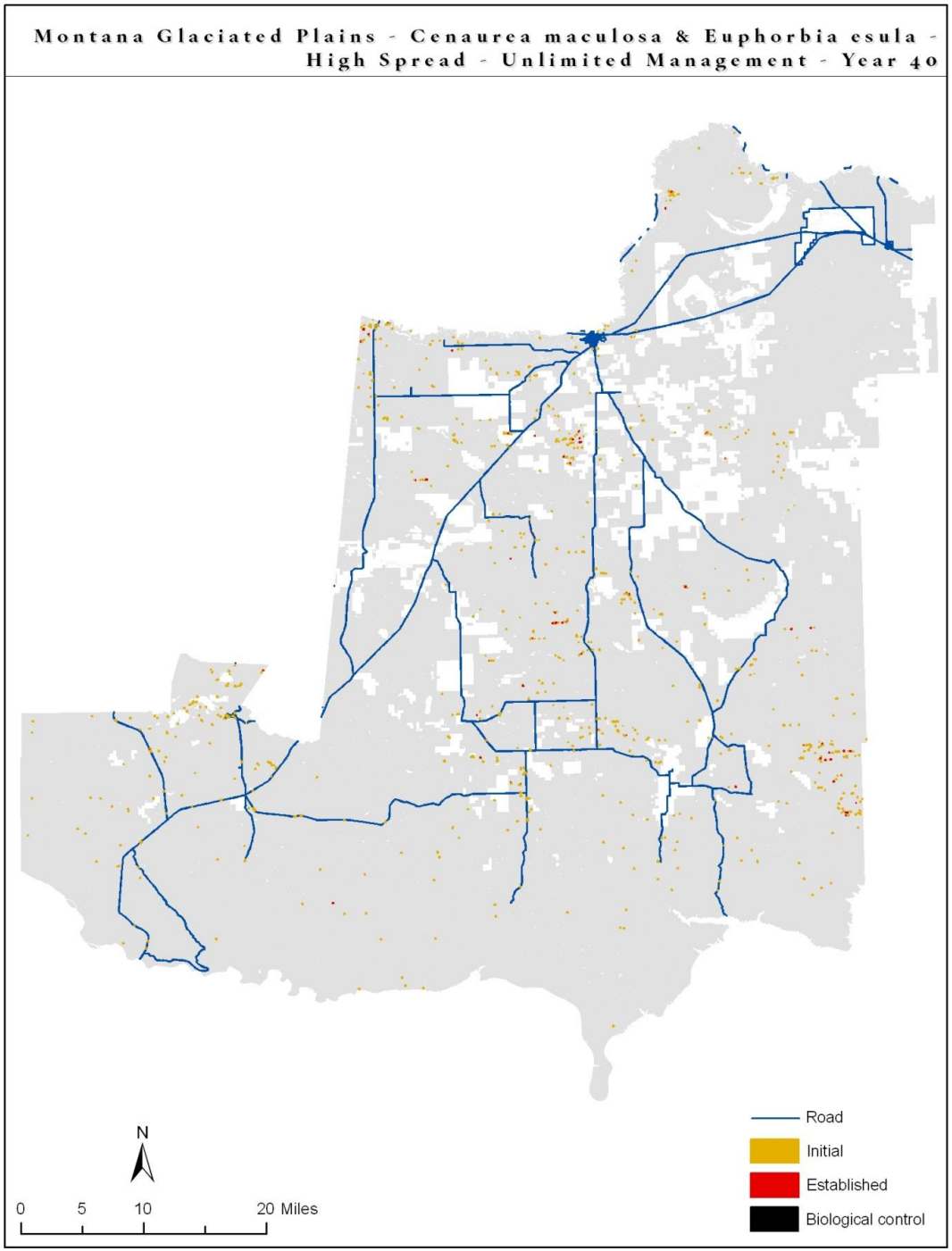
MGP Results

Strategy	Area Invaded (ha)		Area Treated (ha)	
Spread Rate	High	Low	High	Low
No Management	6,050	3,150	0	0
Unlimited Management	61	49	2,155	1,733

Spread Rate	Discount Rate	NPV (2008 $)	BCR
High	2.7%	86,424	1.51
Low	2.7%	944	1.00

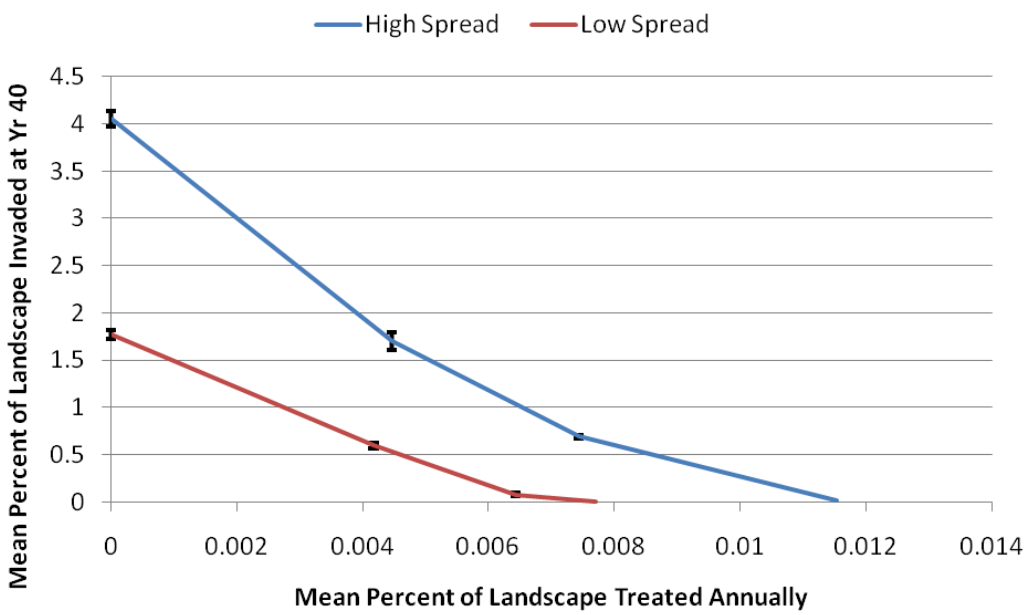

Montana Glaciated Plains - Cenaurea maculosa & Euphorbia esula - Initial
N
0
5
10
20 Miles
Road
Initial
Established
Biological control


Montana Glaciated Plains - Cenaurea maculosa & Euphorbia esula - High Spread - No Management - Year 40
N
0 5 10 20 Miles
Road
Initial
Established
Biological control

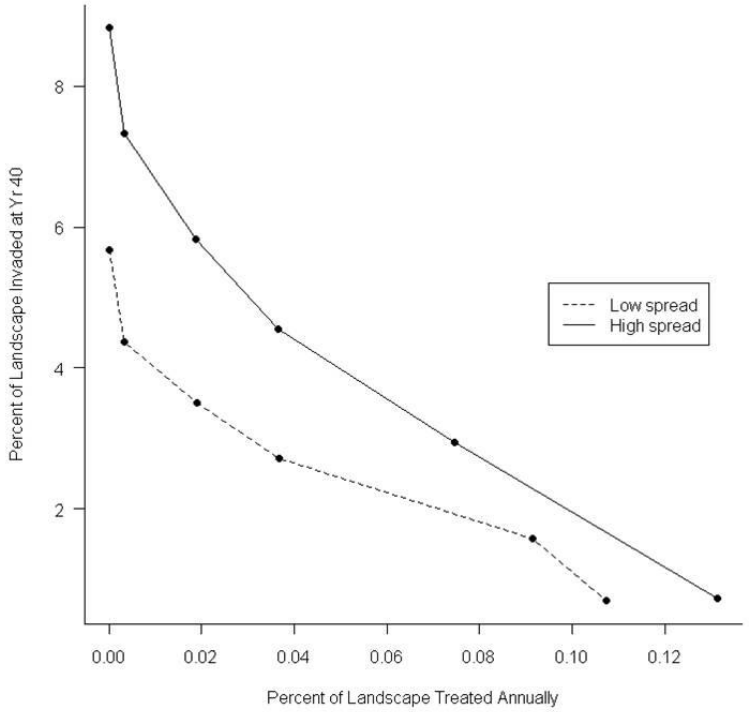

Montana Glaciated Plains - Cenaurea maculosa & Euphorbia esula -
High Spread - Unlimited Management - Year 40
N
0 5 10 20 Miles
Road
Initial
Established
Biological control

Effects of Management on Weed Distribution at Year 40

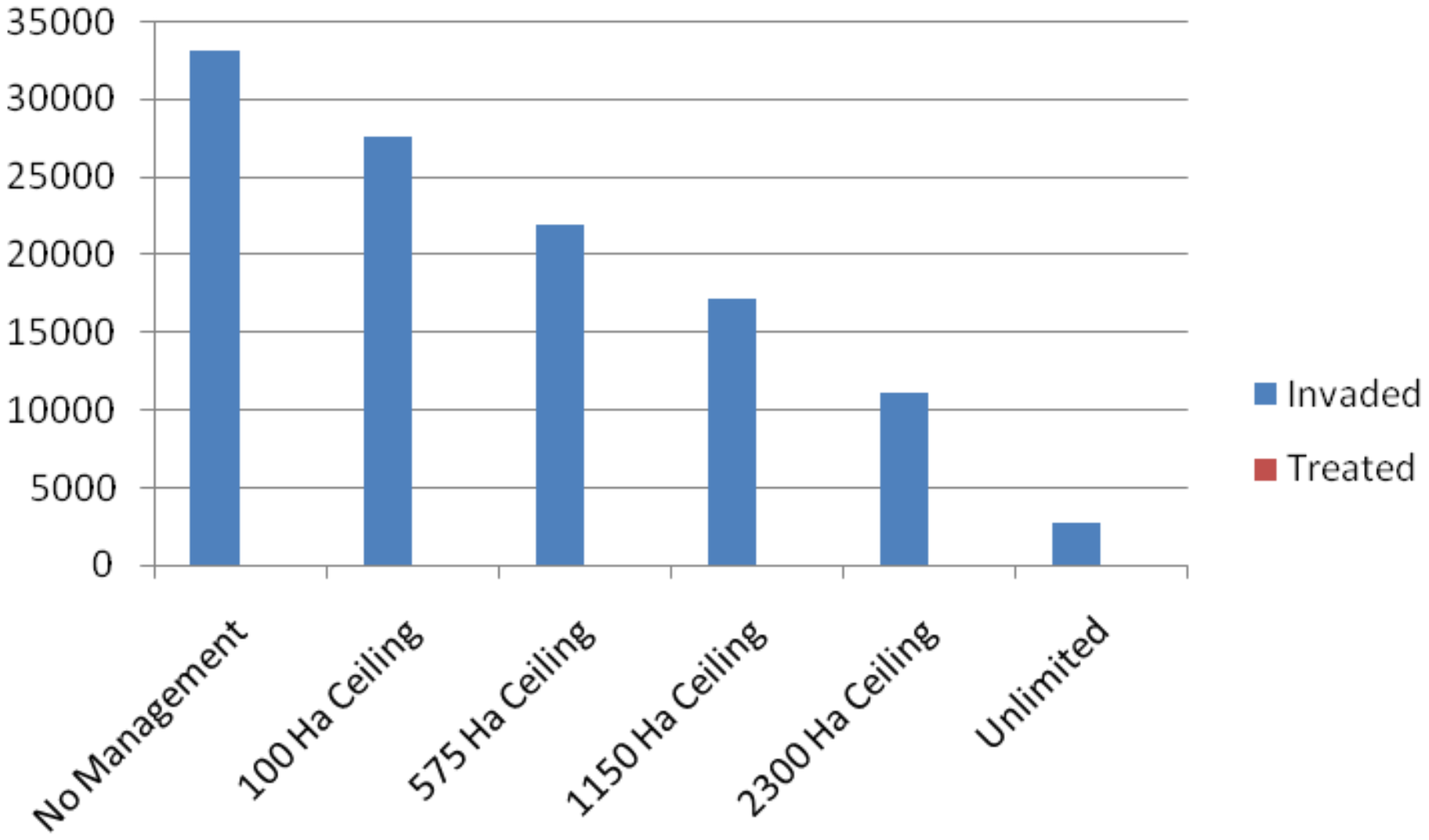
Centennial Valley



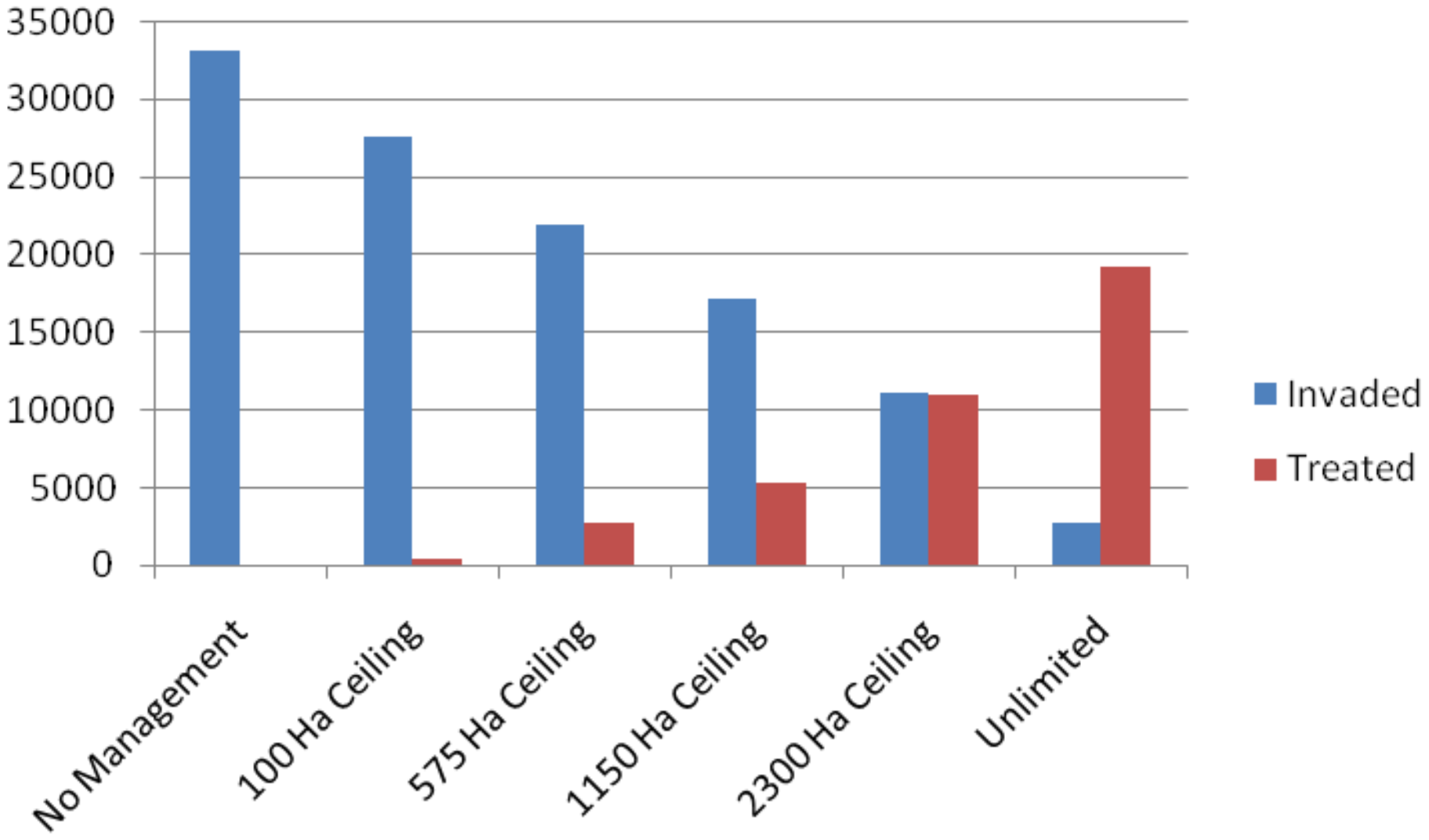
Rocky Mountain Front



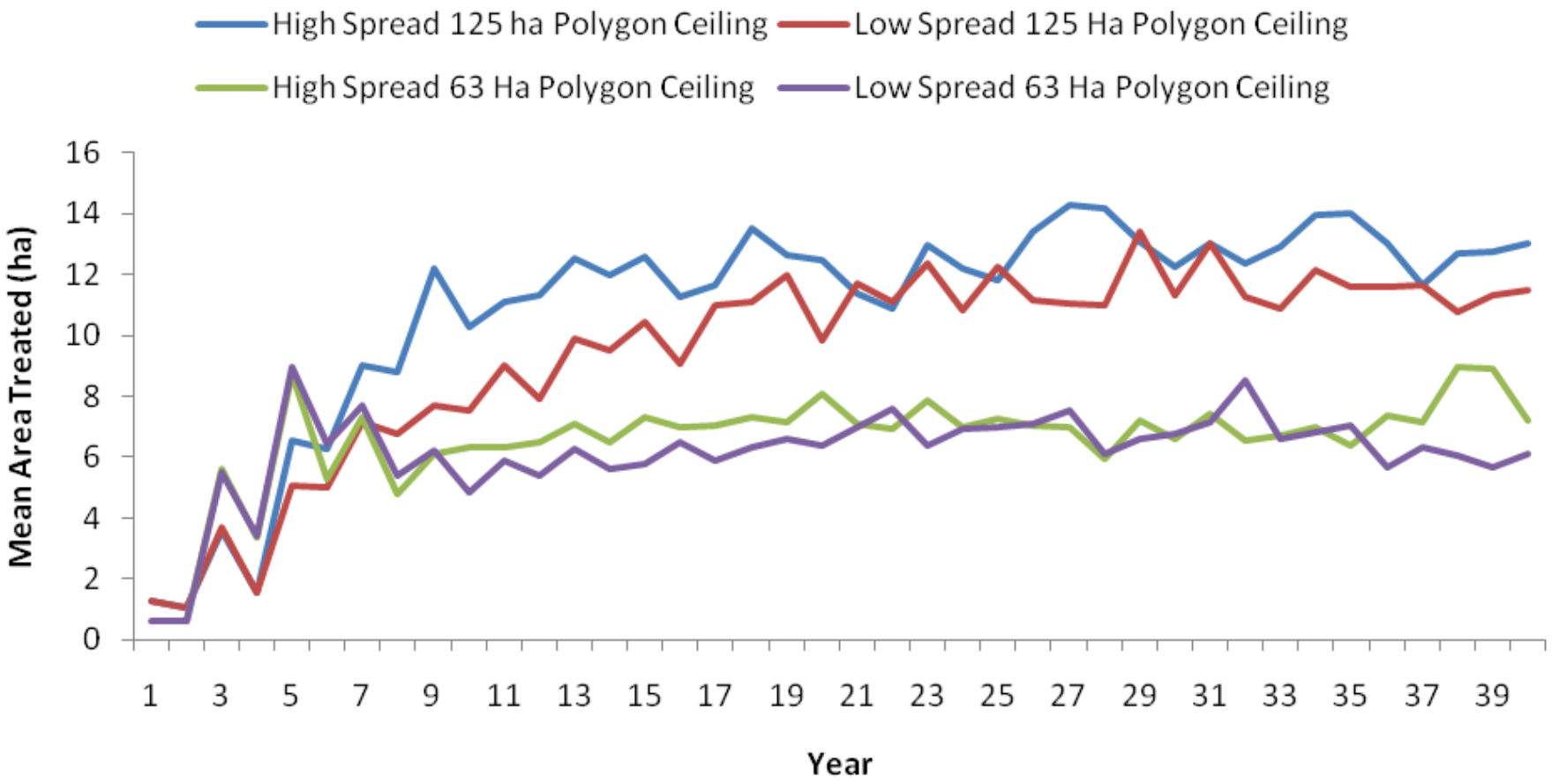
RMF Area Invaded by Treatment Ceiling



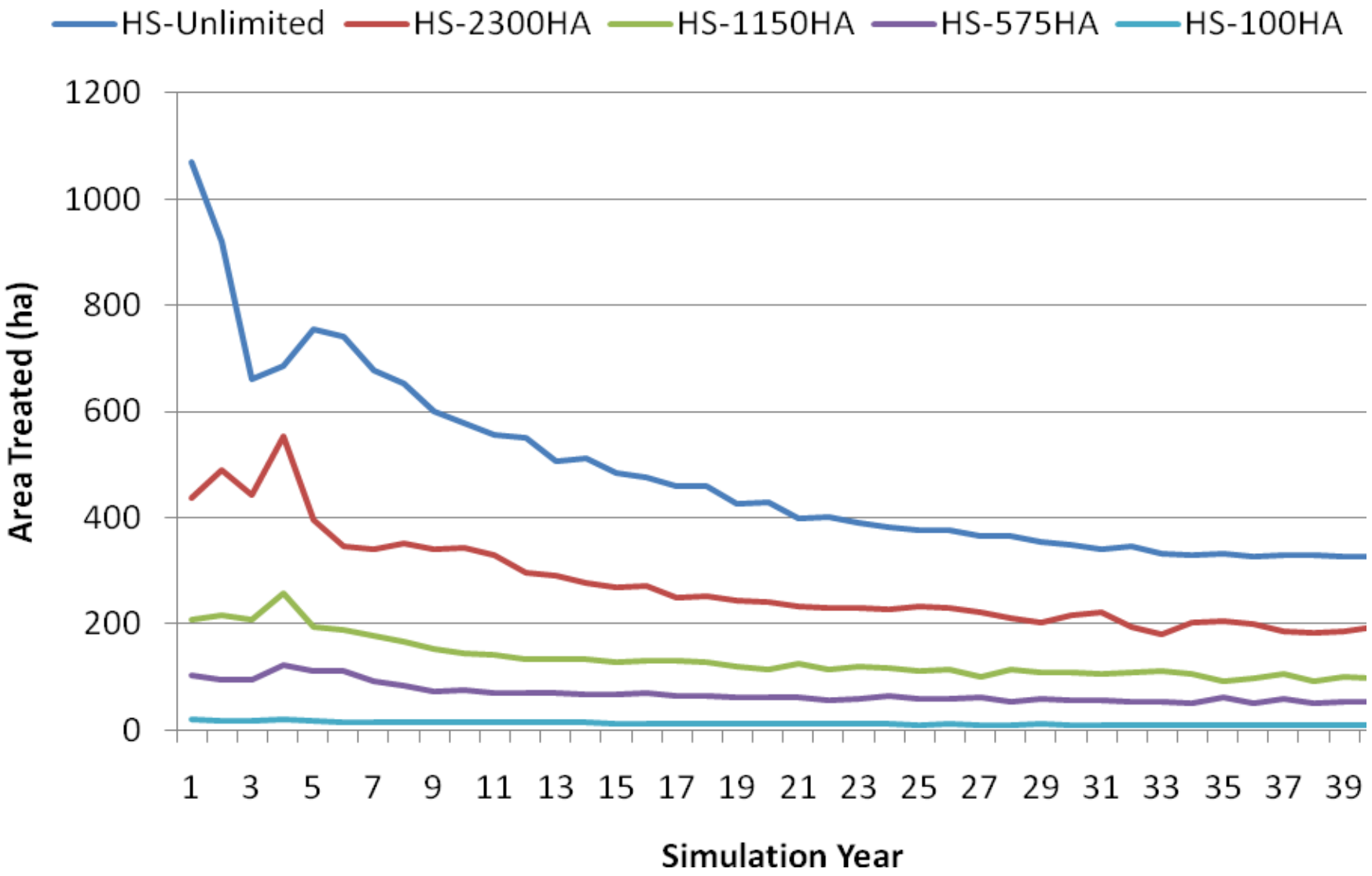
RMF Area Invaded and Treated by Treatment Ceiling



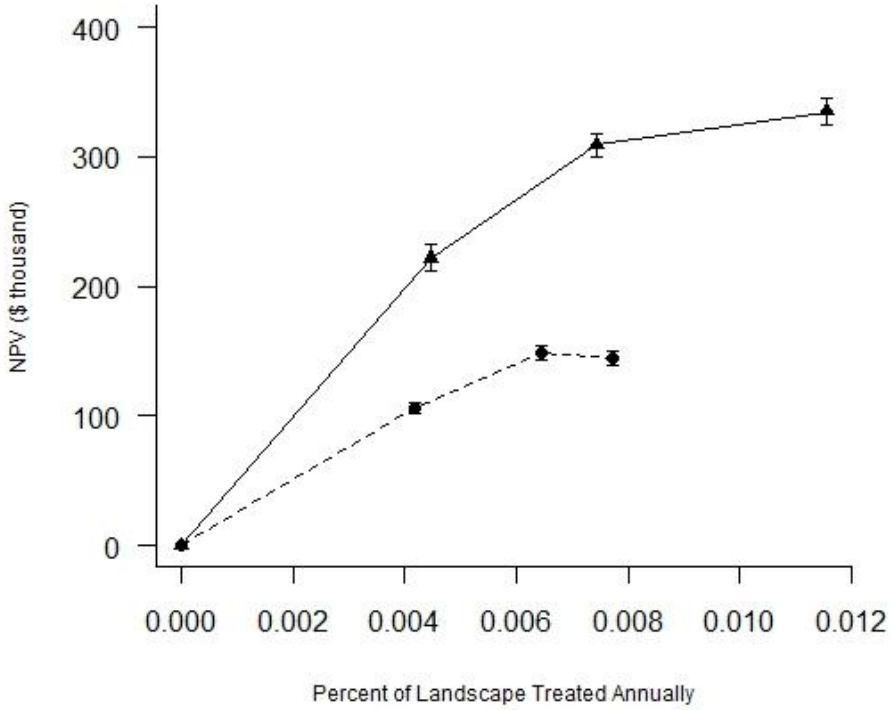
CV Treatment over Time, High Spread Scenarios

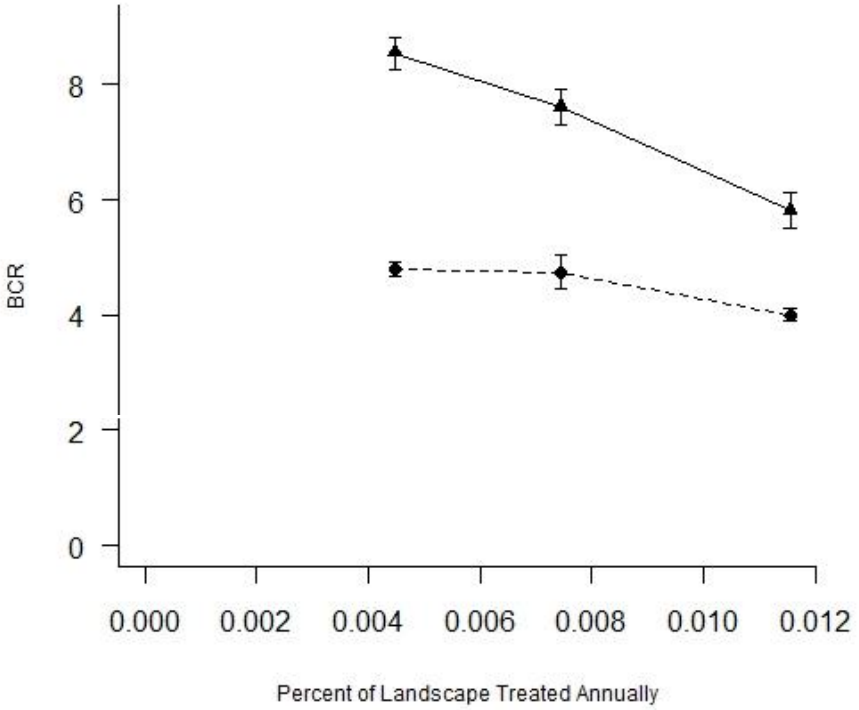


RMF Treatment over Time, High Spread Scenarios



CV Net Present Value and Benefit-cost Ratio (±SE) by Mean % of Landscape Treated Annually

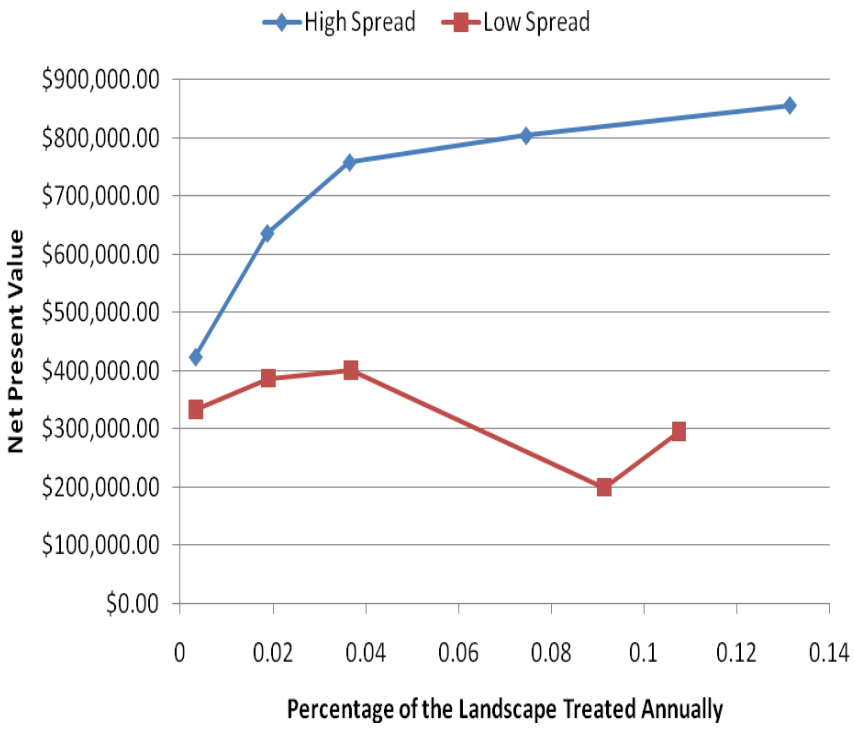


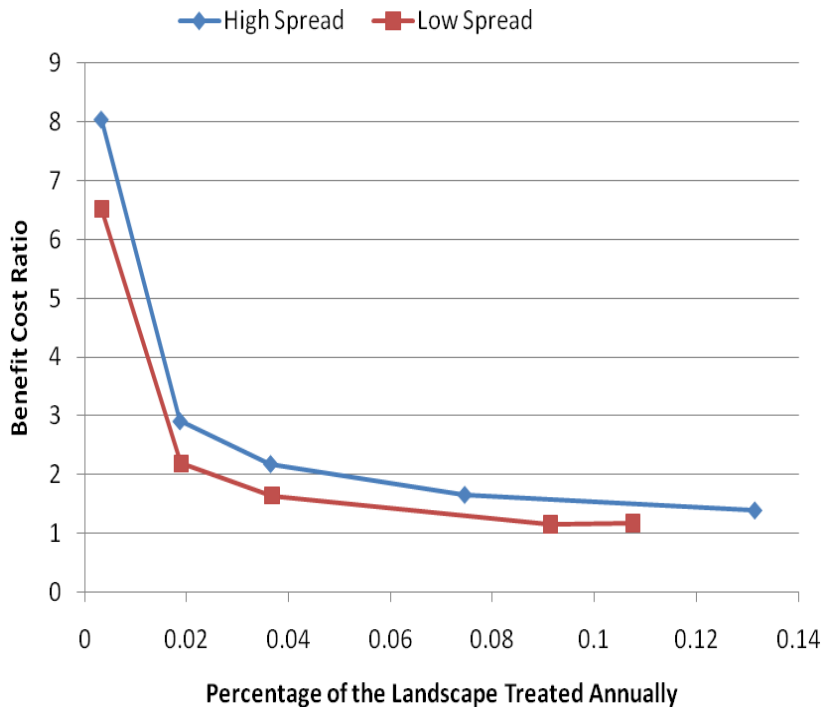


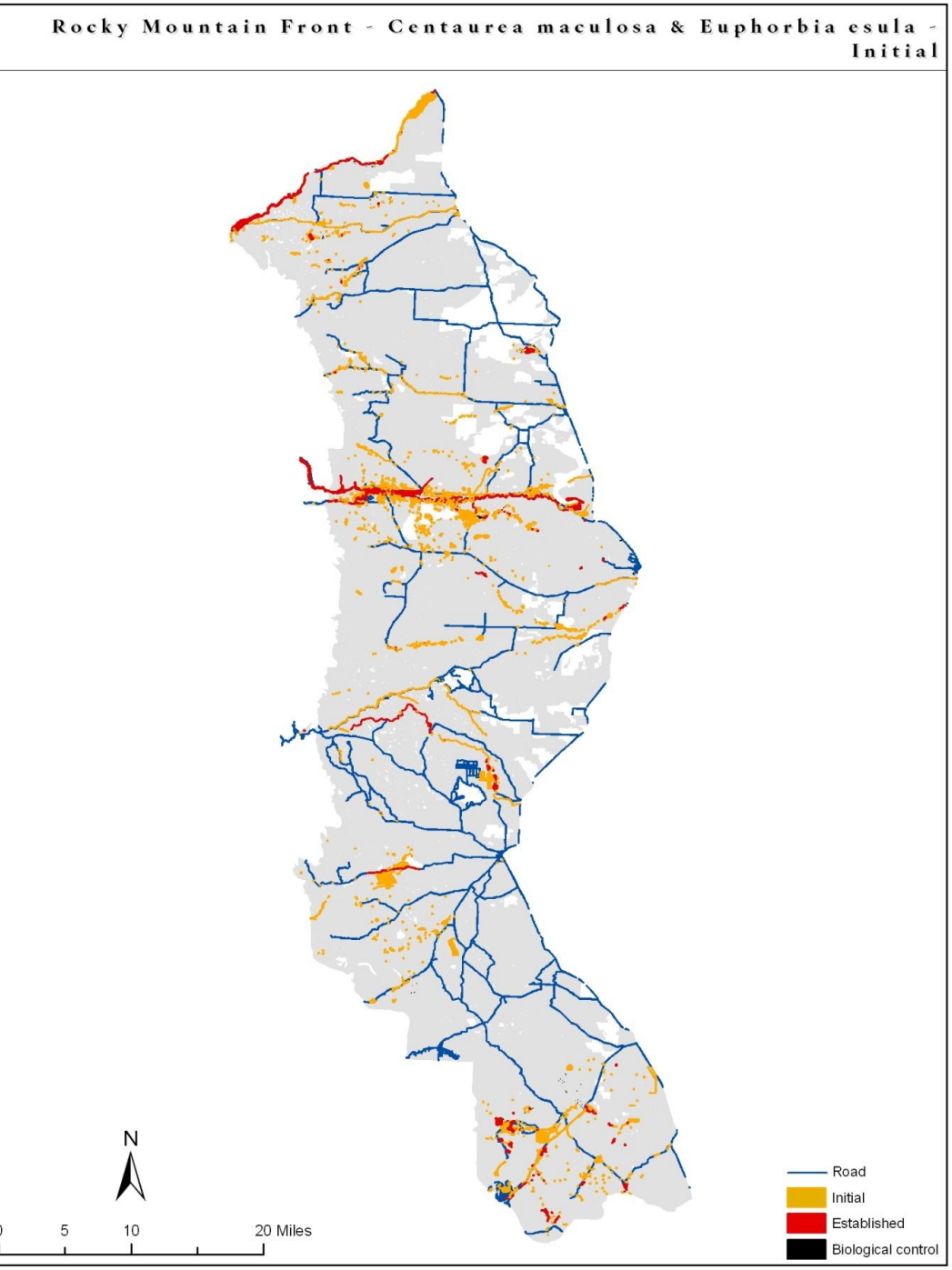
Weed Spread Rate

High ▲ Low ●

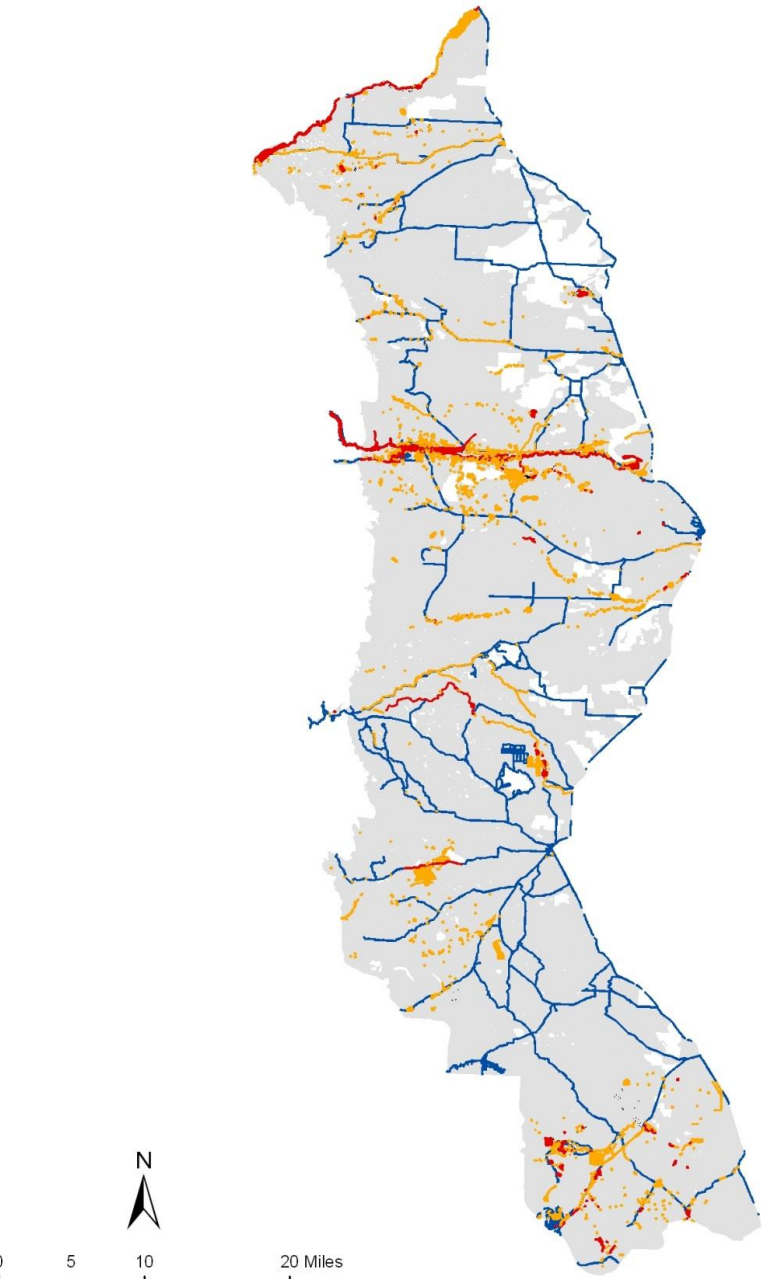
RMF
Net Present Value and Benefit Cost Ratio



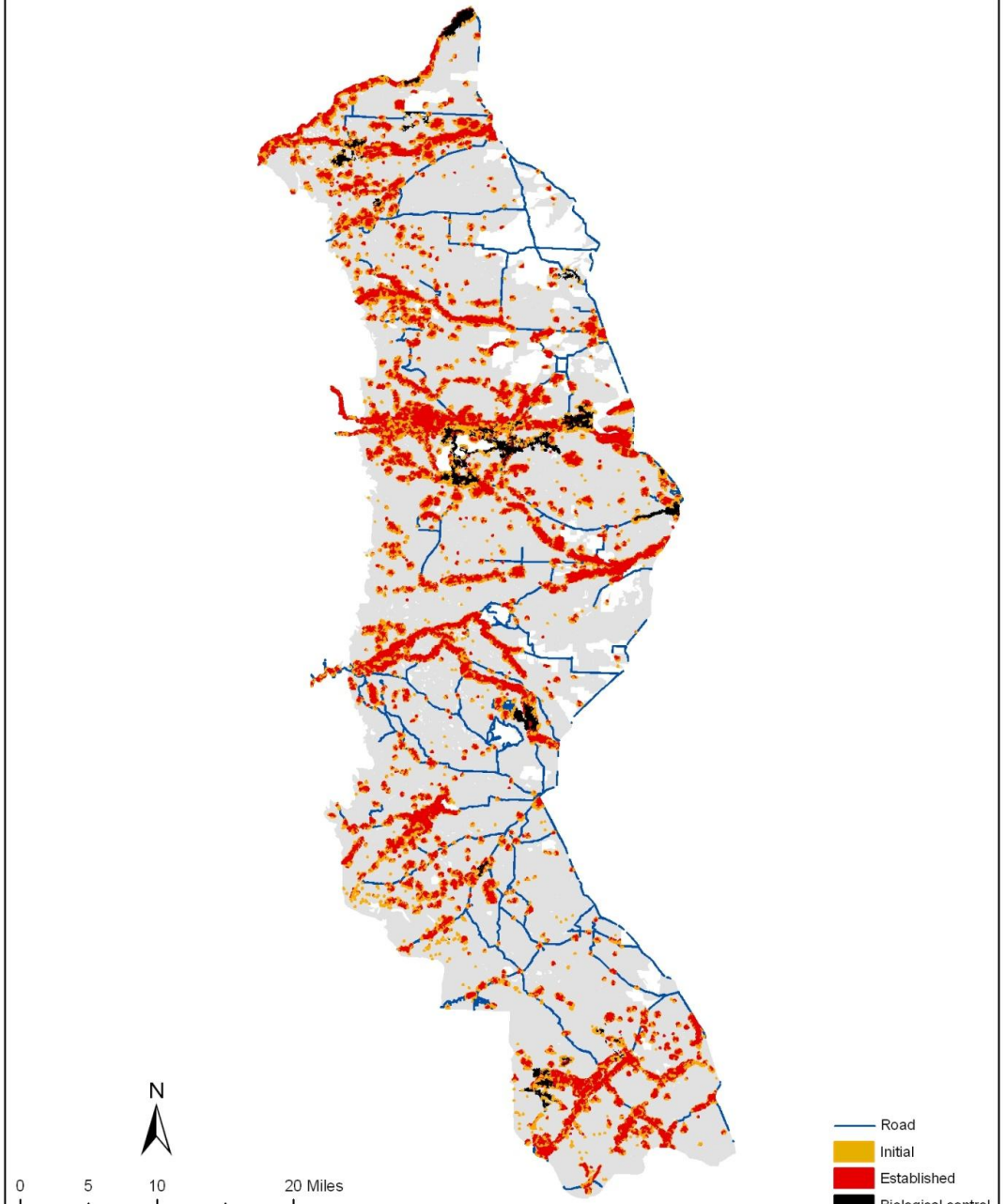



Rocky Mountain Front - Centaurea maculosa & Euphorbia esula - Initial
N
5
10
20 Miles
Road
Initial
Established
Biological control

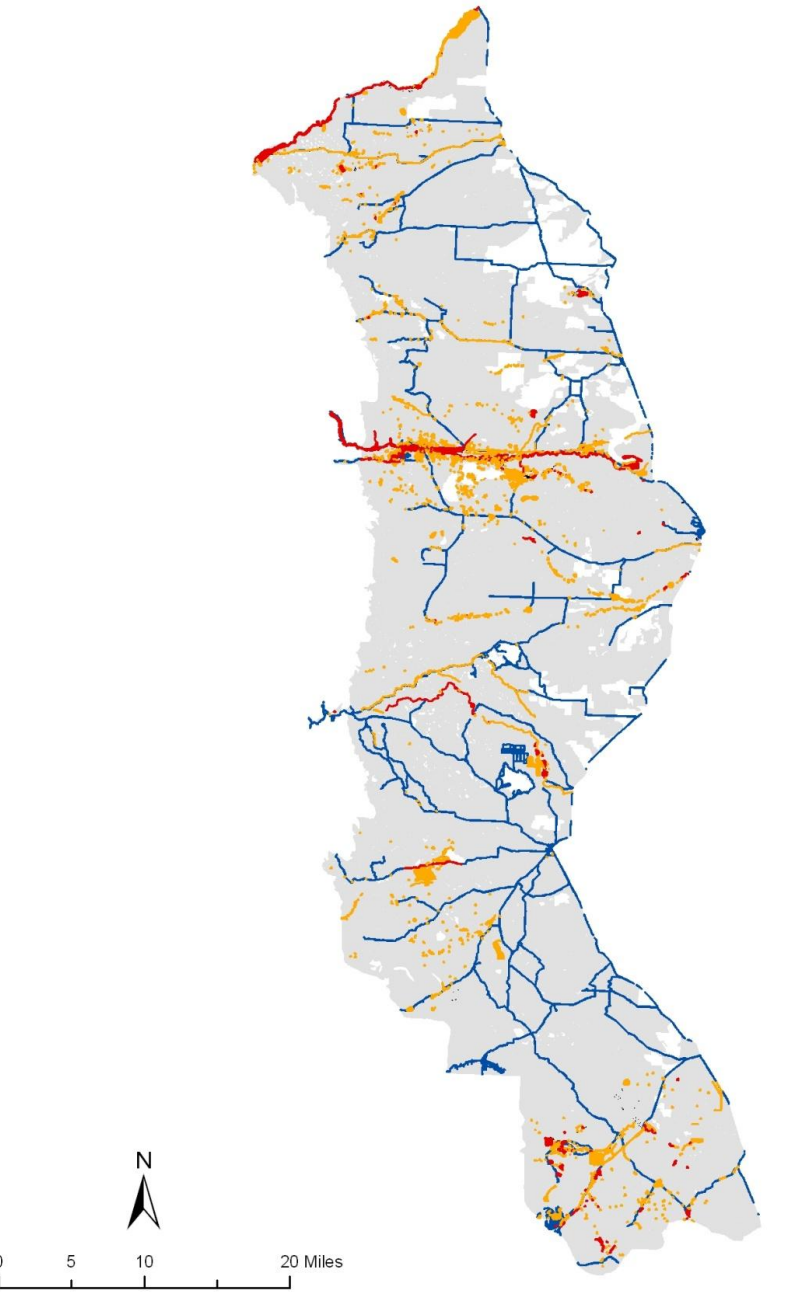
Rocky Mountain Front - Centaurea maculosa & Eu



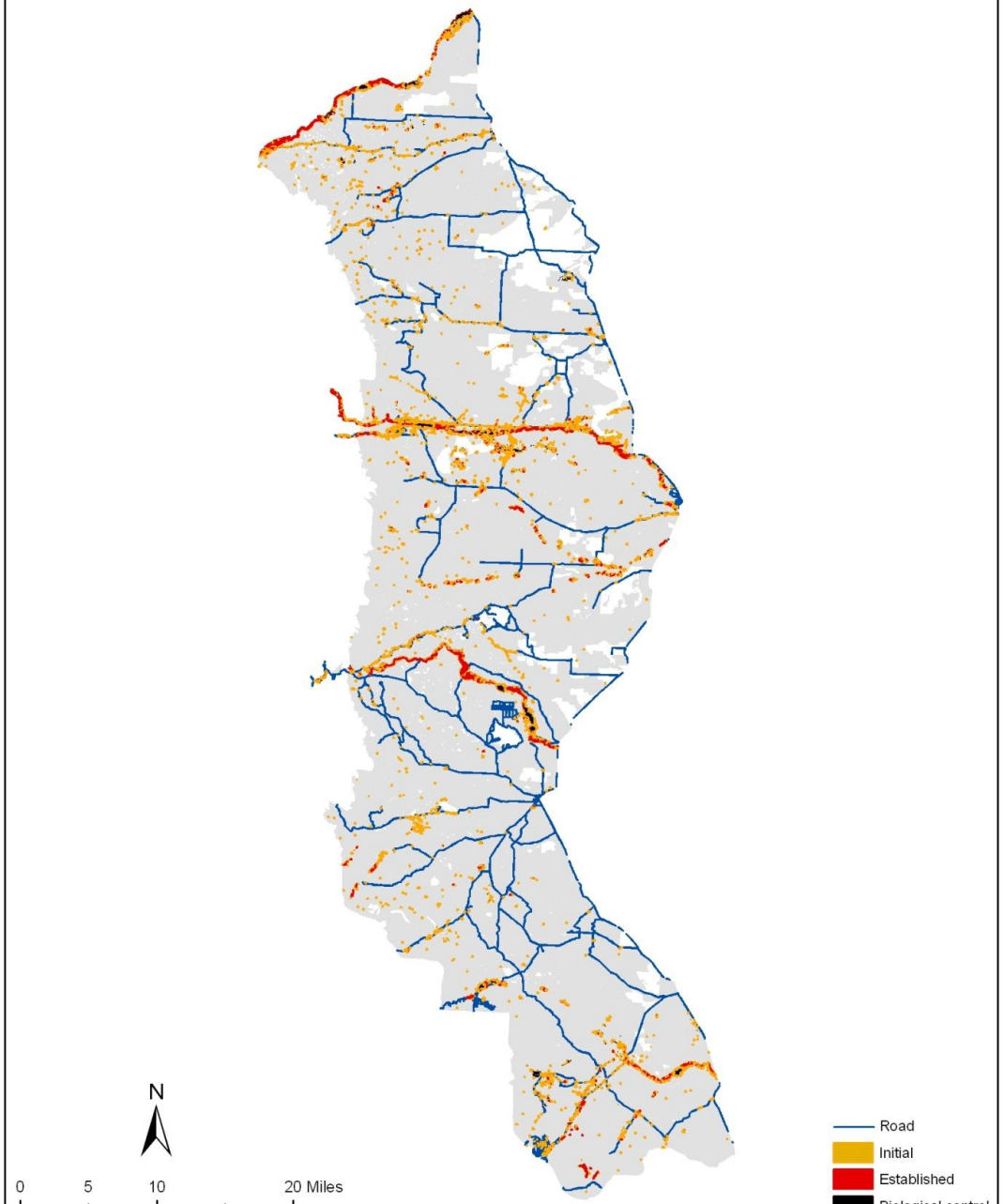
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - No Management - Year 40



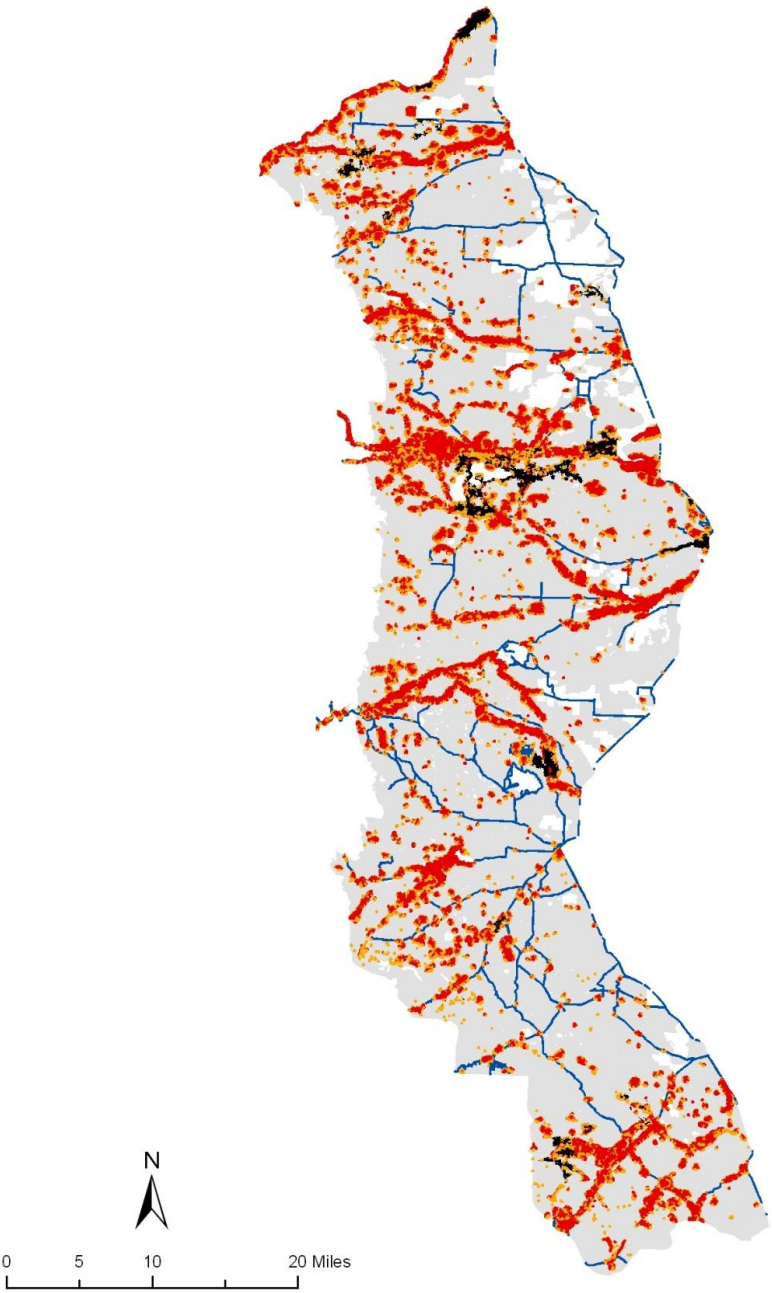
Rocky Mountain Front - Centaurea maculosa & Eu



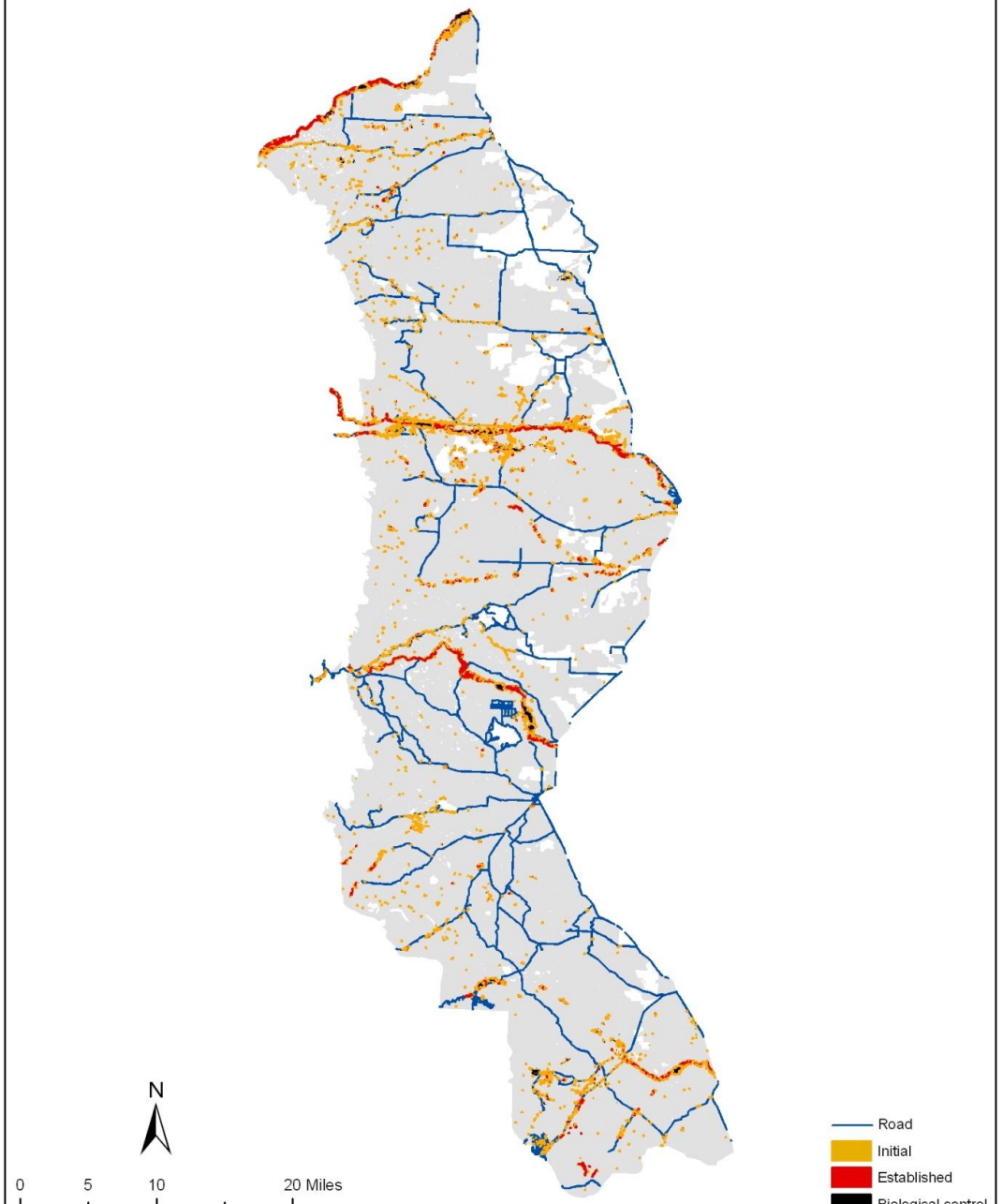
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula - High Spread - Unlimited Management - Year 40



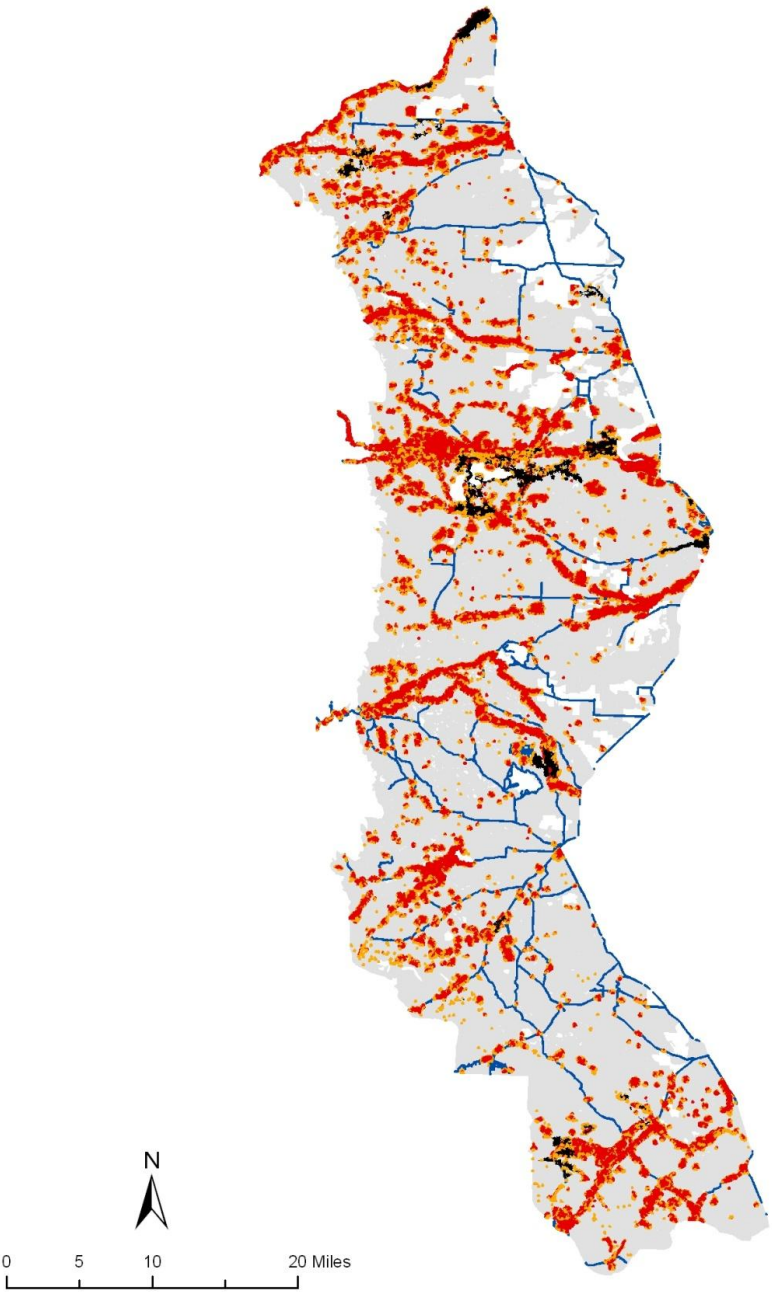
Rocky Mountain Front - Centaurea maculosa & Eu
High Spread - No Manag



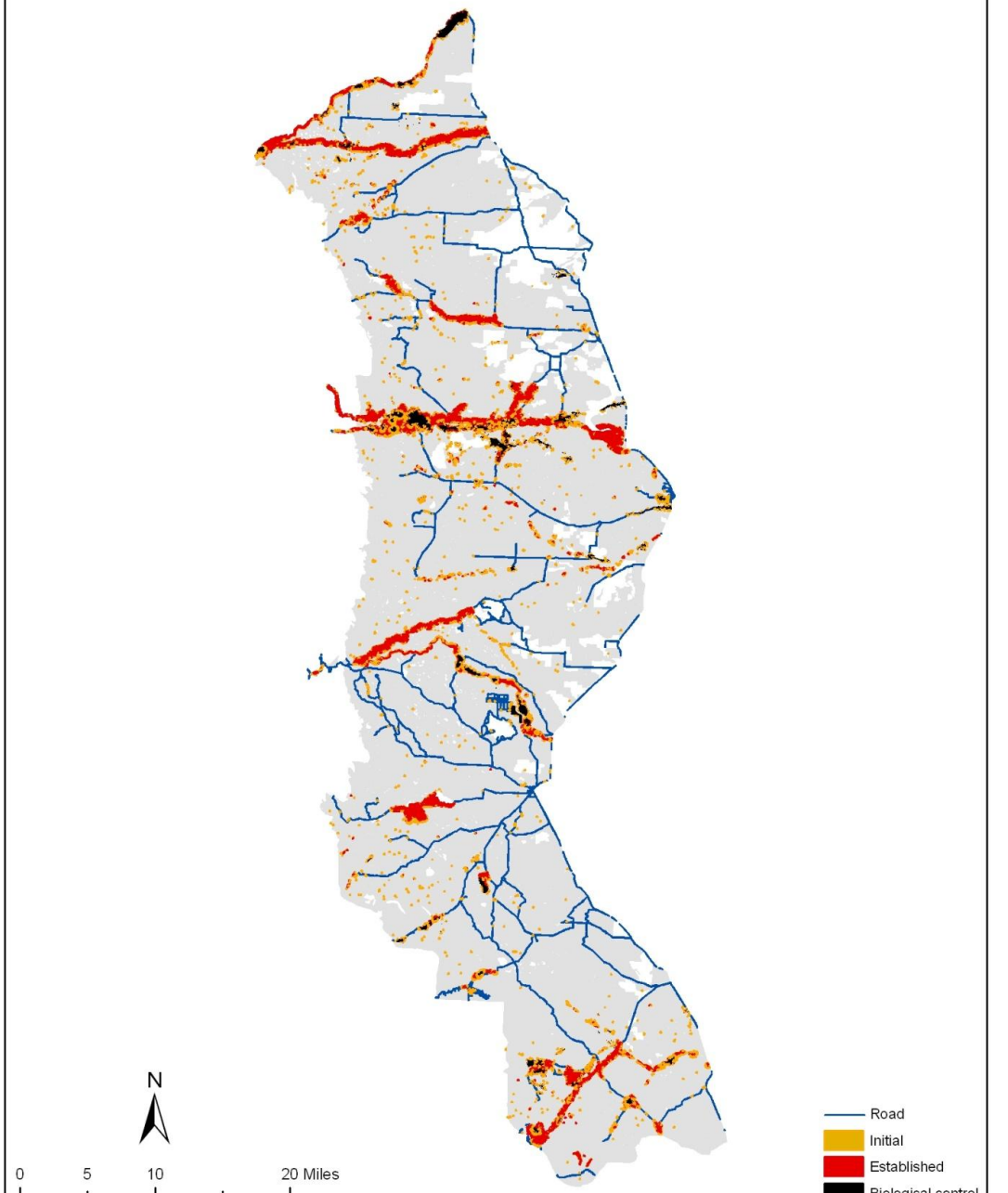
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - Unlimited Management - Year 40



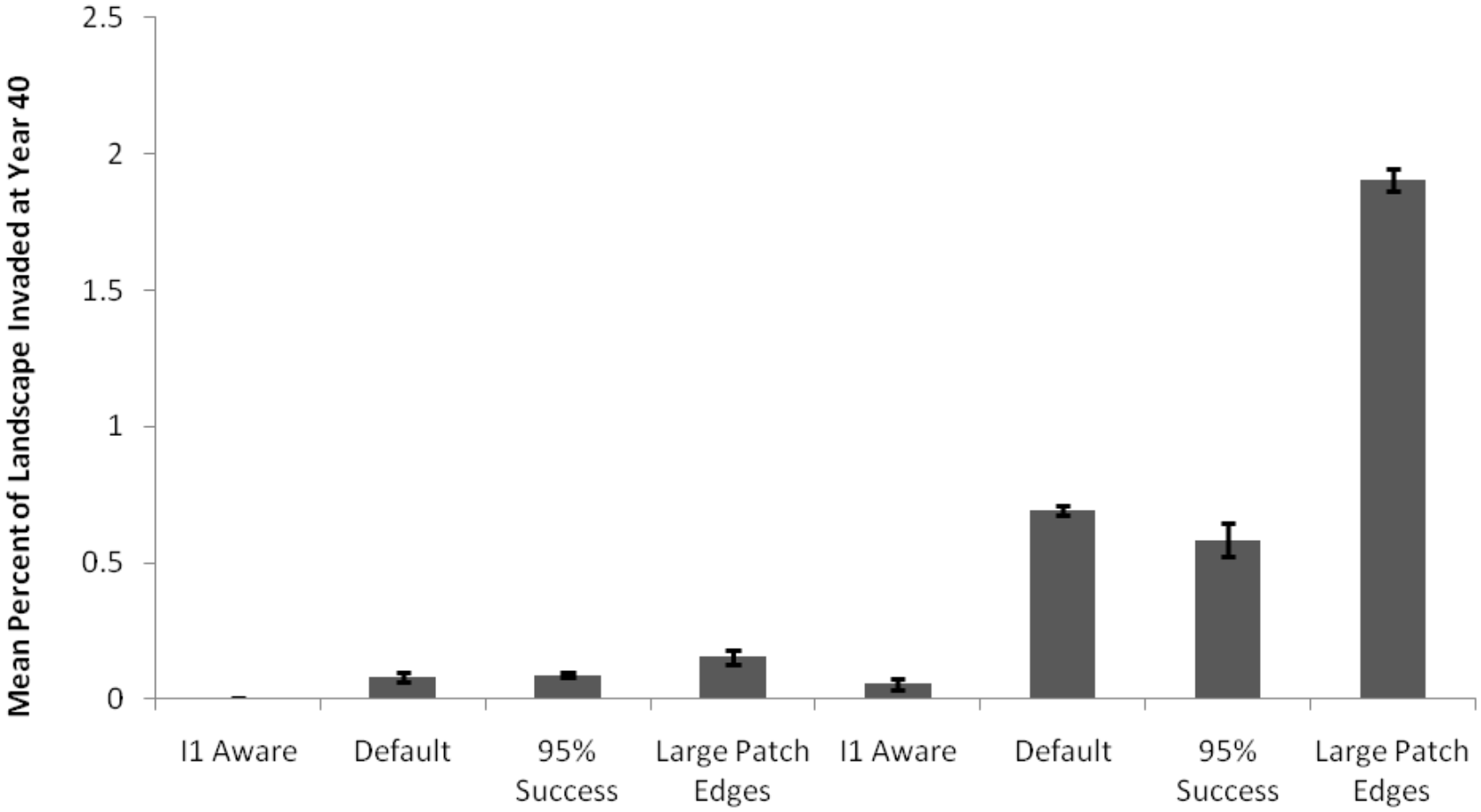
Rocky Mountain Front - Centaurea maculosa & Eu
High Spread - No Manag



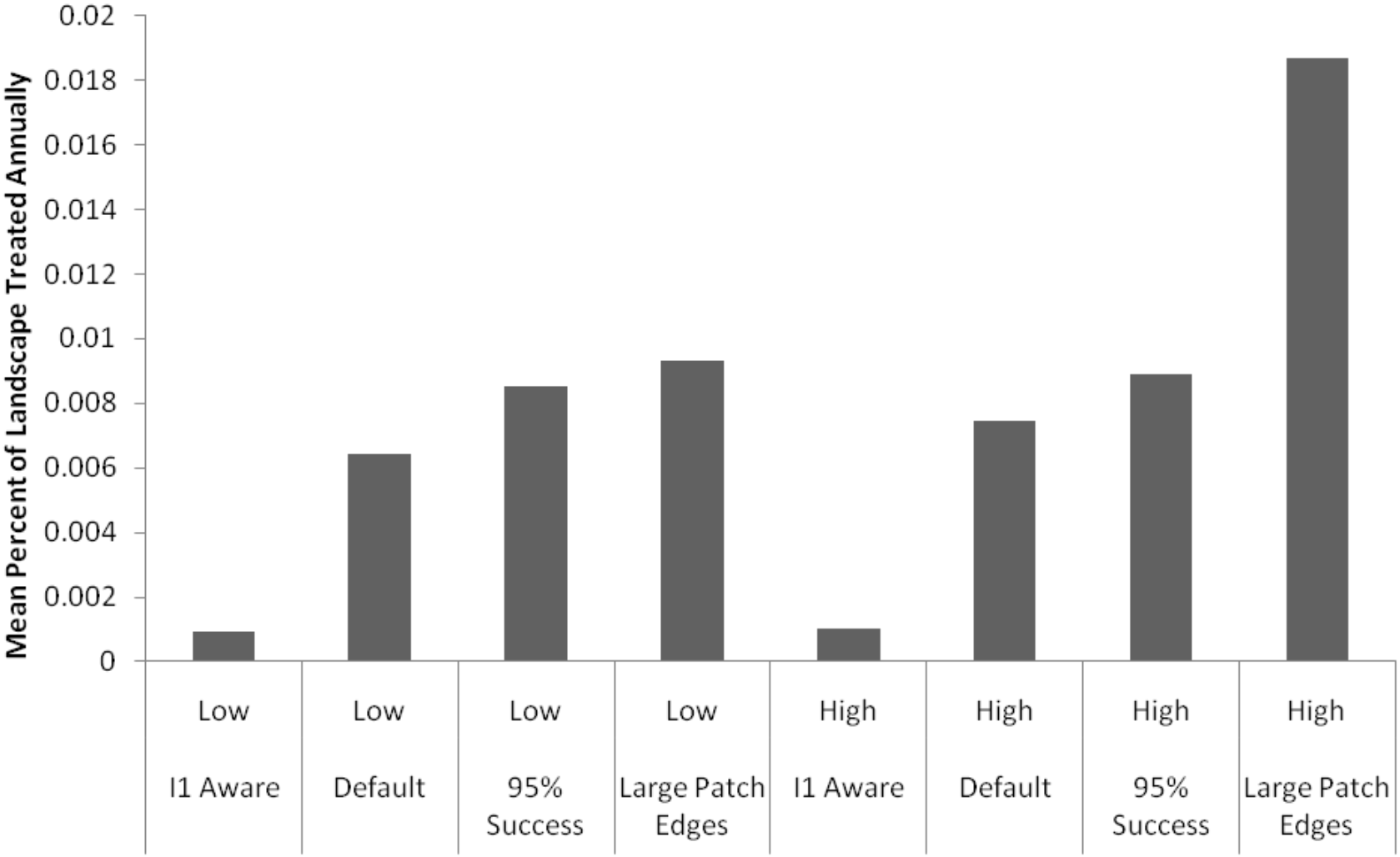
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - 2300 ha Management Ceiling - Year 40



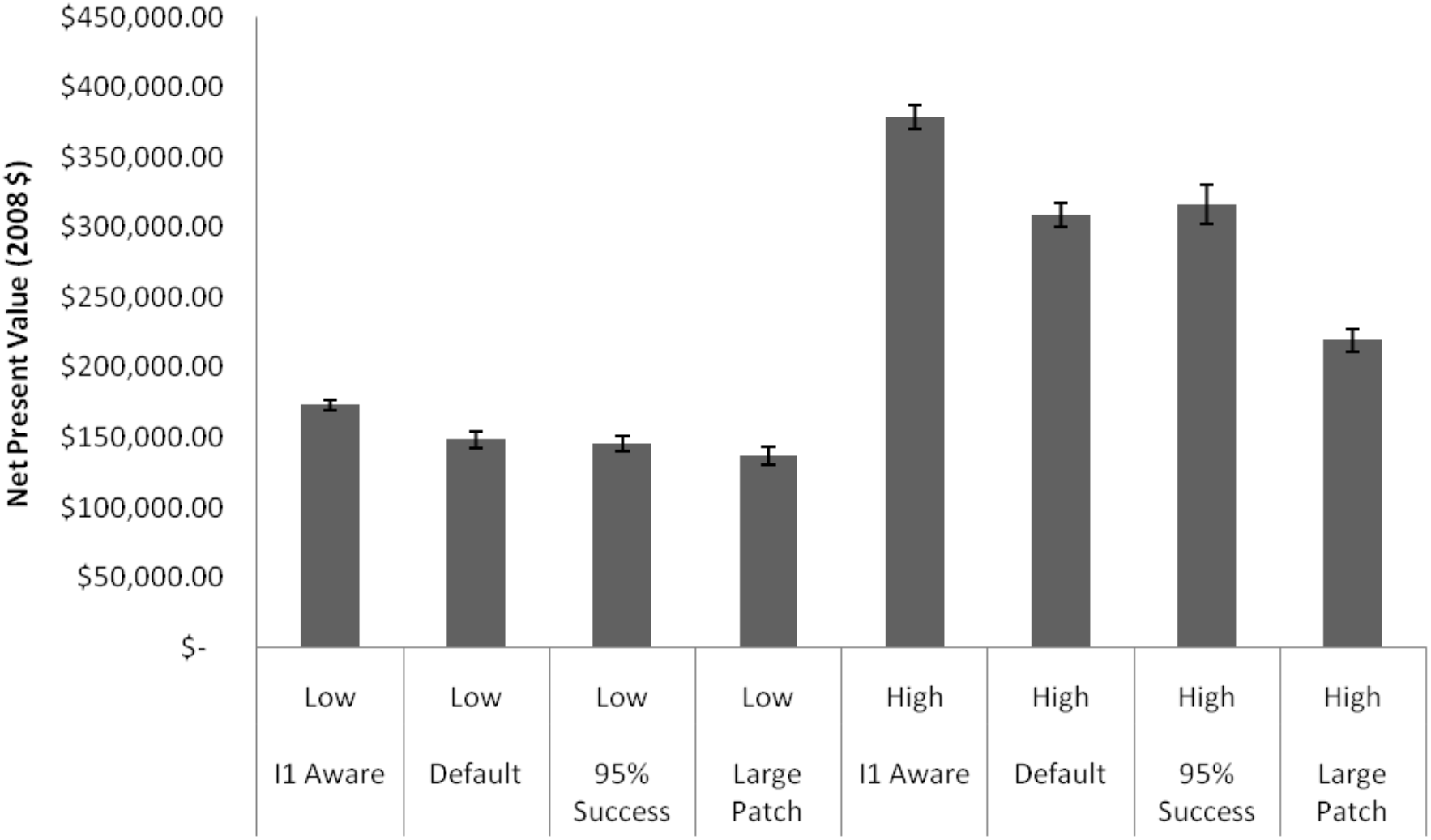
CV Percent of Landscape Invaded at Year 40: Effects of Weed Spread and Strategy



CV Percent of Landscape Treated Annually
Effects of Weed Spread and Strategy



CV Net Present Value (2008 $) at Year 40
Alternative Strategies



Centennial Valley - TELSA Weed Model

Spotted Knapweed
Initial Conditions

Initial
Established
Seed bank

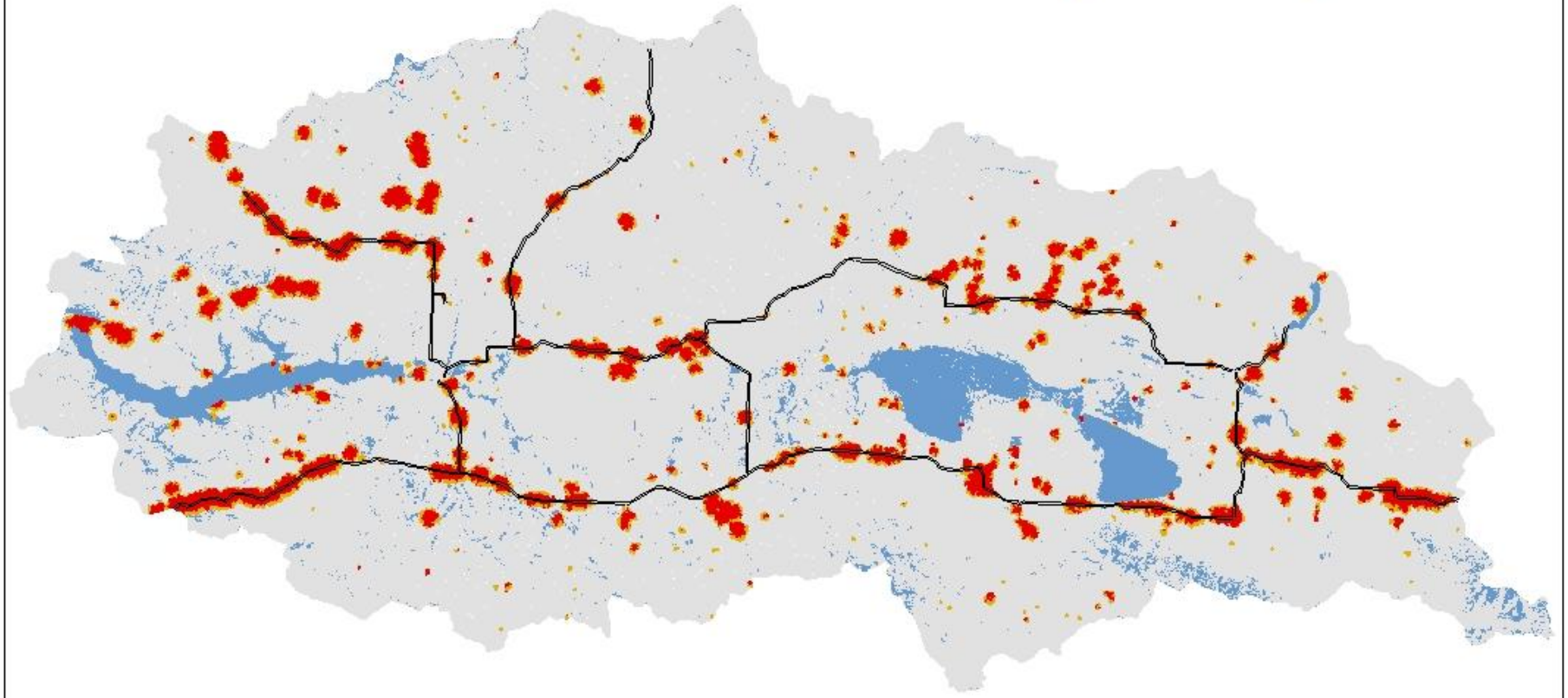
0 2.5 5 10 Kilometers
0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Spotted Knapweed

High Spread - 70 Percent Control Success - No Management - Year 40



Initial

Established

Seed bank

0 2.5 5 10 Kilometers

0 2.5 5 10 Miles

N

Centennial Valley - TELSA Weed Model

Spotted Knapweed

Low Spread - 70 Percent Control Success - I1 Aware Management - Year 40

Initial

Established

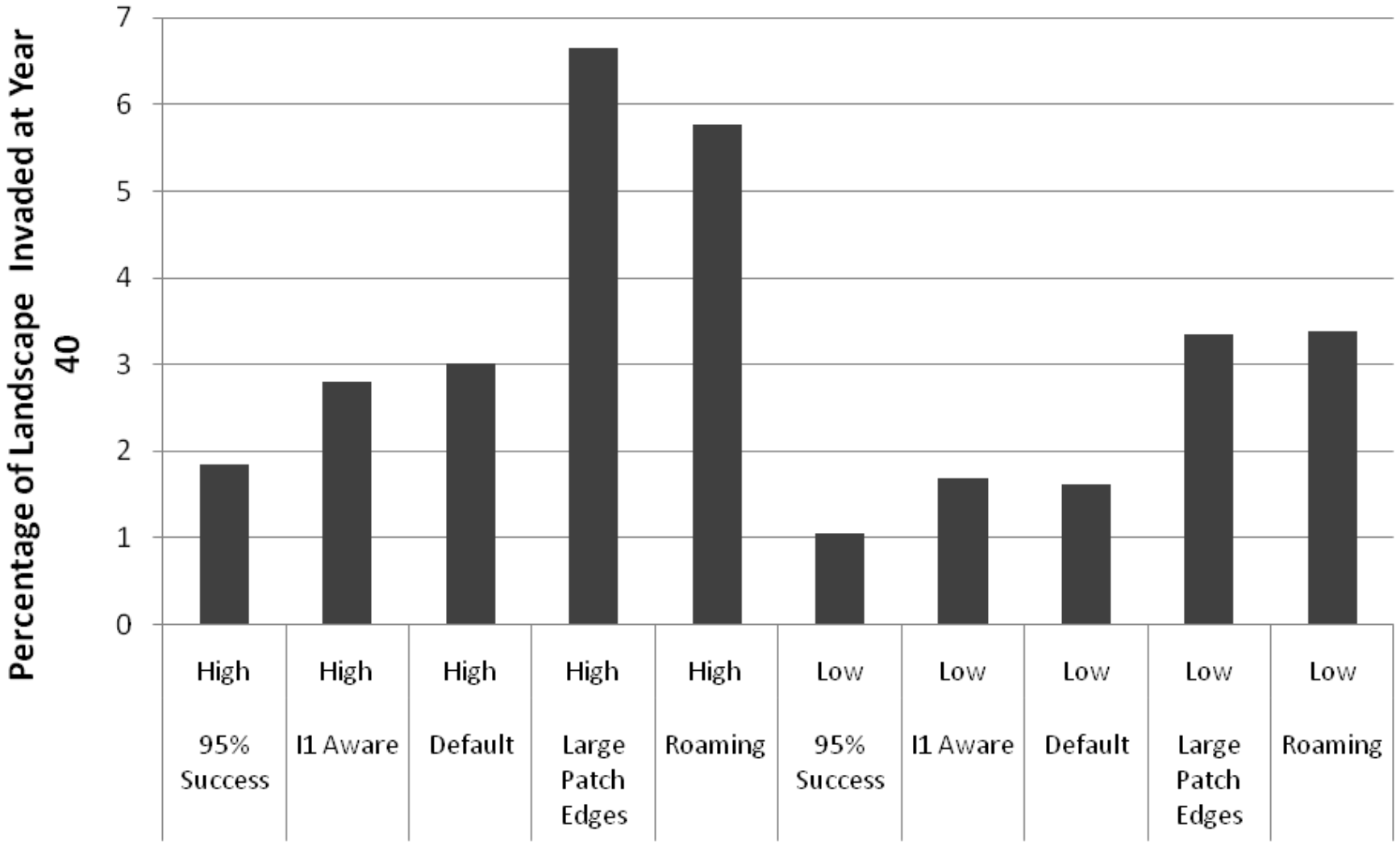
Seed bank

0 2.5 5 10 Kilometers

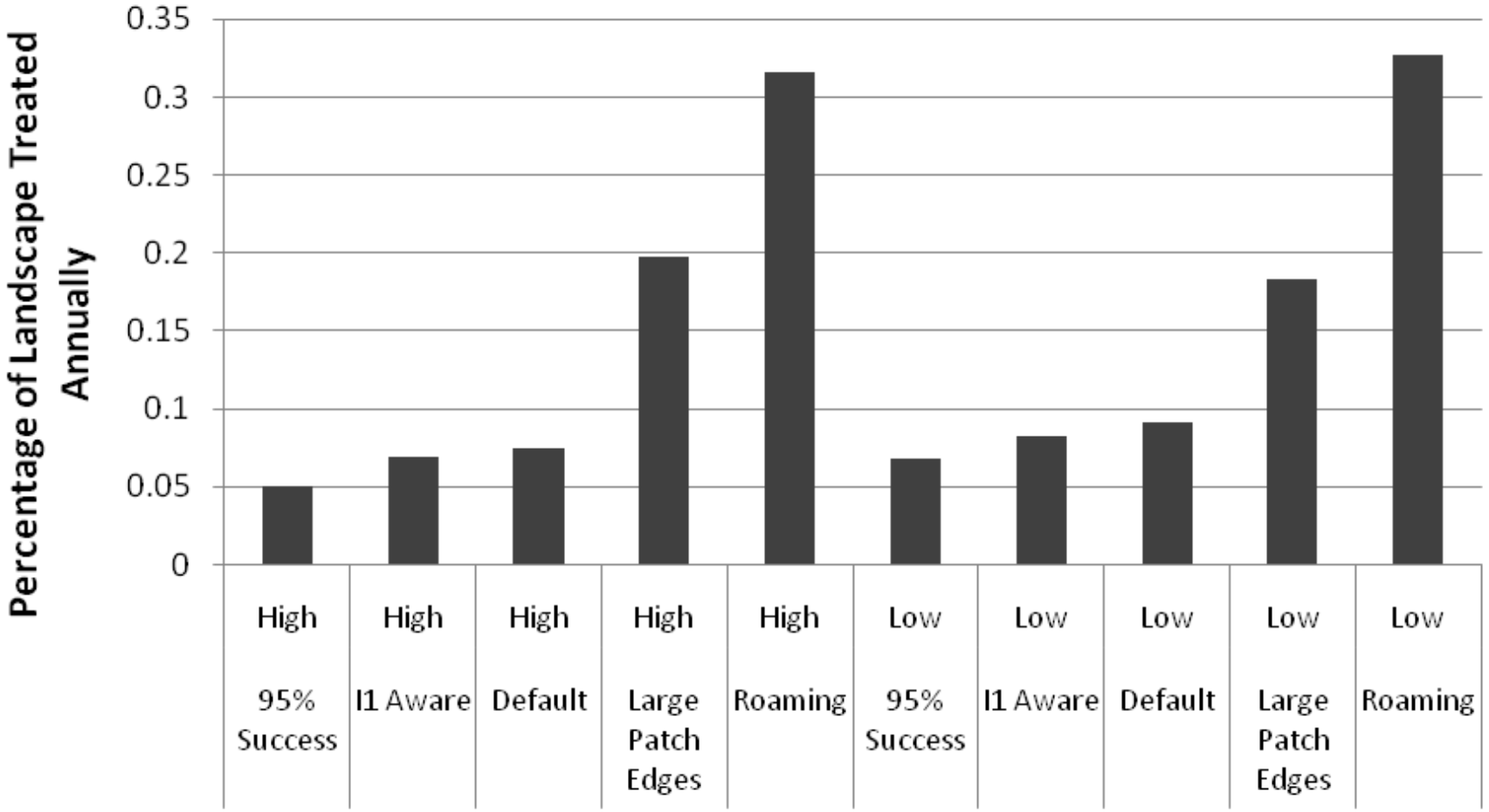
0 2.5 5 10 Miles

N

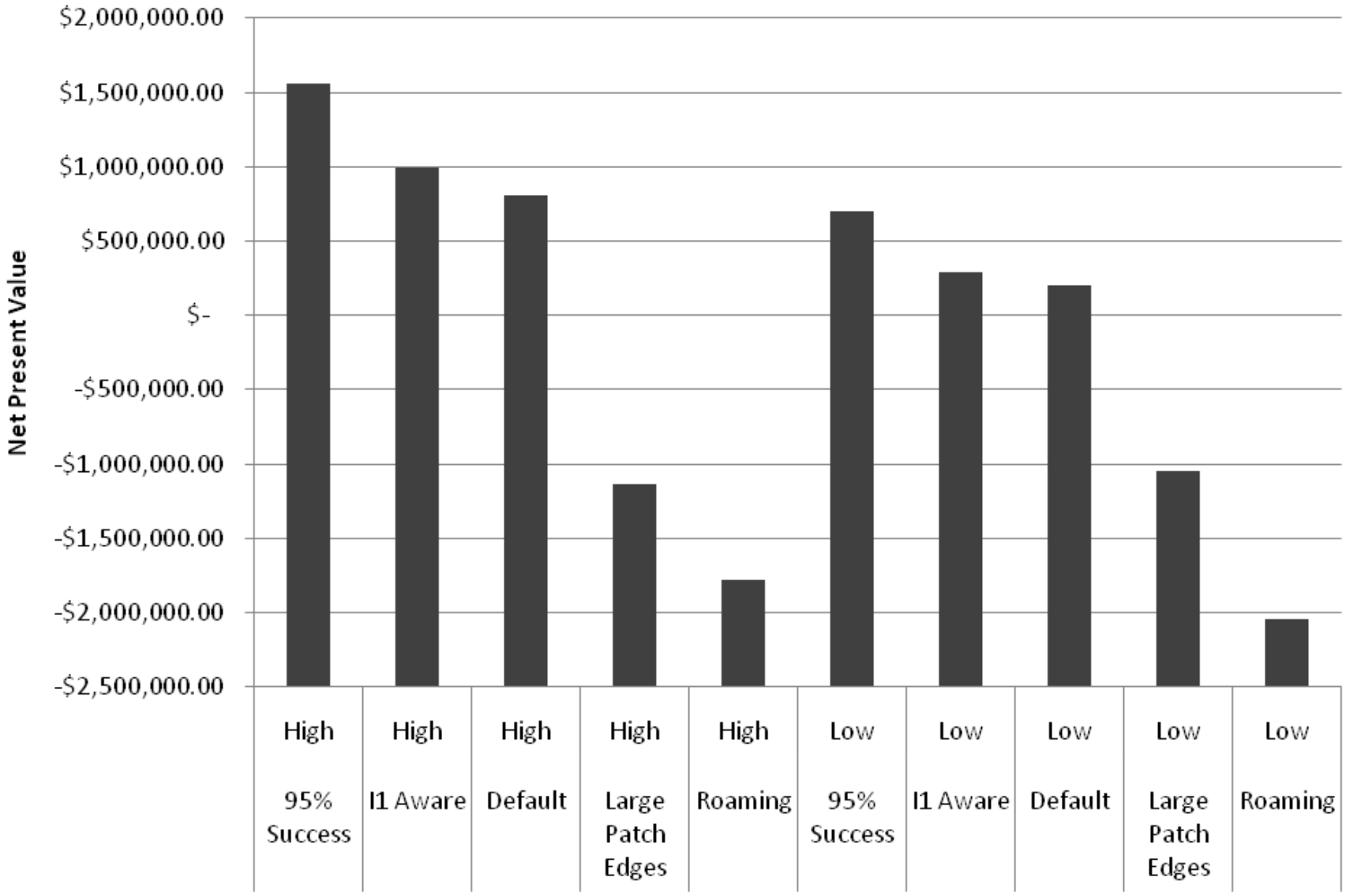
RMF Alternative Strategy Area Invaded



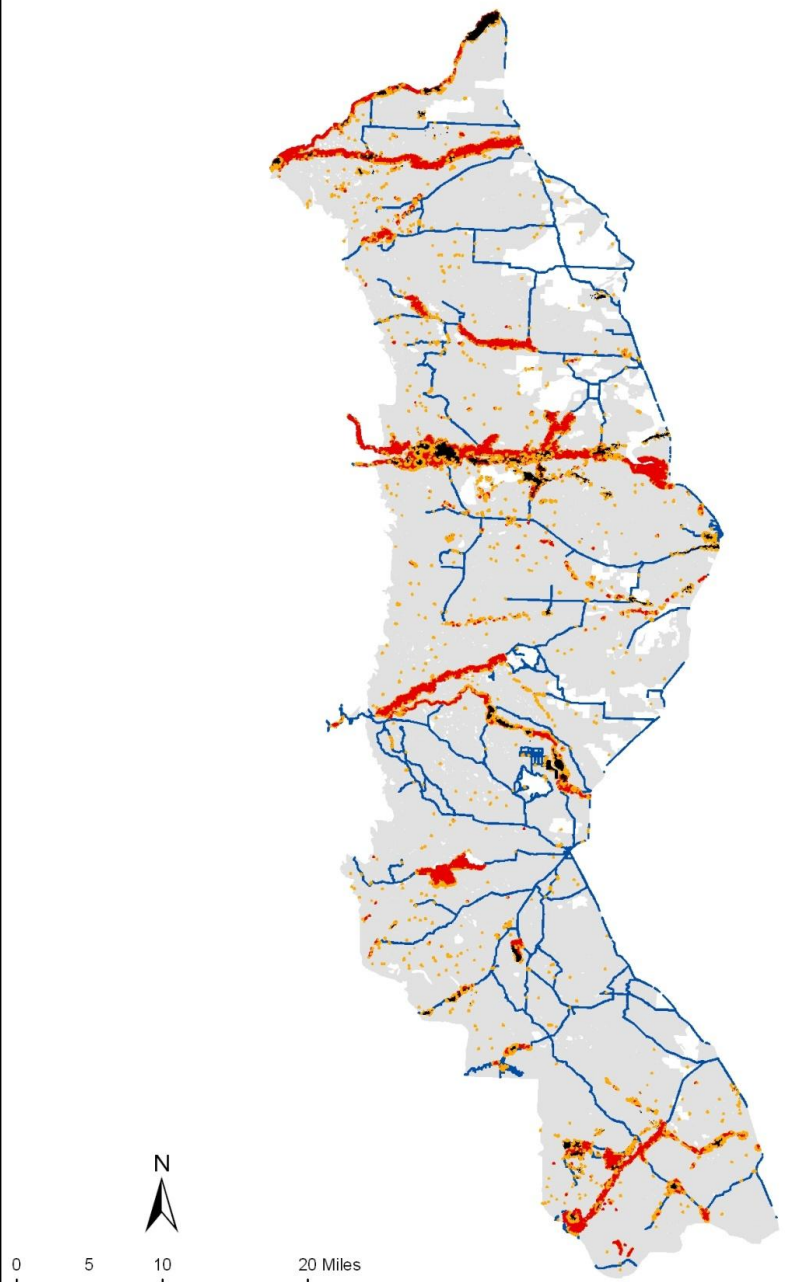
RMF Alternative Strategy Area Treated



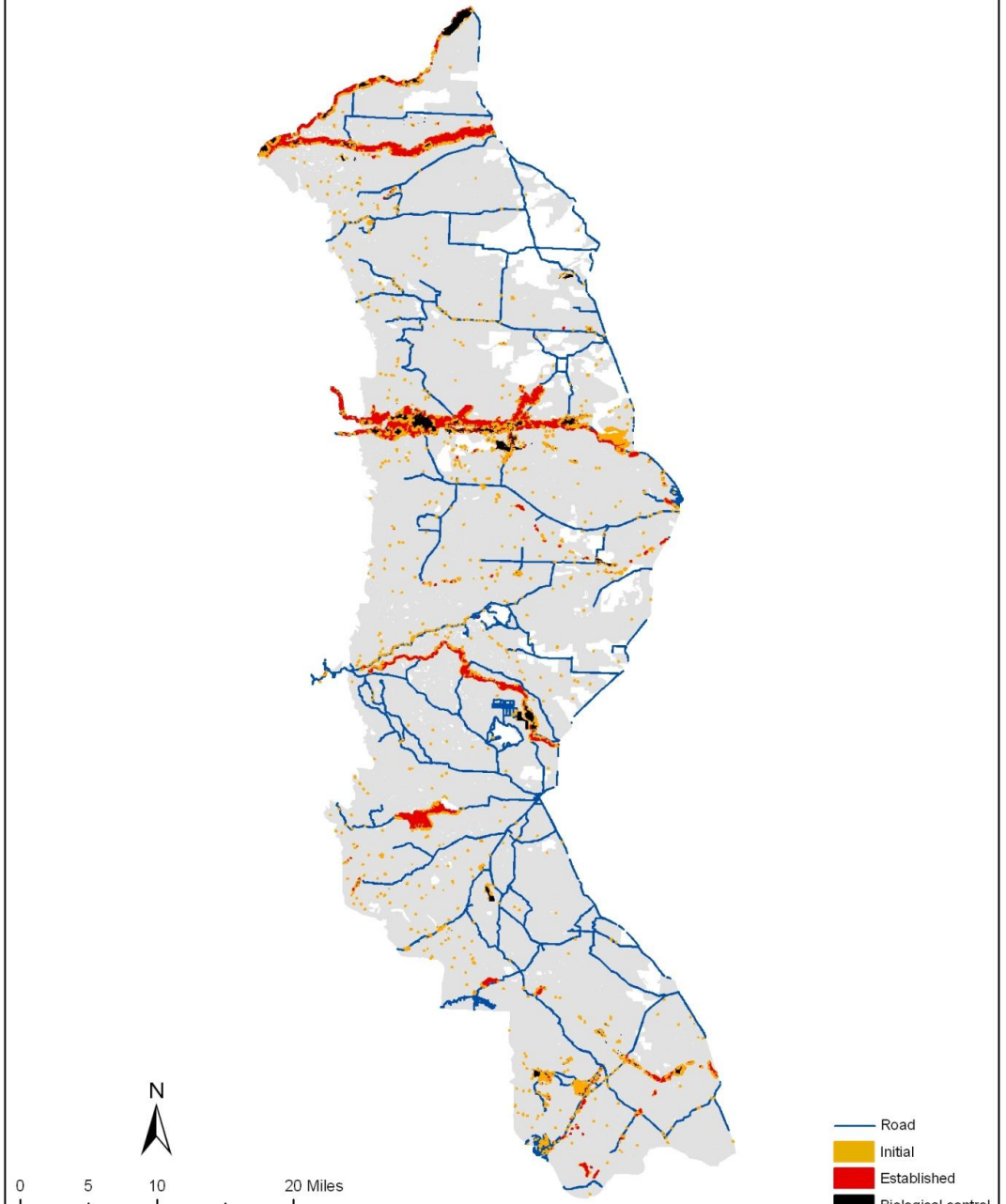
RMF Alternative Strategy NPV



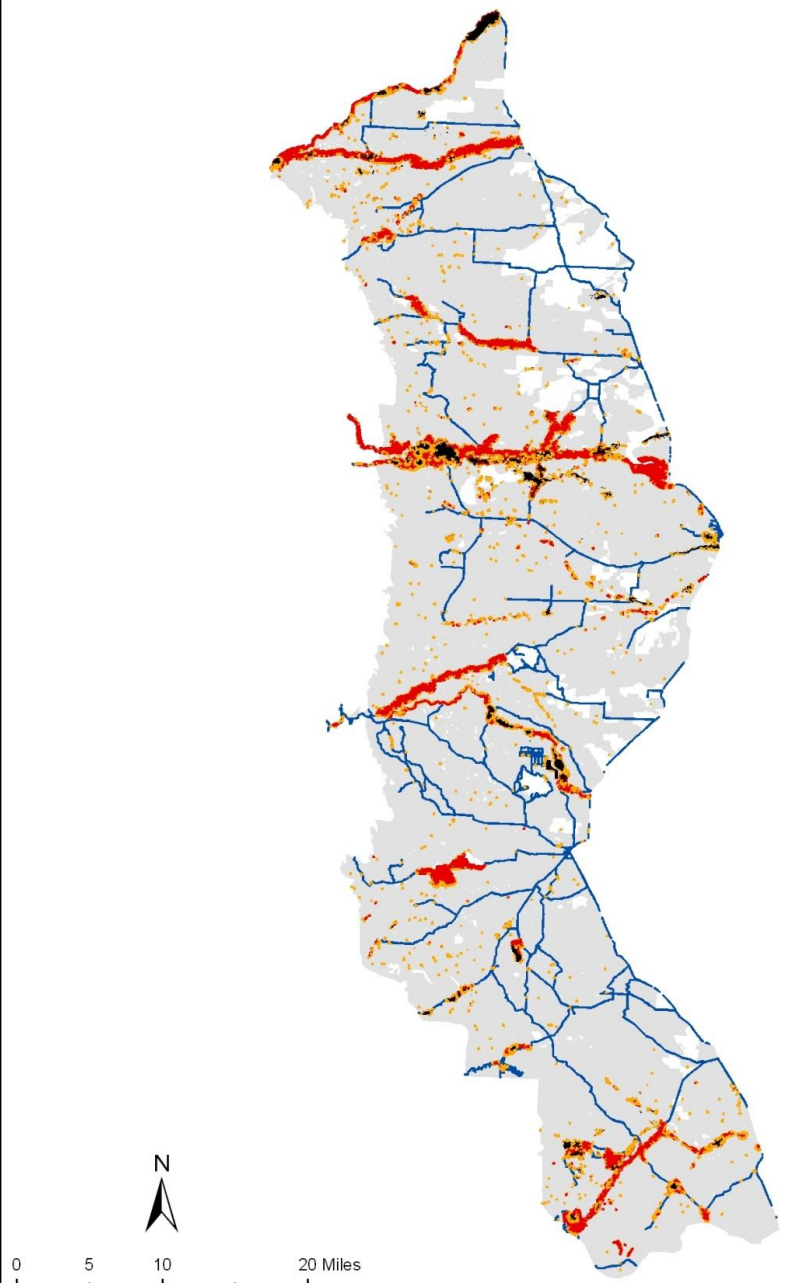
Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



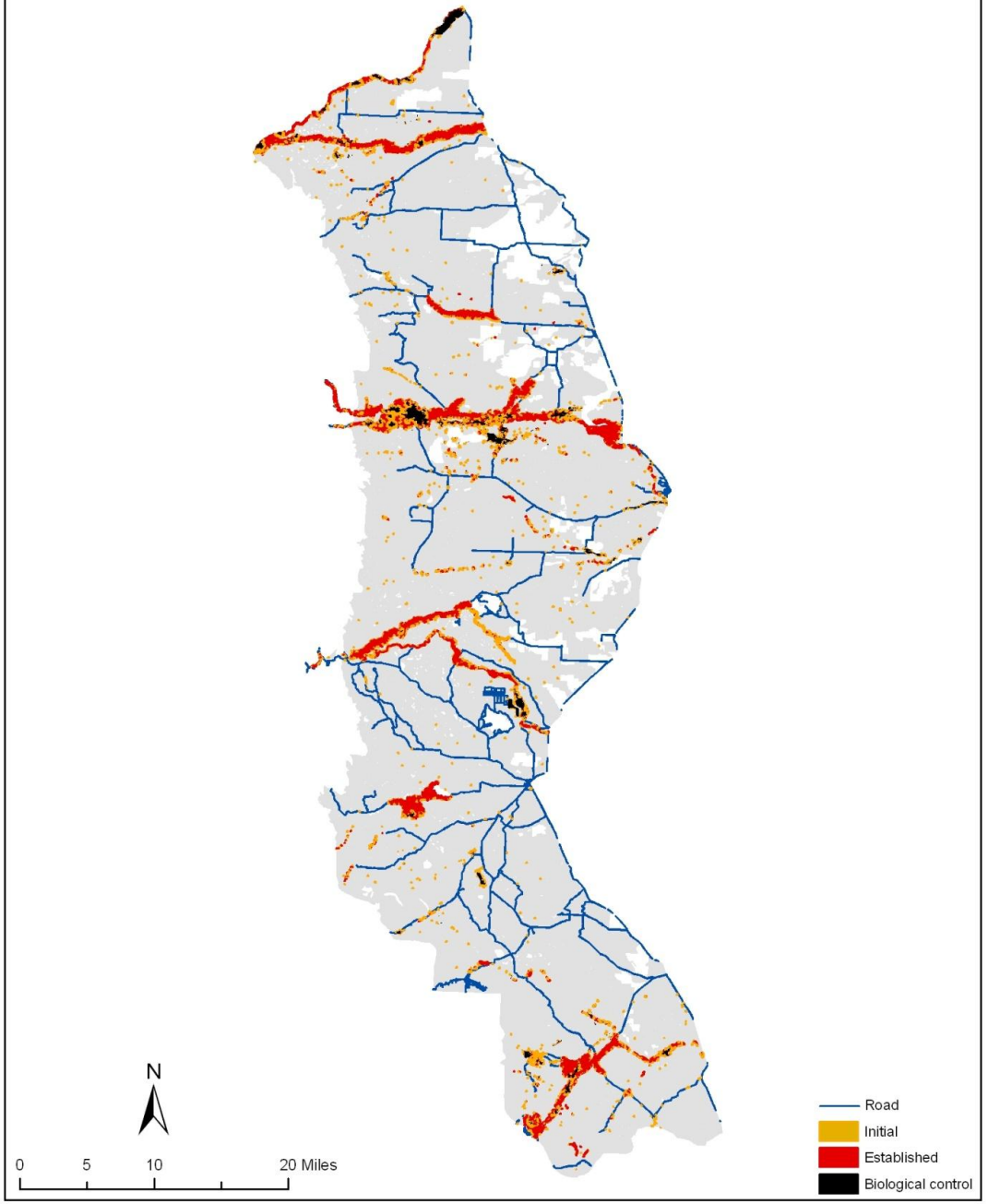
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - High Control Success - Year 40



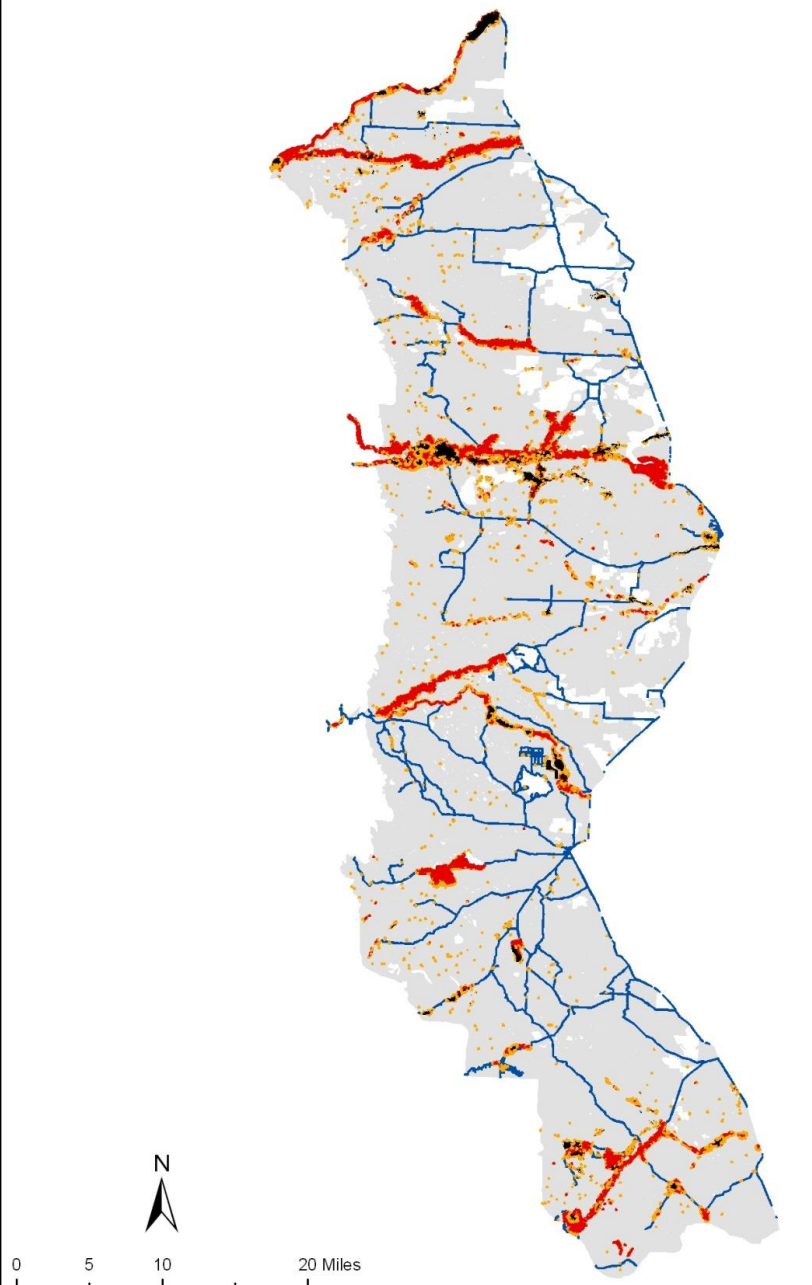
Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



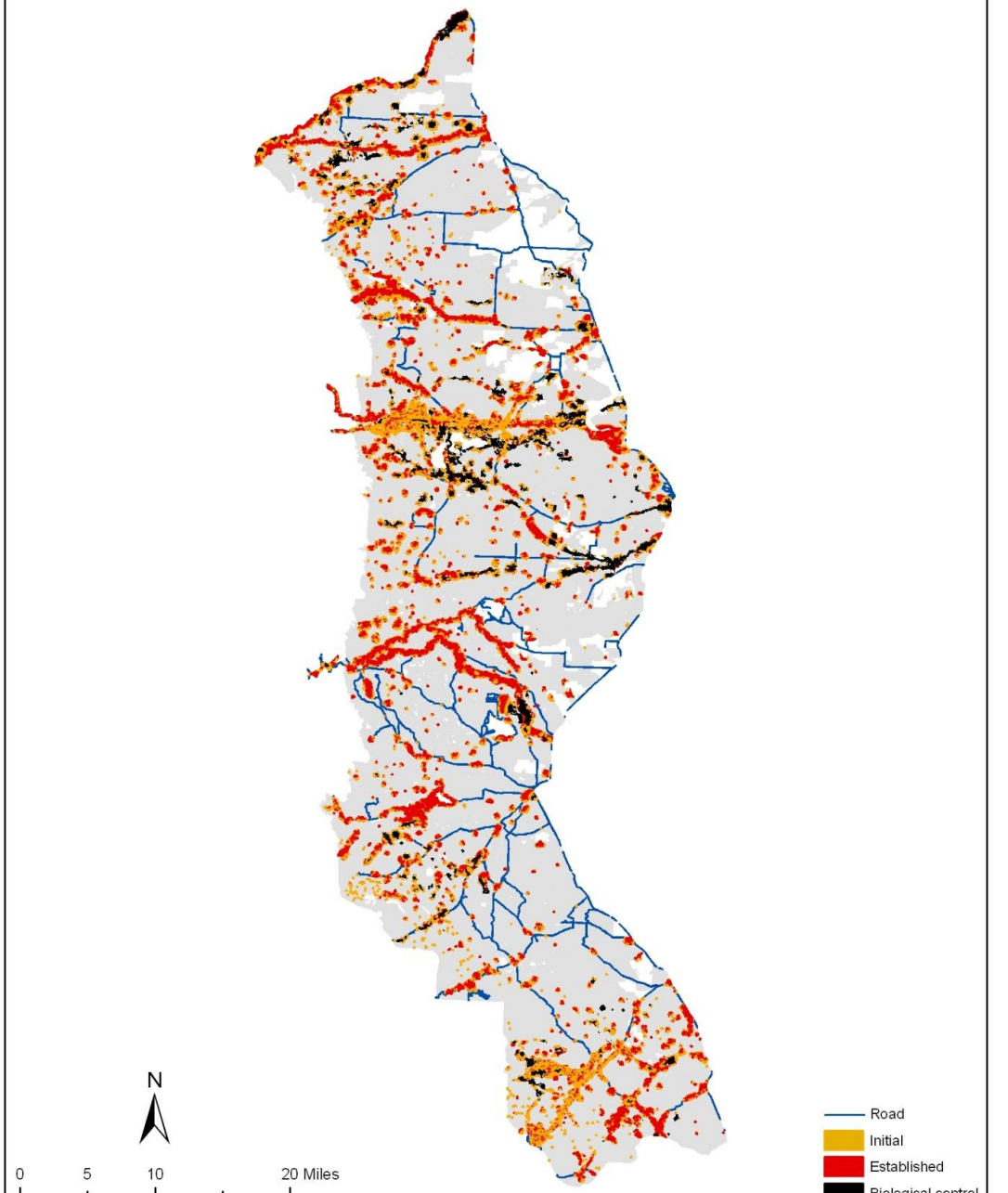
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - I1 Aware - Year 40



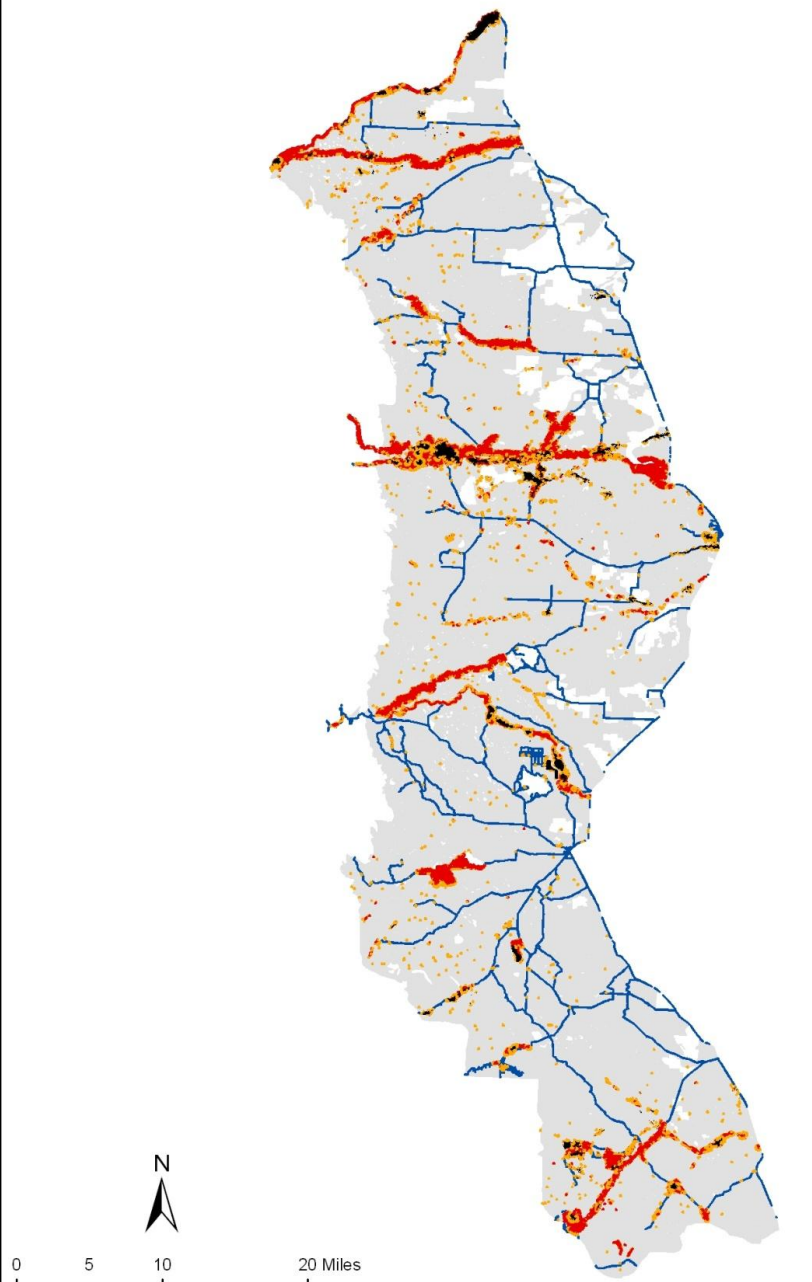
Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



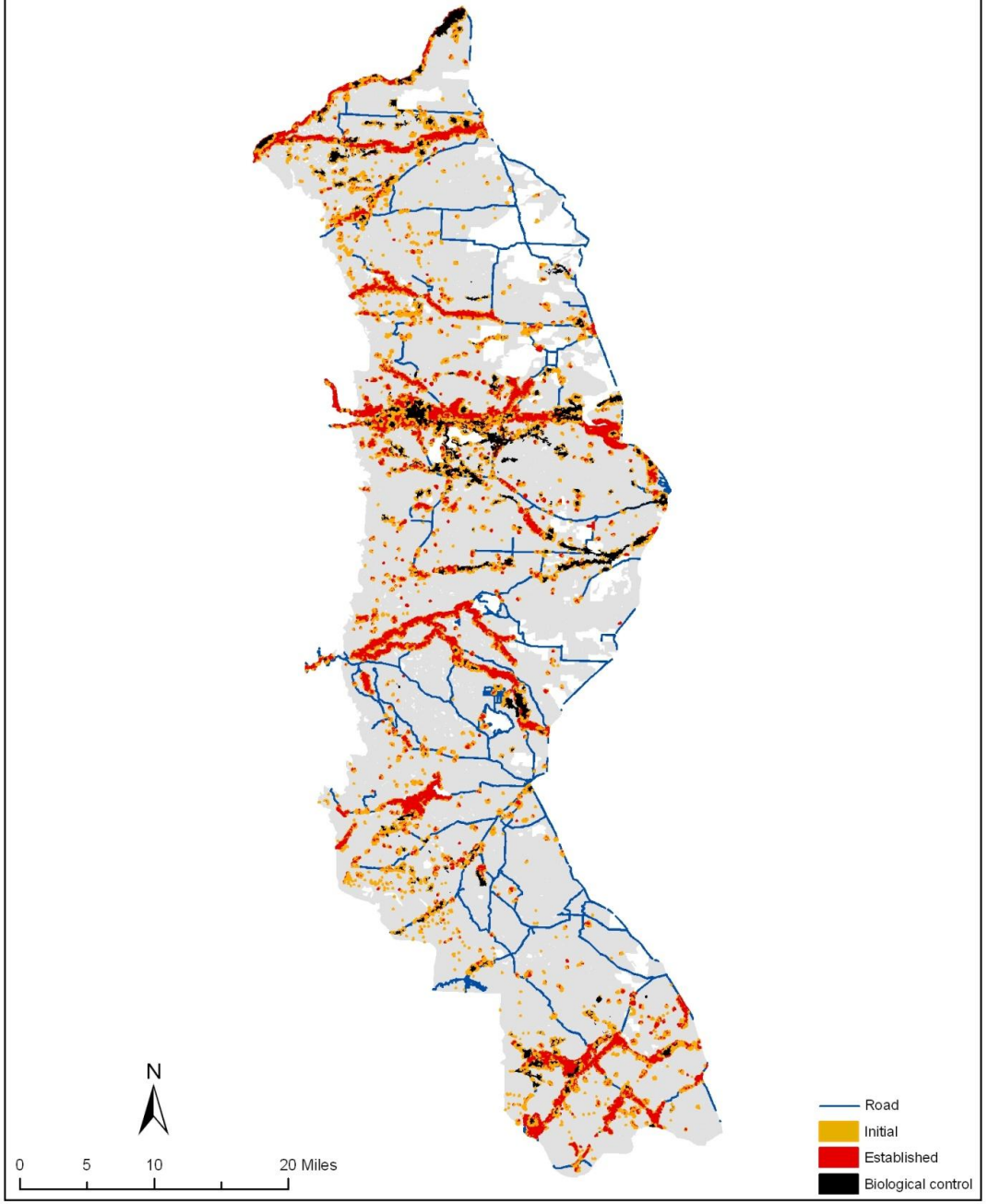
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - Large Patch Edges - Year 40



Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C

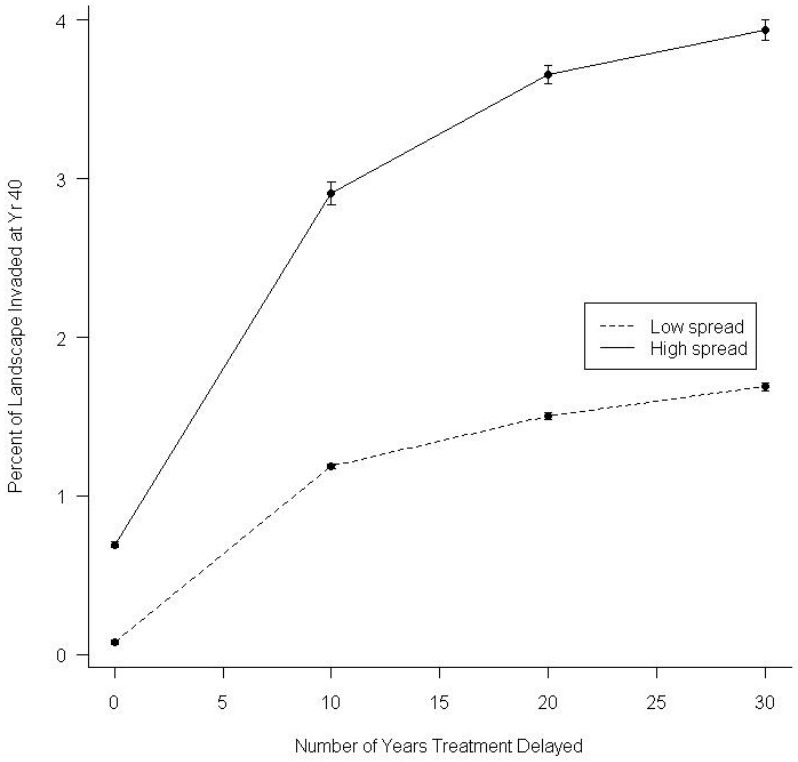


Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - Roaming Treatment - Year 40

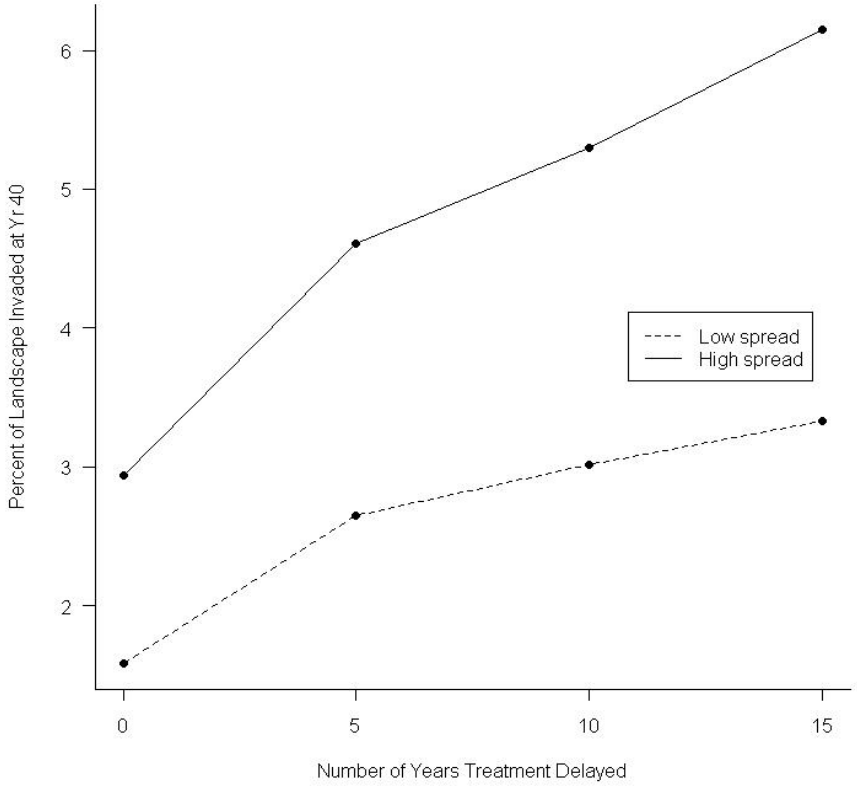


Effects of Delaying Management

Centennial Valley

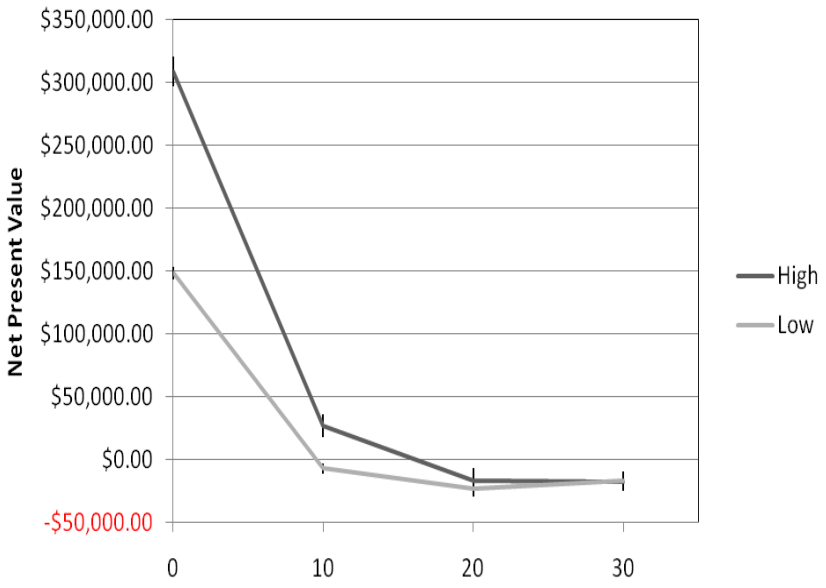


Rocky Mountain Front

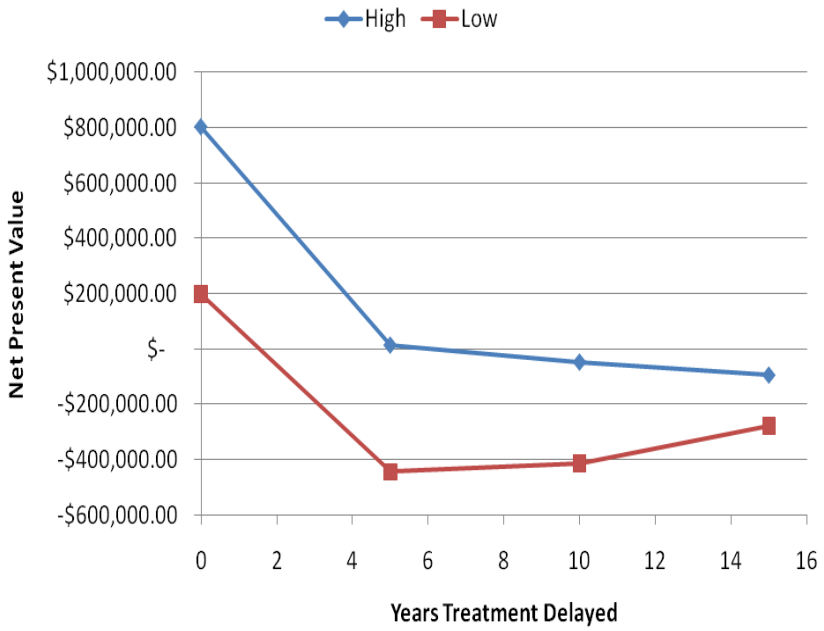


Costs of Delaying Management

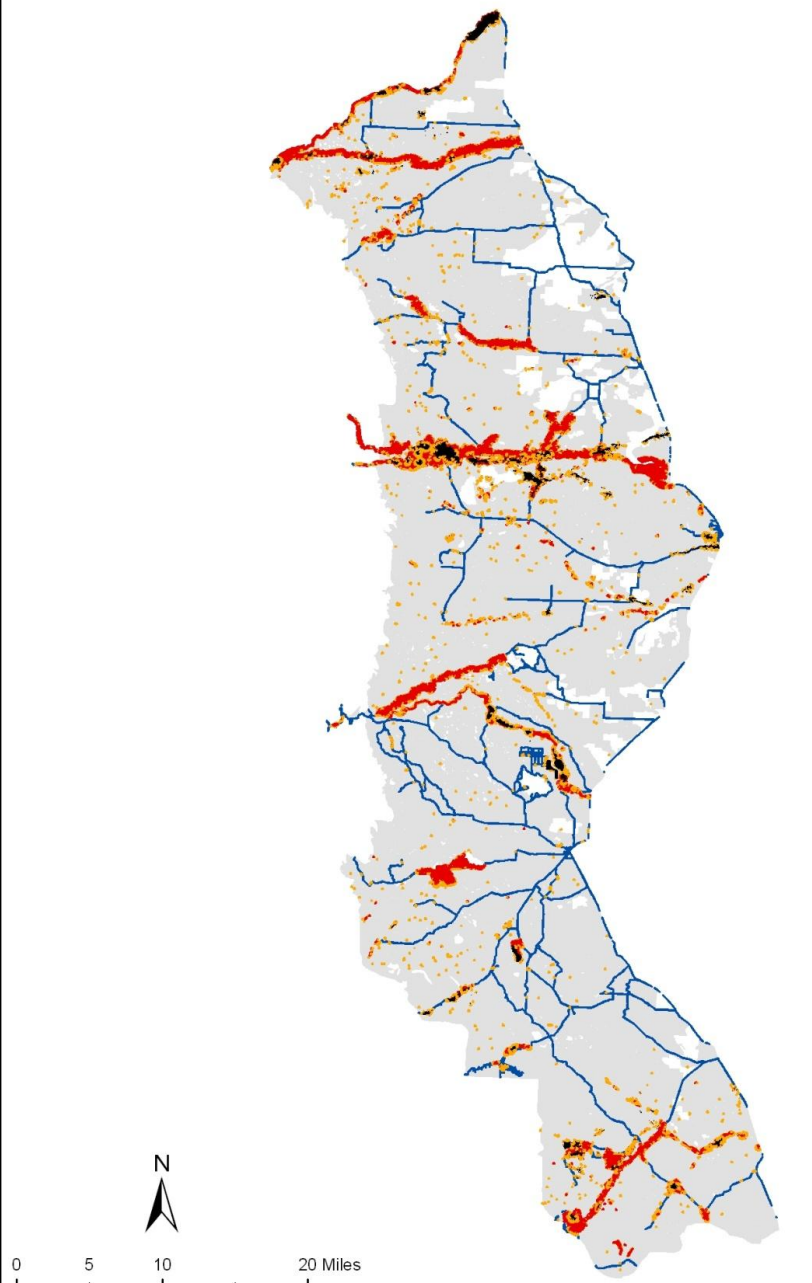
Centennial Valley



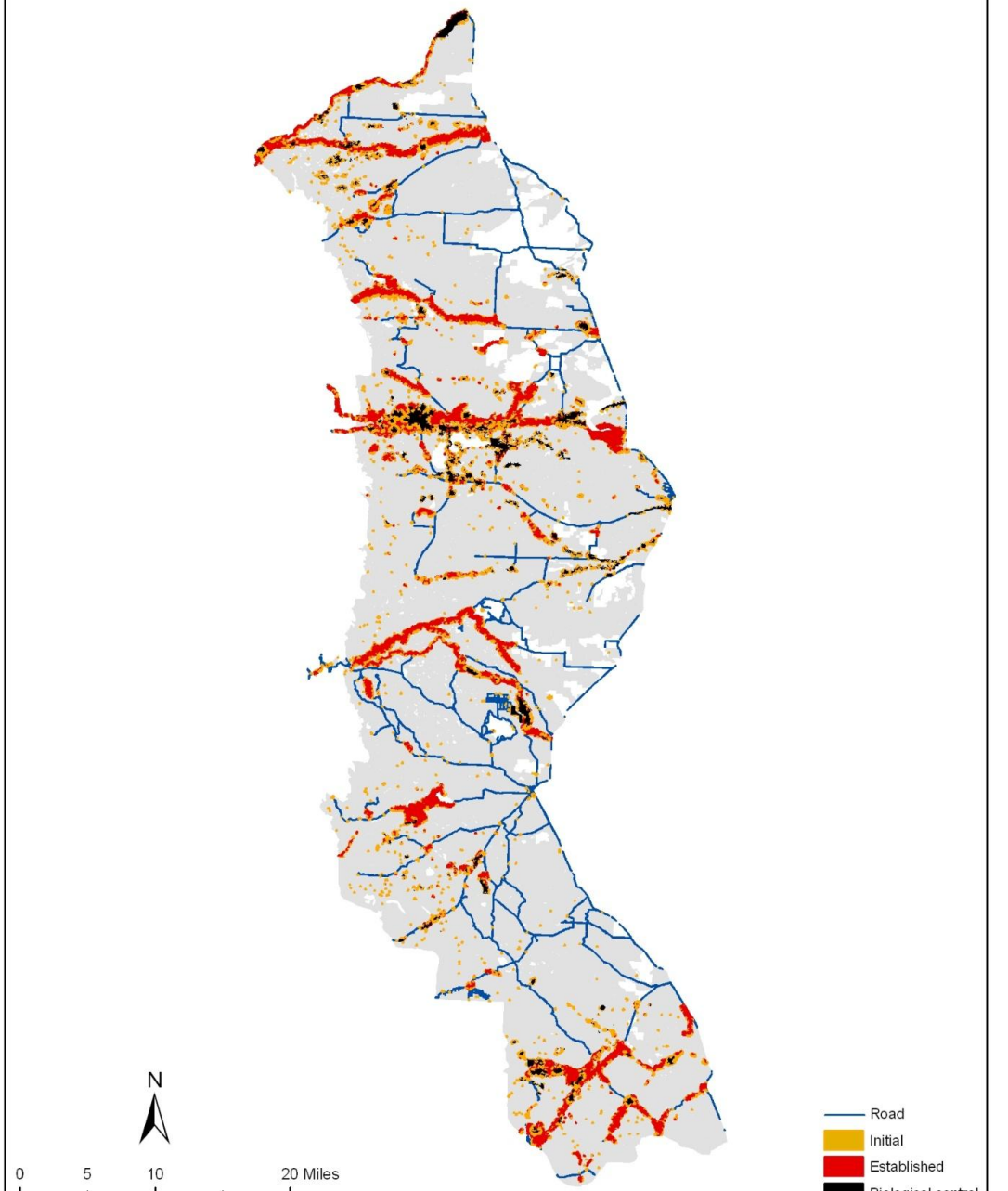
Rocky Mountain Front



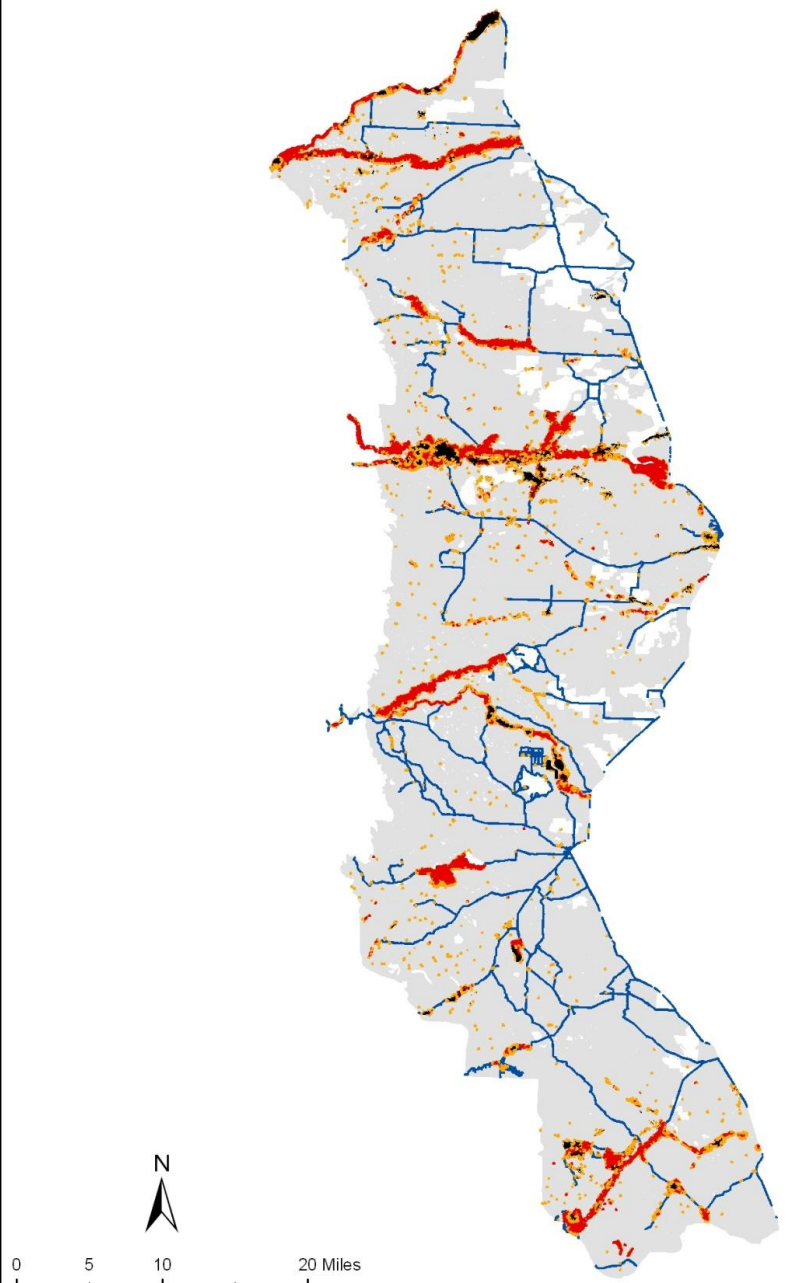
Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



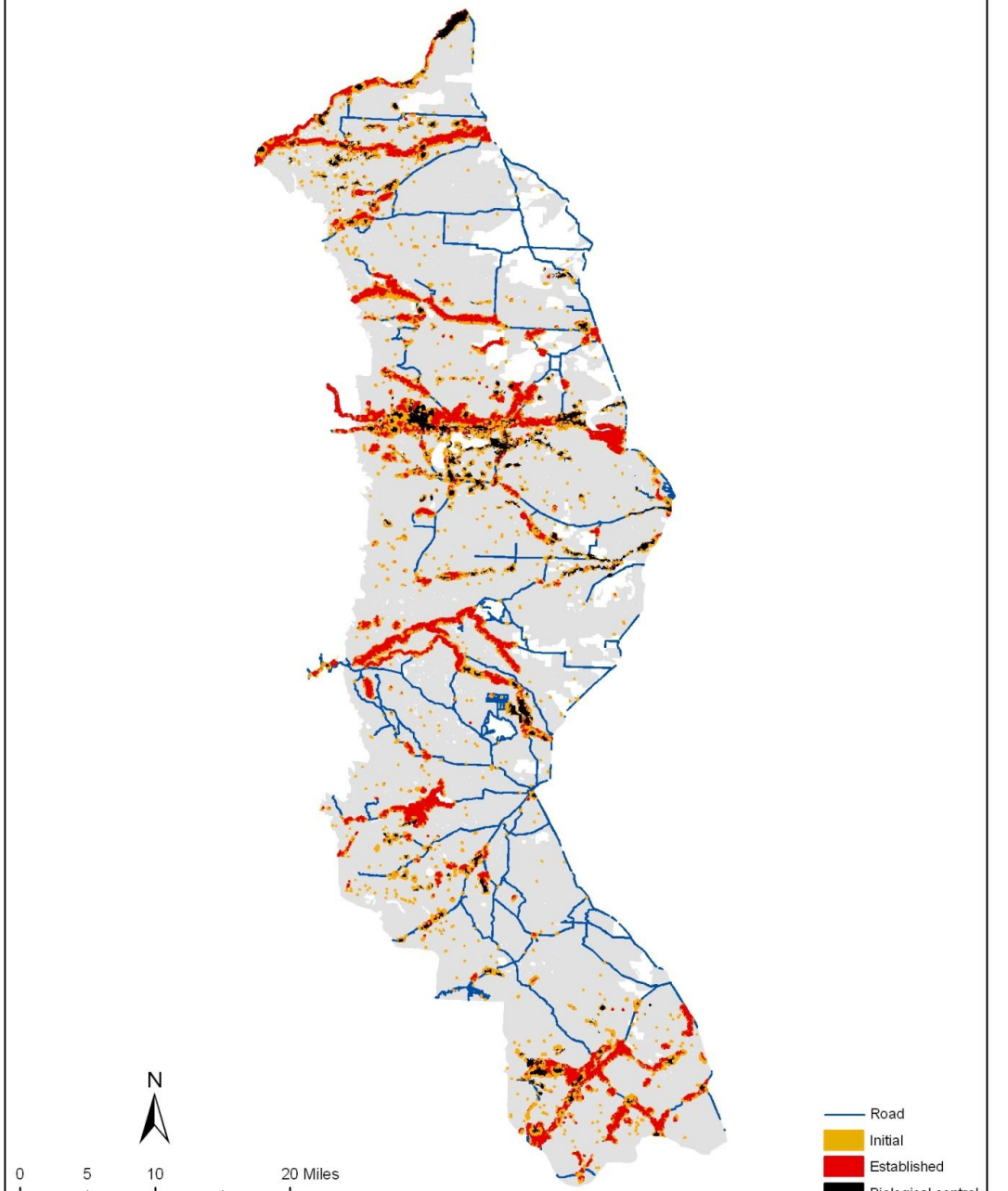
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - 5 Years Delay Before Treatment Starts - Year 40



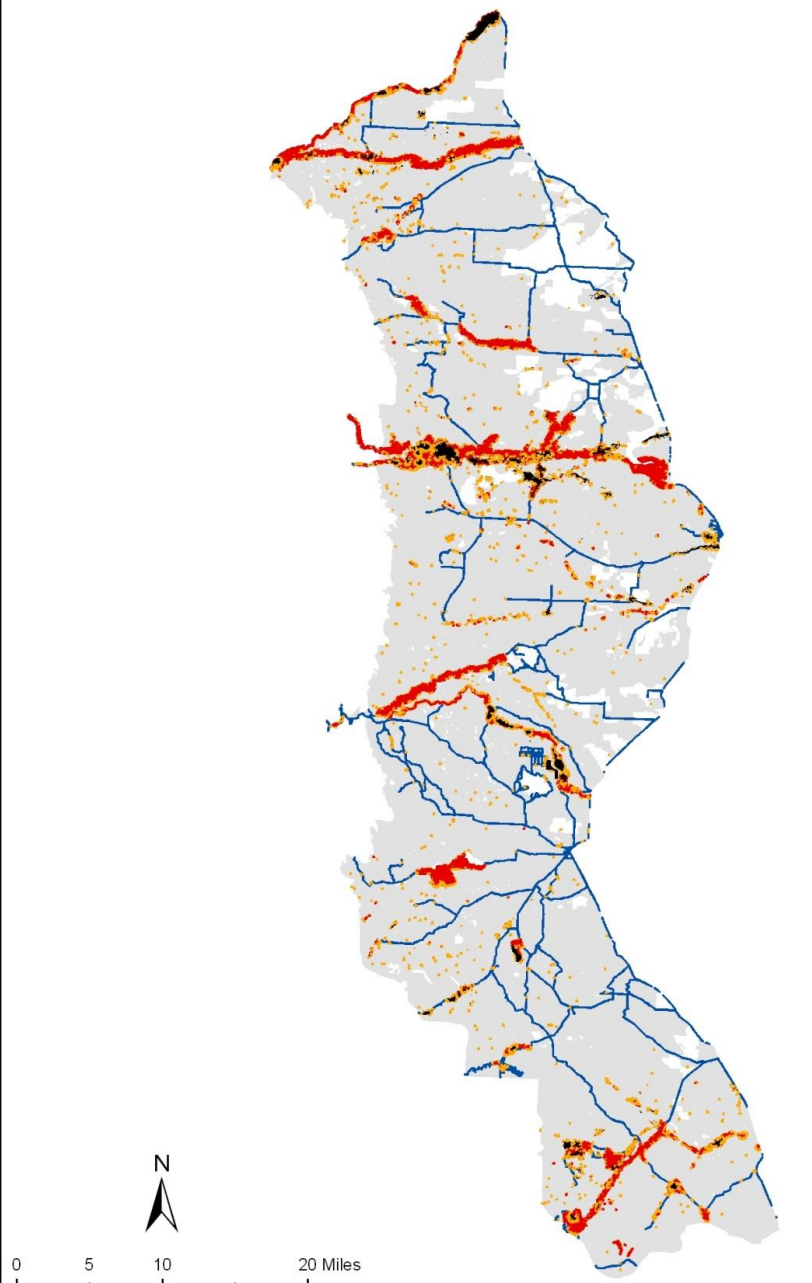
Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



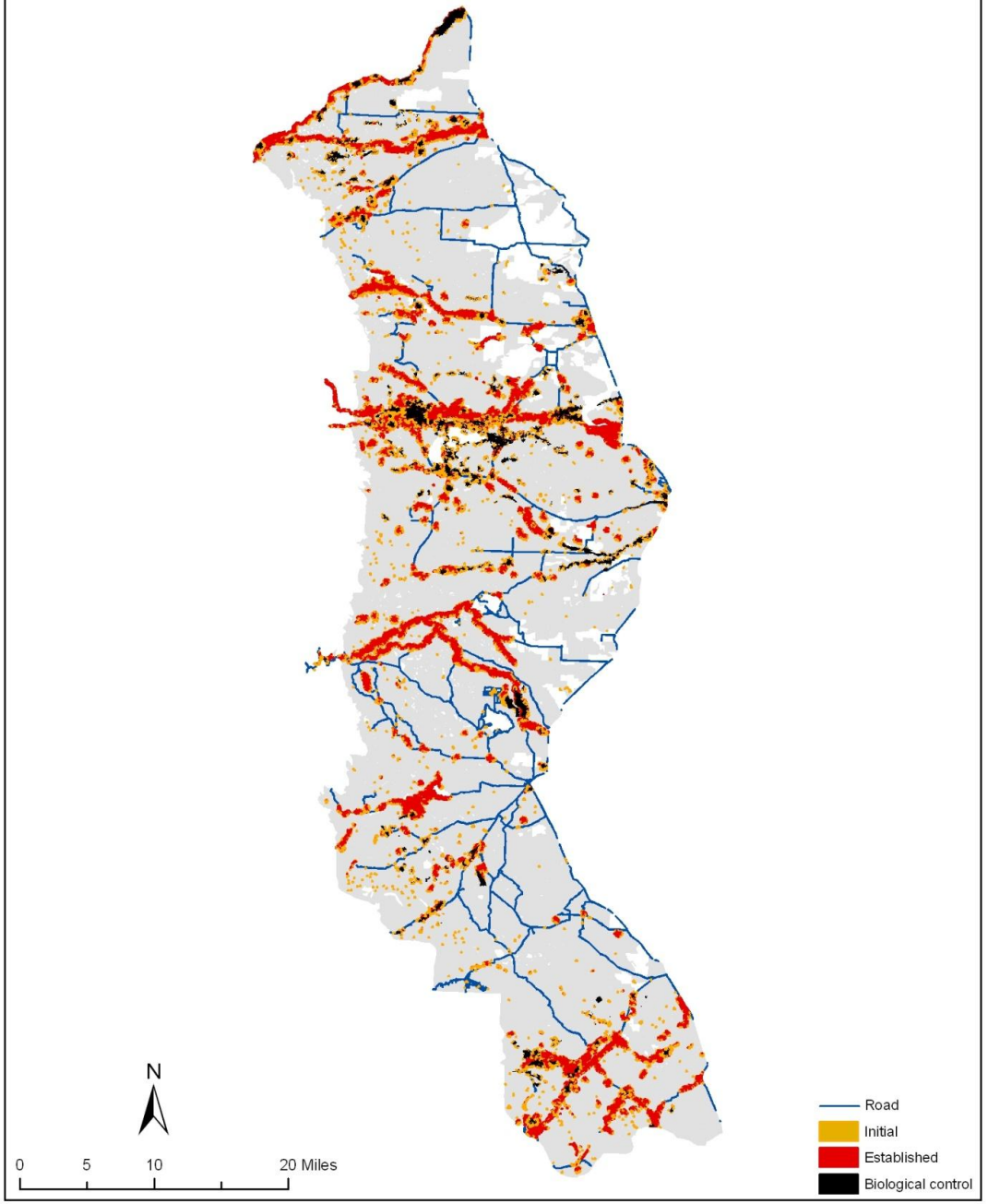
Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - 10 Years Delay Before Treatment Starts - Year 40



Rocky Mountain Front - Centaurea maculosa & E
High Spread - 2300 ha Management C



Rocky Mountain Front - Centaurea maculosa & Euphorbia esula -
High Spread - 15 Years Delay Before Treatment Starts - Year 40



Management Implications

- Importance of detecting and tracking weed locations, including “eradicated” patches – GPS mapping is essential!
- Consistency and management success significantly influence long-term outcomes in these landscapes
- Focus on small patches (EDRR) more effective than prioritizing large patches (containment)
- Delaying treatment or inadequate budgets results in long-term impacts to ecosystems and economies –
“Go Big or Go Home!”

Management Implications

- Prevention important to reduce spread rates
- Effective management has net positive economic outcome for landscapes
- At broad scale prioritize relatively univaded areas over heavily invaded areas

Model Uncertainty

- Weed spread distributions in real landscapes, including patch expansion and long-distance spread
- Quantifying control effectiveness
- Probability of occurrence parameters for vegetation
- Indirect use and non-use costs and benefits of invasion and management actions

Future Model Applications

- Other species and landscapes
- Initial condition thresholds in economic and ecological viability (Prevention – Control – Restoration)
- Decision-making across broader and finer scales (1ha cell)
- Compare future weed distributions and population trends with model predictions
- When is biocontrol enough?

Coming soon to conserveonline.org/workspaces/montanaweedmodel

- Final report
- Executive summaries
- Presentations/Figures
- Maps
- Data
- Model Package

Many Thanks to the Many People who contributed to this Project!

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