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

David Hanna
Nathan Korb
Brad Bauer
Brian Martin

Leonardo Frid
Katy Bryan

Brett Holzer
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!!!
Unmanageable infestations…
Inconsistent effort…
COSTS!!!
Weeds are increasing!!!

Large-scale success???
Long-term success???
Are efforts sustainable?
Are efforts meaningful?
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?
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

- Un-invaded
- Initial Infestation
- Established Infestation
- Seedbank/Monitoring
- Biological Control

Transitions:
- Invasion
- Control
- Resurgence
- Escape
- Setback
- Setback or Failure
- Establishment
- Control Failure
- Eradication
- Dormancy

Increasing Cover of Invasive Weeds
State and Transition Model

- Un-invaded
  - Invasion
  - Control
  - Resurgence
  - Dormancy
  - Eradication

- Initial 1
  - Escape
  - Setback or Failure

- Initial 2
  - Escape
  - Setback or Failure
  - Biological Control

- Established
  - Escape
  - Setback
  - Control Failure
  - Extinction

Increasing Cover of Invasive Weeds
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

- **Un-invaded**
- **Initial 1**
- **Initial 2**
- **Established**

- **Invasion**
- **Control**
- **Escape**
- **Setback**

- **Eradication**
- **Resurgence**
- **Setback or Failure**
- **Establishment**
- **Control Failure**
- **Extinction**

- **Seedbank/Monitoring**
- **Biological Control**

- **Dormancy**

Increasing Cover of Invasive Weeds
Spatial Inputs

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

Not a Magic Black Box!
Knapweed Calibration
Spurge Calibration
Calibration Results

Area Invaded (ha)

<table>
<thead>
<tr>
<th>Year</th>
<th>Knapweed</th>
<th>Spurge</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>300</td>
<td>400</td>
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<tr>
<td>2008</td>
<td>500</td>
<td>600</td>
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</table>
Sample Management Scenarios

- No management
- No constraints
- Blocked
- Delay
- Small patch
- Large patch
Centennial Valley - TELSA Weed Model

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

Potential Vegetation Types
- Sagebrush
- Aspen
- Sandhills
- Riparian
- Water/Wetland
- Conifer
- Wet Meadow
- Unprojectable
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Scale: 0 2.5 5 10 Kilometers

N

0 2.5 5 10 Miles
Centennial Valley - TELSA Weed Model

Seedbank & Initial Knapweed
-- High Control -- Large Patch Edge Priority --
Year 50
0.05 spread with 400ha ceiling
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
- Aspen
- Sandhills
- Riparian
- Water/Wetland
- Conifer
- Wet Meadow
- Unprojectable

Scale: 1 inch = 1 mile (0.16 km)
Area Invaded and Treated After 50 Years
Centennial Valley
Spotted Knapweed - High Spread/Low Control

<table>
<thead>
<tr>
<th>Strategies</th>
<th>Area Invaded</th>
<th>Area Treated (cumulative)</th>
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<tr>
<td>No-MGT</td>
<td>25000</td>
<td>20000</td>
</tr>
<tr>
<td>200-LPE</td>
<td>25000</td>
<td>20000</td>
</tr>
<tr>
<td>200-SP</td>
<td>10000</td>
<td>10000</td>
</tr>
<tr>
<td>400-LPE</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>400-SP</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>
Sensitivity Analysis: Area Invaded or Treated by Strategy After 50 Years


NMGT  |  LPE-200  |  SP-200  |  LPE-400  |  SP-400

Treated

Invaded
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

HS 70% - Leafy Spurge Cover Type - Year 40

Leafy Spurge Cover
- Initial
- Established
- Biological control
- Seed bank
- Uninvaded

Scale: 0 0.5 1 2 3 Miles
Chemical Management and Biocontrol

HS 70% - Leafy Spurge Cover Type - Year 40

Leafy Spurge Cover
- Yellow: Initial
- Red: Established
- Black: Biological control
- Gray: Seed bank
- Uninvaded

Legend:
- 0 0.5 1 2 3 Miles
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%**
Management Scenarios

• **Standard** – Small patch priority, 70% treatment success rates
  – Range of treatment ceilings

• **Large patch priority**

• **I1 Aware**

• **95% treatment success**

• **Roaming**
# MGP Results

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Area Invaded (ha)</th>
<th>Area Treated (ha)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>No Management</td>
<td>6,050</td>
<td>3,150</td>
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<tr>
<td>Unlimited</td>
<td>61</td>
<td>49</td>
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<table>
<thead>
<tr>
<th>Spread Rate</th>
<th>Discount Rate</th>
<th>NPV (2008 $)</th>
<th>BCR</th>
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<tr>
<td>High</td>
<td>2.7%</td>
<td>86,424</td>
<td>1.51</td>
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<tr>
<td>Low</td>
<td>2.7%</td>
<td>944</td>
<td>1.00</td>
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Effects of Management on Weed Distribution at Year 40

Centennial Valley

Rocky Mountain Front

Mean Percent of Landscape Treated Annually

Mean Percent of Landscape Invaded at Yr 40

High Spread
Low Spread
CV Treatment over Time, High Spread Scenarios

[Graph showing the mean area treated (ha) over time for different 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

[Graph showing Net Present Value and Benefit Cost Ratio for High and Low Spread against Percentage of the Landscape Treated Annually]
CV Percent of Landscape Invaded at Year 40: Effects of Weed Spread and Strategy

![Graph showing mean percent of landscape invaded at year 40 for different strategies. The strategies include I1 Aware, Default, 95% Success, Large Patch Edges, I1 Aware, Default, 95% Success, Large Patch Edges. The graph indicates significant differences in the extent of invasion among the strategies.]
CV Percent of Landscape Treated Annually
Effects of Weed Spread and Strategy
CV Net Present Value (2008 $) at Year 40
Alternative Strategies

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<td>Low 95% Success</td>
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<td>Low Large Patch</td>
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<td>High I1 Aware</td>
<td>$450,000.00</td>
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<tr>
<td>High Default</td>
<td>$350,000.00</td>
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<tr>
<td>High 95% Success</td>
<td>$300,000.00</td>
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<tr>
<td>High Large Patch</td>
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Centennial Valley - TELSA Weed Model
Spotted Knapweed
Low Spread - 70 Percent Control Success
In Aware Management - Year 40
RMF Alternative Strategy Area Invaded

Percentage of Landscape Invaded at Year

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Effects of Delaying Management

Centennial Valley

Rocky Mountain Front

![Graphs showing the effects of delaying management across Centennial Valley and Rocky Mountain Front, with data points indicating the percent of landscape invaded at Yr-40 in relation to the number of years treatment delayed, for both low and high spread scenarios.](image-url)
Costs of Delaying Management

Centennial Valley

Rocky Mountain Front

[Graphs showing Net Present Value over Years Treatment Delayed for both high and low scenarios in Centennial Valley and Rocky Mountain Front.]
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 uninvaded 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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