Weed Treatment Planner (WTP) – A Spatial Decision Support System for Invasive Weed Management

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  - Background
  - Objectives

- Weed Treatment Planner (WTP 1.0)
  - Conceptual model
  - User interfaces for data entry

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  - Results and sensitivity analysis

- Concluding Remarks
Project Overview

- **Project period**
  - September 15, 2006 – September 30, 2010

- **Research Personnel**
  - **Project Investigators**
    - Woodam Chung, University of Montana
    - Greg Jones, USDA Forest Service
    - Peter Rice, University of Montana
    - Timothy Prather, University of Idaho
  - **Other research personnel**
    - Pablo Aracena, University of Montana
    - Janet Sullivan, USDA Forest Service
    - Kurt Krueger, USDA Forest Service
    - Larry Lass, University of Idaho
  - **Collaborators**
    - Gil Gale, Invasive Plants Program Leader, Bitterroot NF, MT
    - Pat Green, Forest Ecologist, Nez Perce NF, ID
    - Carl Crabtree, County Weed Program Leader, Idaho County, ID
It is difficult to optimize the use of suppression resources, especially late in the “eradication priority” stage and during most of the “control priority” stage.
Background

- Lack of the ability to analyze trade-offs between alternative spatial and temporal treatment strategies

- Trade-off analyses are critical to developing cost-effective treatment decisions in the usual case of limiting resources and budgets
Objectives

- Develop a spatially explicit decision support system for invasive weed species management
  - The system will offer the optimization of resource allocation in deciding among treatment alternatives by incorporating species specific spread dynamics

- Test the system on two National Forests: Bitterroot NF in Montana and Nez Perce NF in Idaho
Weed Treatment Planner (WTP)
Conceptual Model

Tabular Information

Spatial Data
- Weed species
- Vegetation types
- Site priority
- Streams
- Roads & trails

Susceptibility

Spread rates

Treatments
- Types
- Effectiveness
- Costs

Priority

Objectives

Budget Constraints

Simulated Annealing Algorithm For Optimization

- Optimal resource allocation
- What-if and trade-off analyses
Conceptual Model

Simulated Annealing Algorithm
For Optimization

Spatial Data
- Weed species
- Vegetation types
- Site priority
- Streams
- Roads & trails

Susceptibility

Spread rates

Treatments
- Types
- Effectiveness
- Costs

Priority

Objectives

Budget Constraints

"Weed species" layer

Optimal resource allocation
What-if and trade-off analyses
Conceptual Model

Simulated Annealing Algorithm For Optimization

- Spread rates
- Susceptibility

Tabular Information

- Treatments
  - Types
  - Effectiveness
  - Costs

Spatial Data
- Weed species
- Vegetation types
- Site priority
- Streams
- Roads & trails

GIS

Priority
Objectives
Budget Constraints

Optimal resource allocation
What-if and trade-off analyses

“Site priority” layer
Conceptual Model

Spatial Data
- Weed species
- Vegetation types
- Site priority
- Streams
- Roads & trails

“Treatment zone” layer

Tabular Information

- Spread rates
- Treatments
  - Types
  - Effectiveness
  - Costs

Simulated Annealing Algorithm For Optimization

GIS

- Priority
- Objectives
- Budget Constraints

Optimal resource allocation
What-if and trade-off analyses
Conceptual Model

Tabular Information

Simulated Annealing Algorithm For Optimization

Spread rates

Treatments
• Types
• Effectiveness
• Costs

Susceptibility

Spatial Data
• Weed species
• Vegetation types
• Site priority
• Streams
• Roads & trails

Priority

Objectives

Budget Constraints

"Accessibility" layer

GIS

• Optimal resource allocation
• What-if and trade-off analyses
“Weed species” layer

“Accessibility” layer

“Treatment zone” layer

“Site priority” layer

Rasterization and Union

Treatment units with unique attributes

Creating treatment units

Simulated Annealing Algorithm For Optimization
Conceptual Model

Tabular Information

Simulated Annealing Algorithm
For Optimization

Spatial Data
- Weed species
- Vegetation types
- Site priority
- Streams
- Roads & trails

Susceptibility

Spread rates

Treatments
- Types
- Effectiveness
- Costs

Priority

Objectives

Budget Constraints

- Optimal resource allocation
- What-if and trade-off analyses
Solution Evaluation

- **Temporal consideration**
  - The decision support system (DSS) is designed to develop yearly weed treatment plans for up to 5 years, but the effects of treatment plans are analyzed for 10 years

- **Objective Function**

\[
\text{Min } \sum_{j=1}^{10} \sum_{i=1}^{I} \left( \text{Infested Area}_{ij} \times \text{Species Priority Index}_i \times \text{Site Priority Index}_i \right)
\]

where \( i \) represents a grid cell, and \( j \) is year
Modeling Weeds Spread

- Modeling weeds spread and treatment effectiveness

Current

- Unsusceptible
- Susceptible

- Currently infested area

Future

- 2nd Year
- 4th Year
- Newly infested areas

Without treatment

With treatment
Developing Alternative Treatments

- Determining alternative application methods
Developing Alternative Treatments

- Determining alternative application methods
Developing Alternative Treatments

- Determining alternative application methods

Diagram:
- Helicopter
- Truck
- ATV
- Backpack sprayer

Paths:
- Roads
- Trails
Developing Alternative Treatments

- Determining herbicides and application areas

Diagram:
- Roads
- Riparian zones
- Stream
Optimization

- Selecting best locations, methods, timing of weed treatment

Create alternative weed treatment patterns and schedules

Simulated Annealing (SA) iterative optimization

Evaluate alternative treatment patterns and schedules

The optimal treatment location, timing, species to minimize total infested acres over planning periods

- Budget constraints
- Treatment costs and effectiveness
- Spread rates and susceptibility
- Species and site priorities
WTP: User Interfaces
WTP: User Interfaces

Select the layer in each combo-box before click on the Go button.

Select Weed Layer: Weed
Select Main Road Layer: Road
Select Trails Layer: Road&Trail
Select Stream Layer: Stream
Select Vegetation Layer: Vegetation
Select Disturbance Layer: Disturbance Layer...
Select Site Priority Layer: Site Priority

[Images of maps showing different layers]
<table>
<thead>
<tr>
<th>Weed</th>
<th>Rank (1-5)</th>
<th>Spread Rate (m/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffuse knapweed</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Dalmatian toadflax</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Common St. Johnswort</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Common cupina</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Puncturevine</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Mediterranean sage</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Leaky spurge</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Japanese knotweed</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Toched spurge</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Smirled knapweed</td>
<td>3</td>
<td>50</td>
</tr>
</tbody>
</table>
WTP: User Interfaces
<table>
<thead>
<tr>
<th>Weed</th>
<th>Treatment</th>
<th>Method</th>
<th>Cost ($/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow starthistle</td>
<td>Milestone 5 oz</td>
<td>Truck</td>
<td>52.3</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Milestone 5 oz</td>
<td>Helicopter</td>
<td>27.3</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Milestone 5 oz</td>
<td>ATV</td>
<td>112.3</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Milestone 5 oz</td>
<td>Horse</td>
<td>112.3</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Milestone 5 oz</td>
<td>Backpack sprayer</td>
<td>237.3</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Tordon 1.5 pt</td>
<td>Truck</td>
<td>57.21</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Tordon 1.5 pt</td>
<td>Helicopter</td>
<td>32.21</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Tordon 1.5 pt</td>
<td>ATV</td>
<td>117.21</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Tordon 1.5 pt</td>
<td>Horse</td>
<td>117.21</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>Tordon 1.5 pt</td>
<td>Backpack sprayer</td>
<td>242.21</td>
</tr>
<tr>
<td>Toothed spurge</td>
<td>Plateau 11 oz + 1 qt MSO</td>
<td>Truck</td>
<td>58.5</td>
</tr>
<tr>
<td>Toothed spurge</td>
<td>Plateau 11 oz + 1 qt MSO</td>
<td>Helicopter</td>
<td>43.5</td>
</tr>
</tbody>
</table>
System Application
Application Area

- Spatial Data
  - 130,262 acres (a part of the Nez Perce National Forest, ID)
Input Data

- **Spatial Data**
  - Infested Areas: 4,216 acres (6% of the study area)
Input Data

- Spatial Data
  - Existing Roads: 41.7 miles
  - Trails: 510.1 miles
  - Streams: 107.2 miles
### Tabular Data

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Ranks</th>
<th>Spread rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common crupina</td>
<td>3</td>
<td>150 ft/year</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>1</td>
<td>150 ft/year</td>
</tr>
<tr>
<td>Scotch thistle</td>
<td>4</td>
<td>500 ft/year</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>2</td>
<td>150 ft/year</td>
</tr>
<tr>
<td>Yellow starthistle</td>
<td>5</td>
<td>150 ft/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Treatment type</th>
<th>Applicable for riparian zone (Y/N)</th>
<th>Efficacy (Effects right after treatment)</th>
<th>Duration (Weed re-establishment rates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoary cress</td>
<td>Plateau 12 oz + 1 qt MSO</td>
<td>Yes</td>
<td>Stop spreading</td>
<td>2 years</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>2,4-D 4 pt</td>
<td>No</td>
<td>Stop spreading</td>
<td>1 year</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>Tordon 1pt</td>
<td>No</td>
<td>Stop spreading</td>
<td>3 years</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>Milestone 7 oz</td>
<td>Yes</td>
<td>Stop spreading</td>
<td>3 years</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
## Tabular Data

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Weed species</th>
<th>Susceptibility*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas Fir</td>
<td>Scotch thistle</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Common crupina</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Spotted knapweed</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Hoary cress</td>
<td>D</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>Scotch thistle</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Common crupina</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>Spotted knapweed</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>Hoary cress</td>
<td>D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Treatment type</th>
<th>Application method</th>
<th>Cost per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common crupina</td>
<td>Tordon 1 pt</td>
<td>Backpack sprayer</td>
<td>$225/acre + chemical</td>
</tr>
<tr>
<td></td>
<td>Escort 1 oz 0.25% v/v NIS</td>
<td>Backpack sprayer</td>
<td>$225/acre + chemical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATV</td>
<td>$100/acre + chemical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helicopter</td>
<td>$15/acre + chemical</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>Tordon 1pt</td>
<td>Backpack sprayer</td>
<td>$225/acre + chemical</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>2,4-D 4 pt</td>
<td>Horse</td>
<td>$200/acre + chemical</td>
</tr>
</tbody>
</table>

C: Close to invasion
D: Disturbance allows invasion
I: Invasive without disturbance
Application Results

- Treatment schedules

Year 1: 3,109 acres
Year 2: 2,737 acres
Year 3: 1,746 acres
Year 4: 2,372 acres
Year 5: 2,541 acres
Application Results

Estimated infestation acres in year 10 with no action

<table>
<thead>
<tr>
<th></th>
<th>Initial Condition</th>
<th>No Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow starthistle</td>
<td>5,500</td>
<td>14,539</td>
</tr>
<tr>
<td>Scotch thistle</td>
<td>3,350</td>
<td>32,753</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>987</td>
<td>11,188</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>715</td>
<td>2,411</td>
</tr>
<tr>
<td>Common crusina</td>
<td>182</td>
<td>819</td>
</tr>
</tbody>
</table>
### Application Results

#### Estimated infestation acres in year 10

<table>
<thead>
<tr>
<th>Invasive Plant Species</th>
<th>No Action</th>
<th>$50,000</th>
<th>$100,000</th>
<th>$200,000</th>
<th>$400,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow starthistle</td>
<td>14,539</td>
<td>13,287</td>
<td>12,281</td>
<td>12,094</td>
<td>10,390</td>
</tr>
<tr>
<td>Scotch thistle</td>
<td>32,753</td>
<td>27,435</td>
<td>27,063</td>
<td>24,228</td>
<td>22,418</td>
</tr>
<tr>
<td>Spotted knapweed</td>
<td>11,188</td>
<td>8,237</td>
<td>8,807</td>
<td>7,670</td>
<td>5,499</td>
</tr>
<tr>
<td>Hoary cress</td>
<td>2,411</td>
<td>2,335</td>
<td>2321</td>
<td>1,942</td>
<td>1,880</td>
</tr>
<tr>
<td>Common crupina</td>
<td>819</td>
<td>566</td>
<td>666</td>
<td>693</td>
<td>552</td>
</tr>
</tbody>
</table>

#### Map Legend (Budget $50,000)

- **Yellow starthistle** (Y. starthistle)
- **Scotch thistle** (S. thistle)
- **Spotted knapweed** (S. knapweed)
- **Hoary cress** (H. cress)
- **Common crupina** (C. crupina)

#### Map Legend (Budget $100,000)

#### Map Legend (Budget $200,000)

#### Map Legend (Budget $400,000)
Application Results

- Estimated total infested acres per species
Application Results

- Acres to be treated per species

Graph showing treated area (acres) vs. budget ($50,000 to $400,000) for different species:
  - Common crupina
  - Hoary cress
  - Scotch thistle
  - Spotted knapweed
  - Yellow starthistle
  - TOTAL
Application Results

- Application methods allocated under each budget scenario

![Graph showing treated area and average treatment cost by budget scenario and application method.](image)
Concluding Remarks

- Spatial decision support system for invasive weeds management (WTP) has been developed through the funding support of the USDA ERS’s PREISM

- WTP can facilitate trade-off analyses for alternatives
  - Which of multiple invasive species to treat (weed priorities, locations, etc.)
  - How to treat (various treatment methods)
  - Where to treat (site priorities, along road or trail networks, in main infestation areas, in satellite infestations, etc.)
Concluding Remarks

- Helps national forests and other public land management agencies develop efficient management strategies that achieve the maximum amount of weed control for a limited budget.

- Helps weed managers justify budget request and use of funds.

- Helps weed managers realize the importance of inventory, mapping and monitoring of noxious weeds.
Concluding Remarks

- Lack of weed dispersal models and information on efficacy of treatments
- WTP will be improved through another research project funded by the USDA National Research Initiative program (PI: Tim Prather)
  - Developing weed dispersal models
  - Estimating market and non-market damage costs of not treating invaders
  - Incorporating the above outcomes into WTP
Questions or comments?