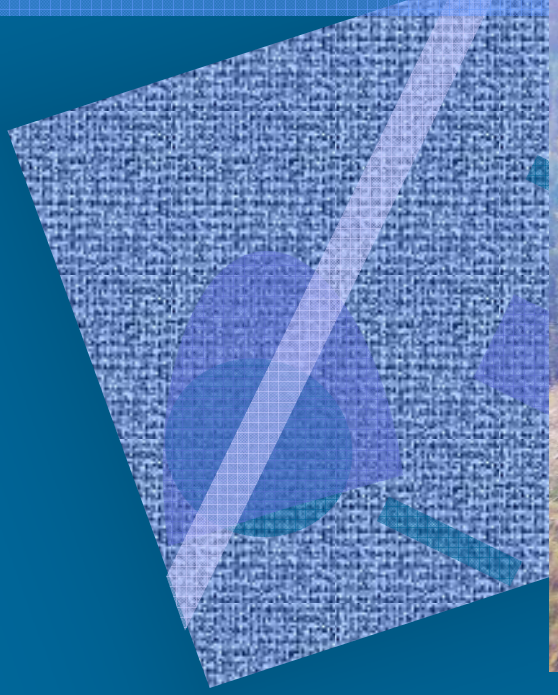
Developing a Landscape-Level Decision Support System (DSS) for Invasive Weed Species Management



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The University of Montana

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  - Objectives
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  - Conceptual Model of DSS
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- Work that remains to be done
  - Heuristic Optimizer
  - Applications
  - Online Tutorials

Project Overview

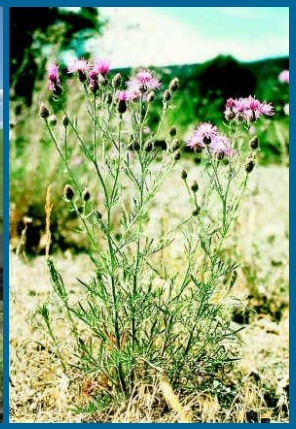
- Project period
  - September 15, 2006 – September 30, 2009
- Research Personnel
  - Project Investigators
    - Woodam Chung, University of Montana
    - Greg Jones, USDA Forest Service
    - Peter Rice, University of Montana
    - Timothy Prather, University of Idaho
  - Other research personnel
    - 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

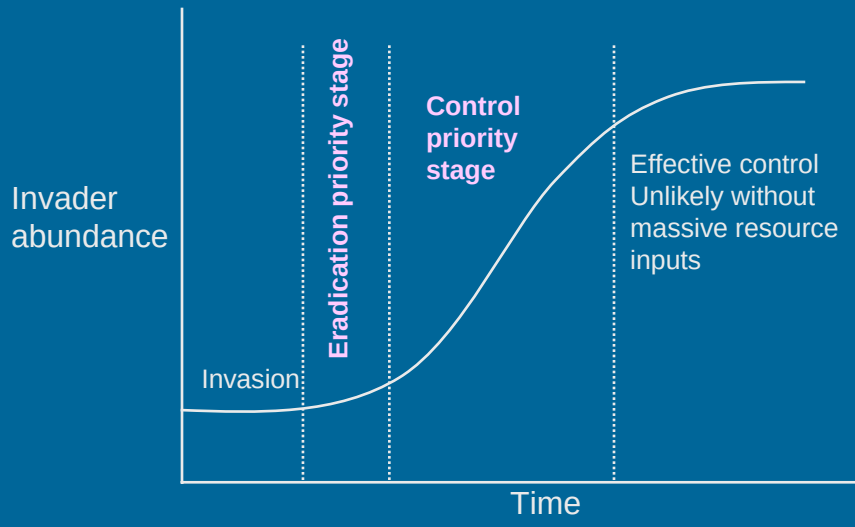
Background

- 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


Rush skeletonweed


Dalmatian toadflax


Spotted knapweed



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

Leafy spurge

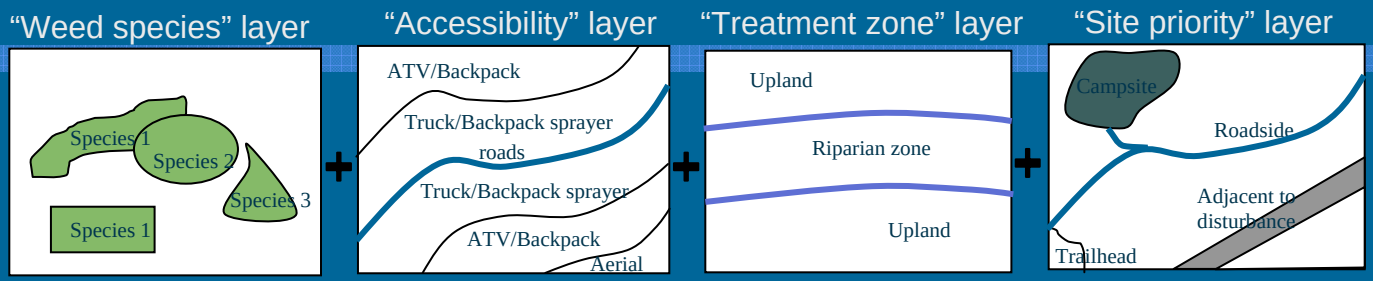
Objectives

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

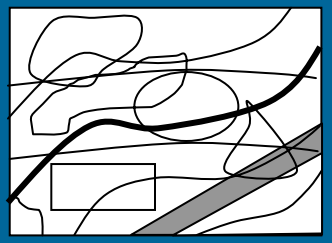
Objectives

- Test the system on two National Forests: Bitterroot NF in Montana and Nez Perce NF in Idaho
- Develop online tutorials and decision support system documentation for other applications

Conceptual Model of DSS



Union



Small polygons within infested areas become unique treatment units

Rasterization

Tabular data
- Species priority index
- Spread rates
- Treatment effects
- Treatment costs
- Susceptibility

Simulated Annealing (SA) iterative optimization

Constraints
- Budget
- …

Outputs

- Treatment plans for next 5 years
- Costs and other information of selected treatments
- Estimated treatment effects over next 10 years

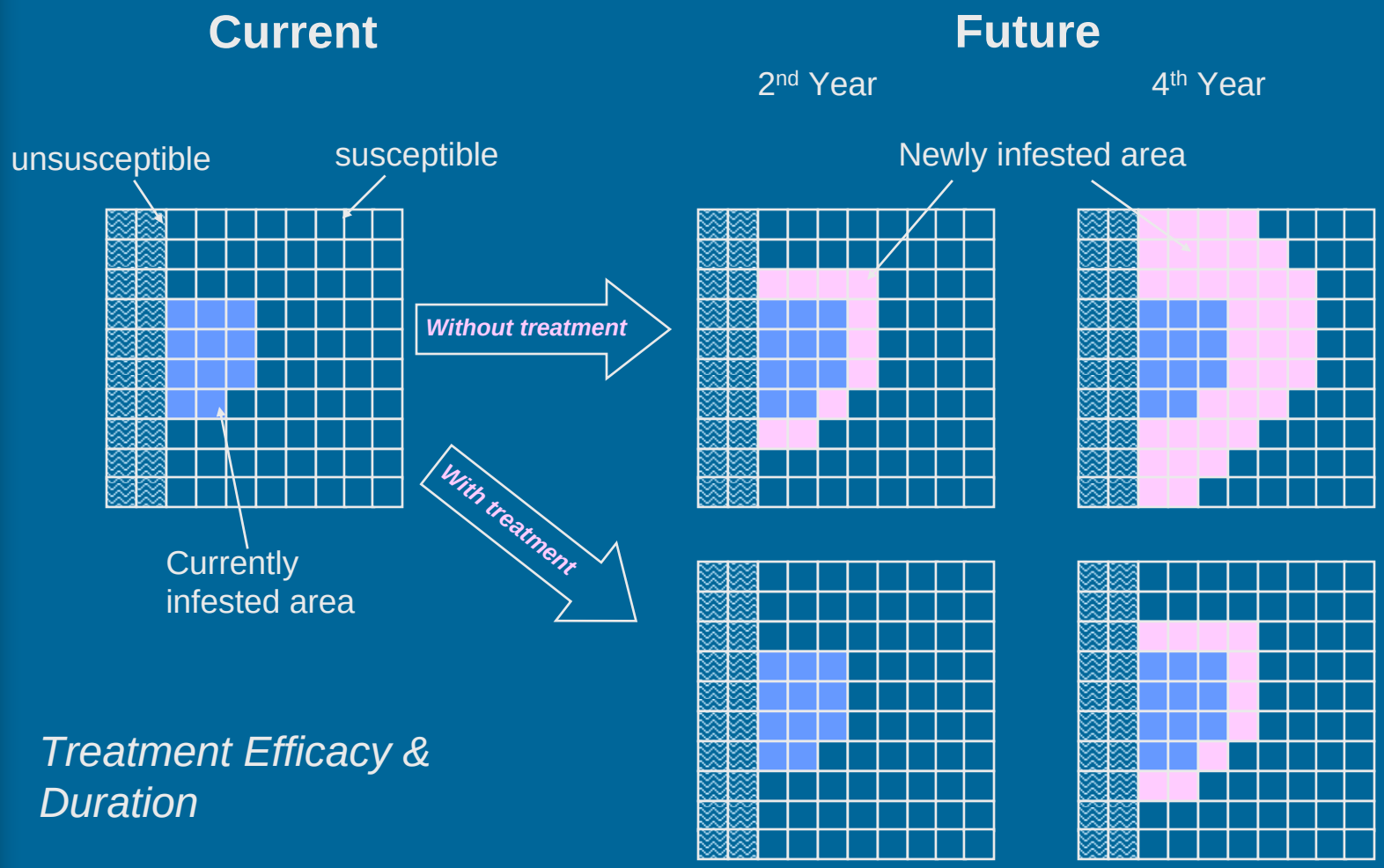
Conceptual Model of DSS

- Objective Function

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

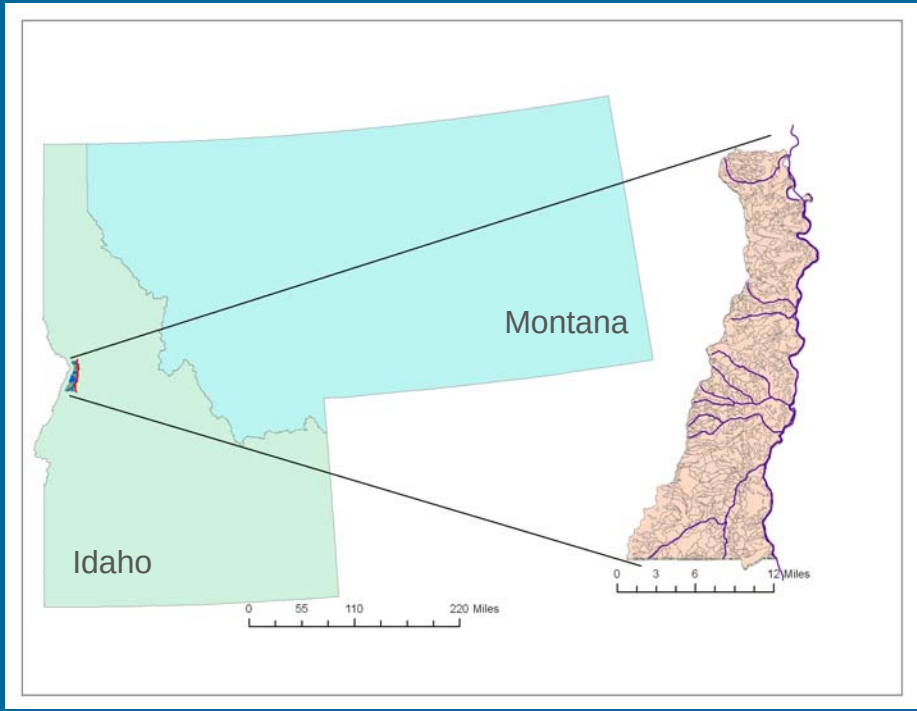
where *i* represents a grid cell, and *j* is year

Conceptual Model of DSS



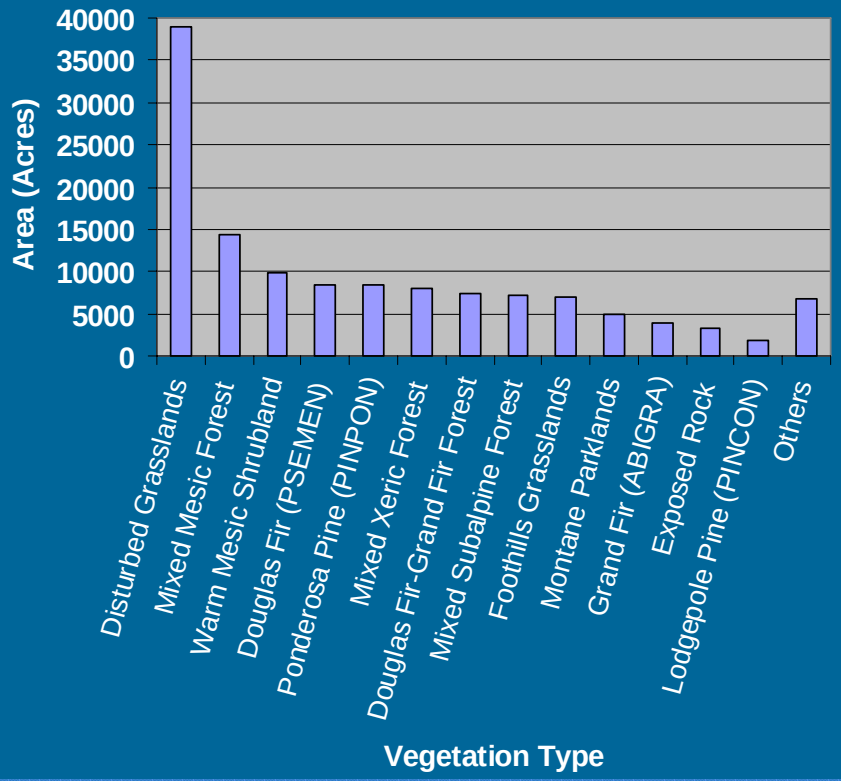
Example Data Collection

- Spatial Data
  - 130,000 acres (part of the Nez Perce National Forest, ID)



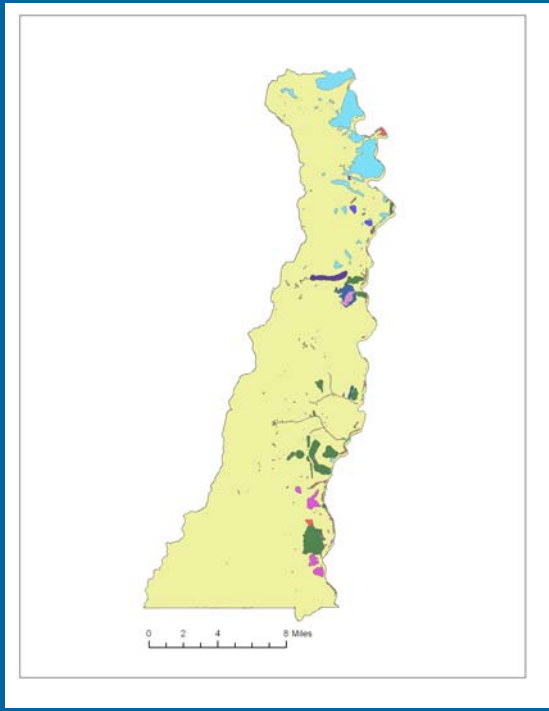
Example Data Collection

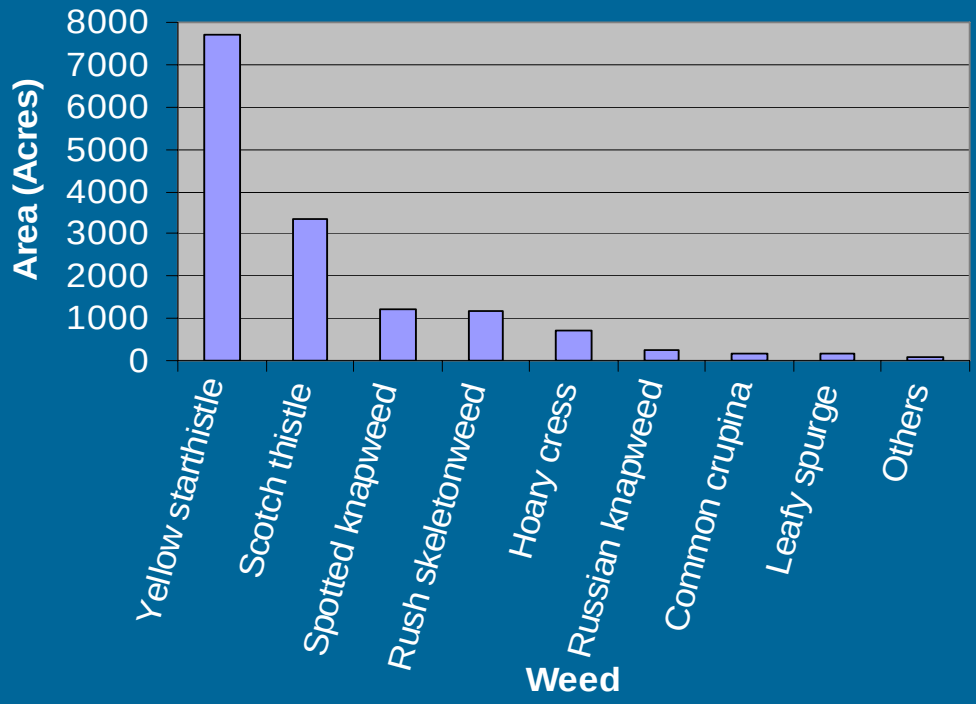
- Spatial Data
  - Vegetation Types (PNV)



Example Data Collection

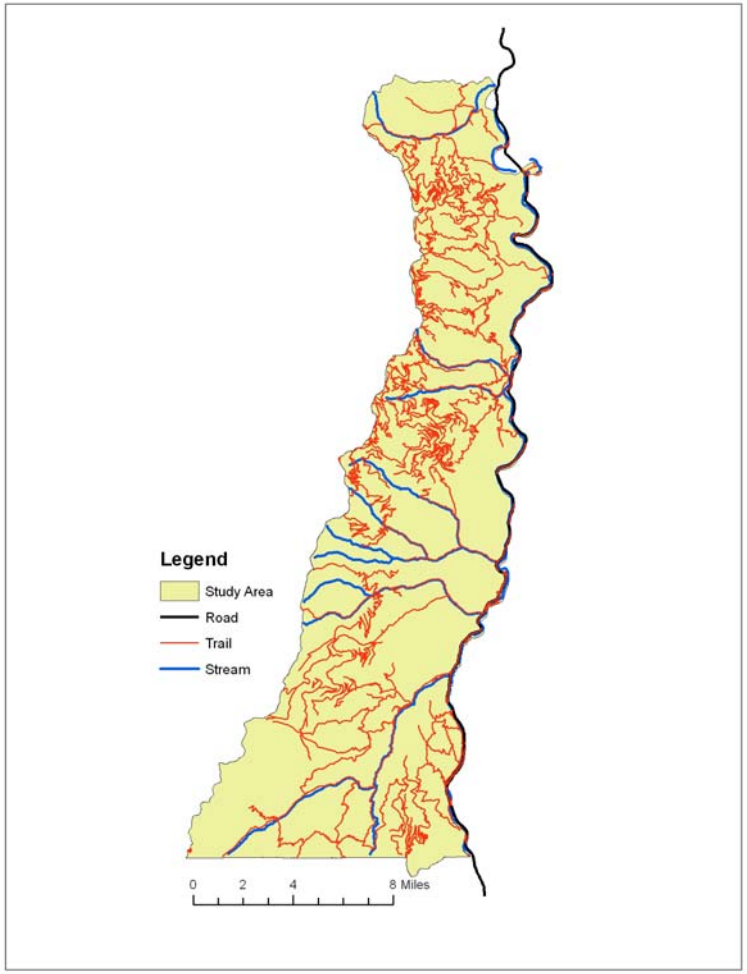
- Spatial Data
  - Infested Areas: 14,800 acres (11% of the study area)





Example Data Collection

- Spatial Data
  - Existing Roads: 42 miles
  - Trails: 563 miles
  - Streams: 126 miles



Example Data Collection

- Spatial Data
  - Site Priority
    - Land types
    - Recreation areas
    - Road locations

Example Data Collection

- Tabular Data

Weed species	***Ranks***
Rush skeletonweed	1 (highest)
Japanese knotweed	3
Mediterranean sage	4
…	…

Weed species	***Spread rates***
Rush skeletonweed	1000 m/year
Japanese knotweed	10 m/year
Mediterranean sage	100 m/year
…	…

Weed species	***Treatment type***	***Applicable for riparian zone (Y/N)***	***Effectiveness***	
			Efficacy (Effects right after treatment)	*Duration (Weed re-establishment rates)*
Rush skeletonweed	Transline 1 pt	No	Stop spreading	2 years
Rush skeletonweed	2,4-D 4 pt	Yes	Stop spreading	1 year
Japanese knotweed	Arsenal 3pt + 1 qt MSO	Yes	Stop spreading	5 years
Mediterranean sage	2,4-D 3 pt + 0.25% v/v NIS	Yes	Stop spreading	2 years
…	…		…	…

Example Data Collection

- Tabular Data

Weed species	*Treatment type*	*Application method*	*Cost per acre*
Rush skeletonweed	Transline 1 pt	Backpack sprayer	$225/acre + chemical
	2,4-D 4 pt	Backpack sprayer	$225/acre + chemical
		ATV	$100/acre + chemical
		Helicopter	$15/acre + chemical
Japanese knotweed	Arsenal 3pt + 1 qt MSO	Backpack sprayer	$225/acre + chemical
		ATV	$100/acre + chemical
Mediterranean sage	2,4-D 3 pt + 0.25% v/v NIS	Horse	$100/acre + chemical
…	…	…	…

Example Data Collection

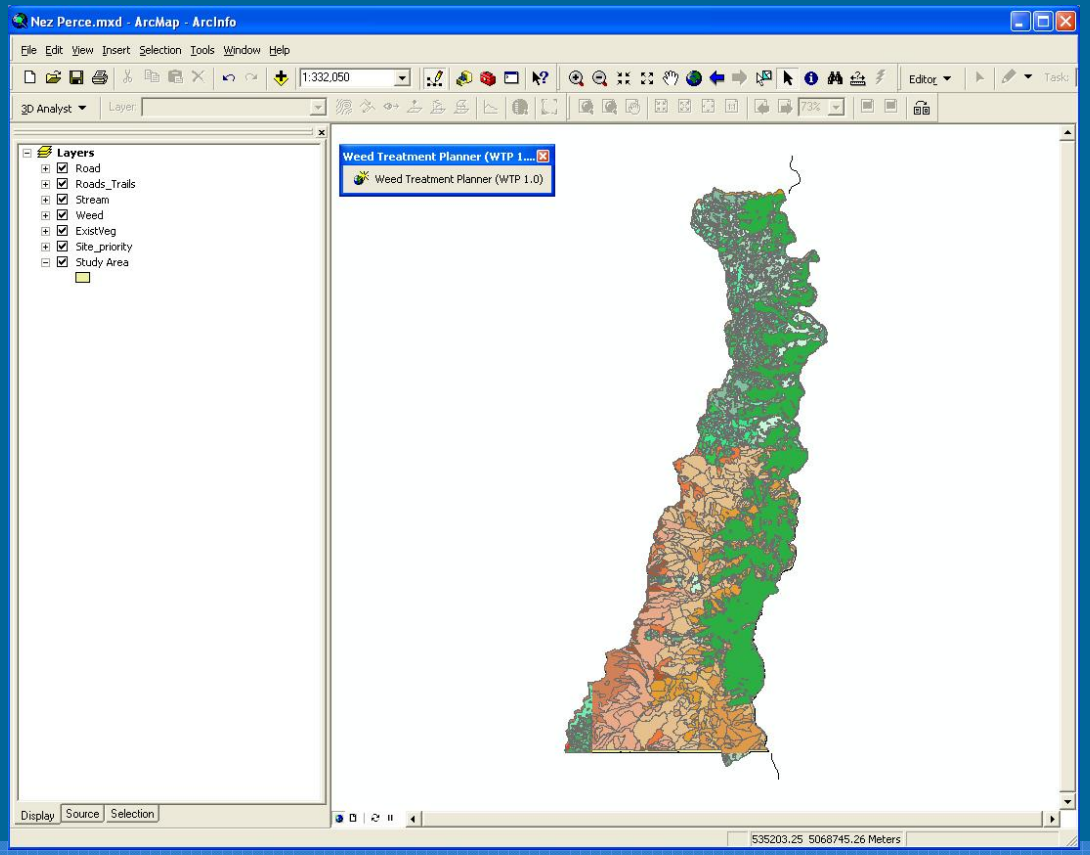
- Tabular Data

Vegetation Type	***Weed species***	***Susceptibility****
Douglas Fir	Rush skeletonweed	D
	Japanese knotweed	D
	Mediterranean sage	D
Ponderosa Pine	Rush skeletonweed	D
	Japanese knotweed	C
	Mediterranean sage	I
…	…	…

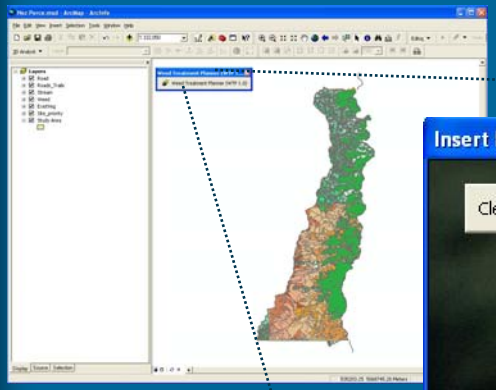
C: Close to invasion
D: Disturbance allows invasion
I: Invasive without disturbance

User Interfaces

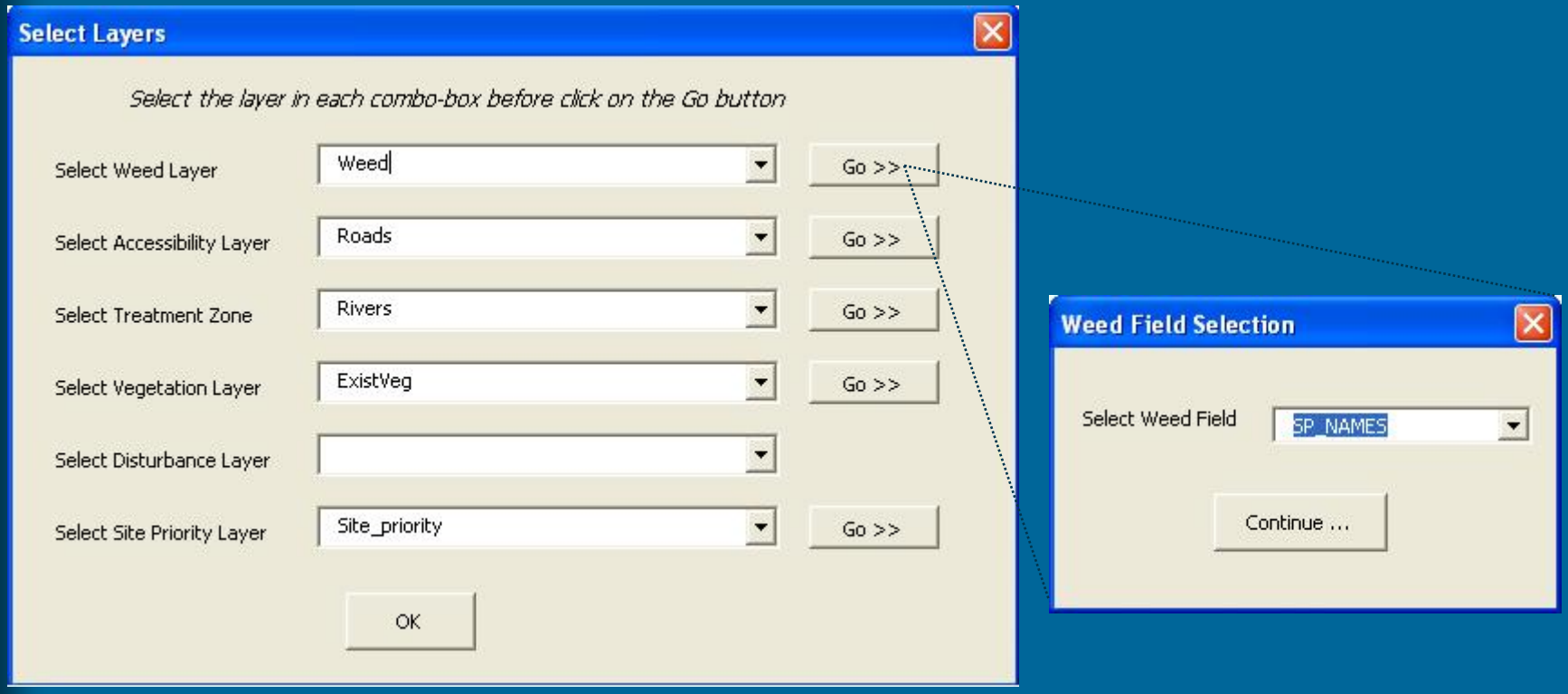
- ArcGIS Application (Weed Treatment Planner 1.0)

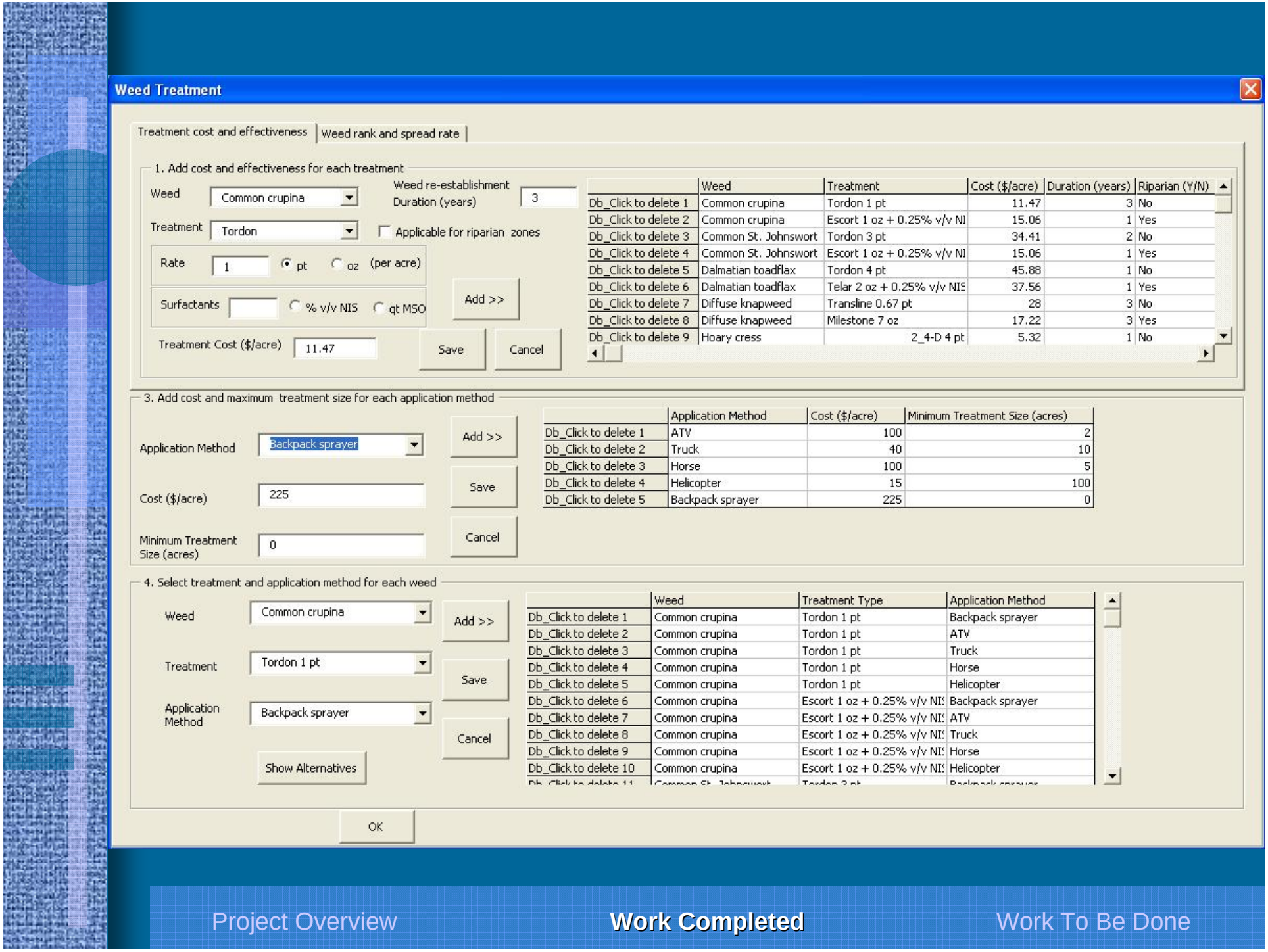


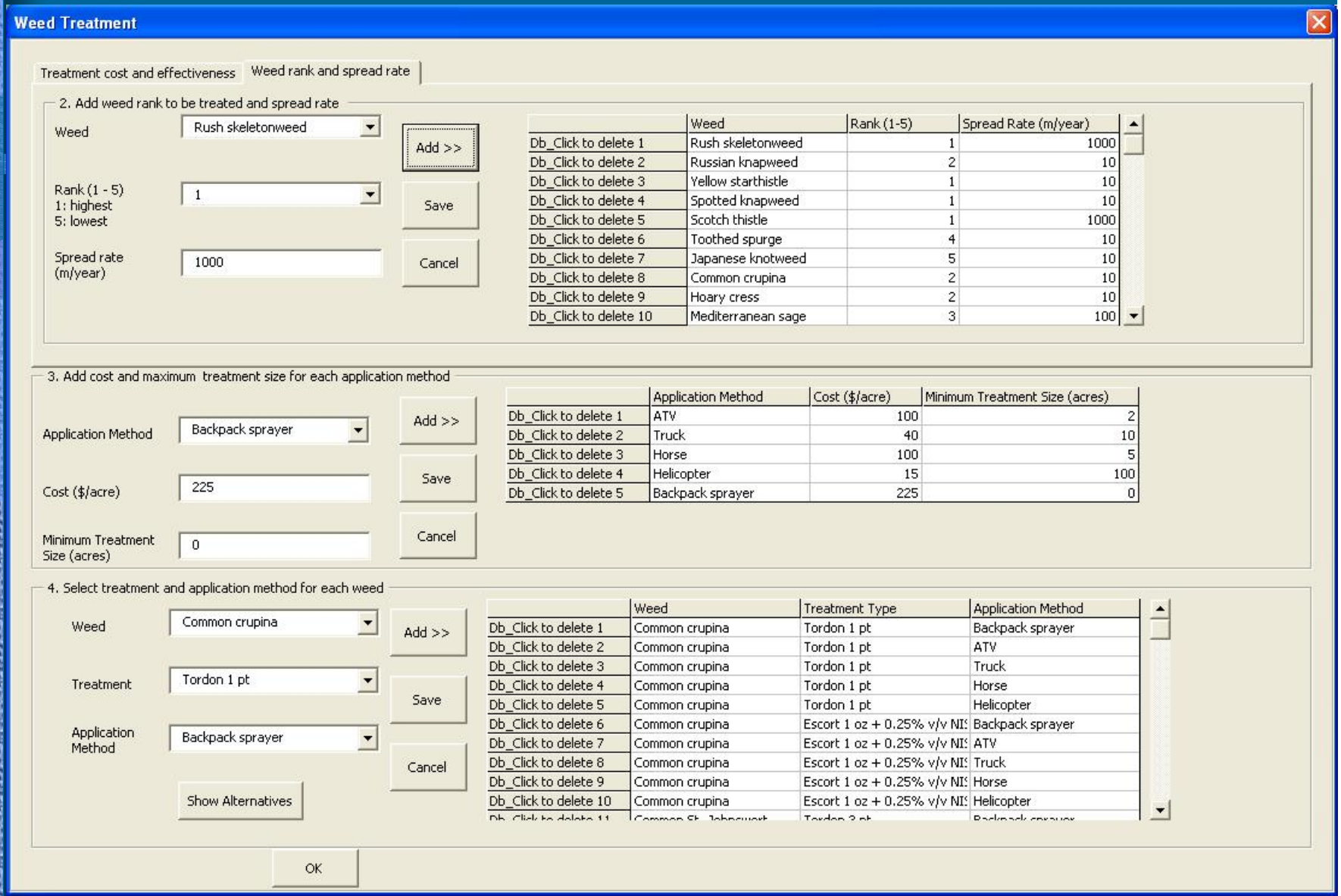
User Interfaces

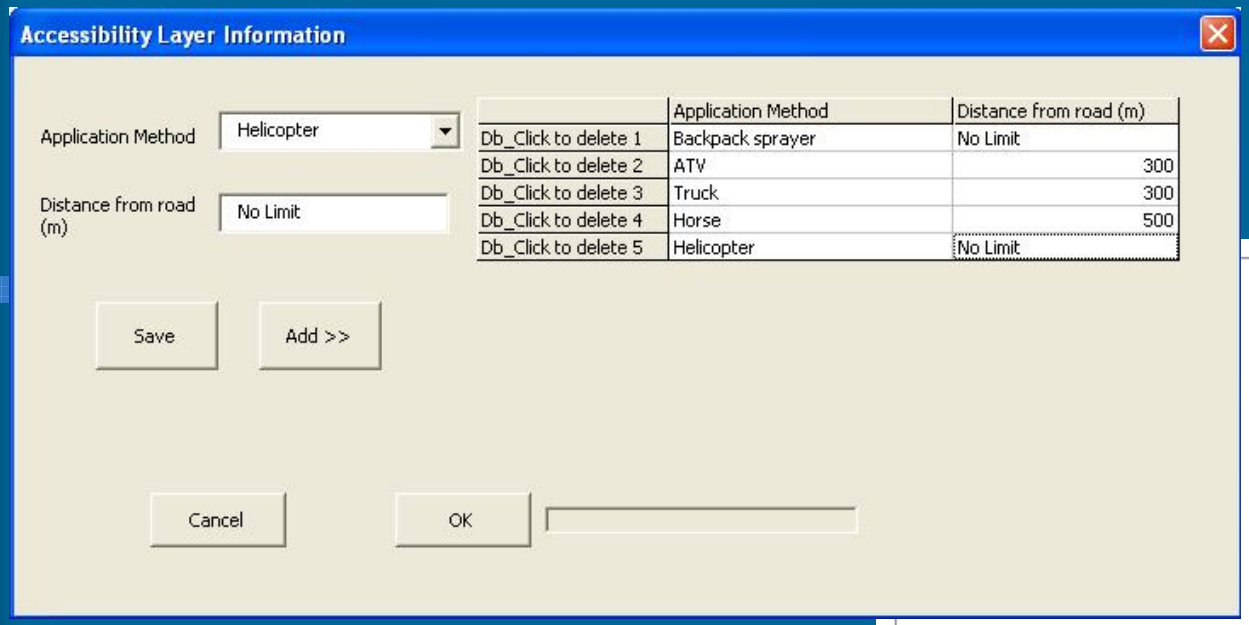


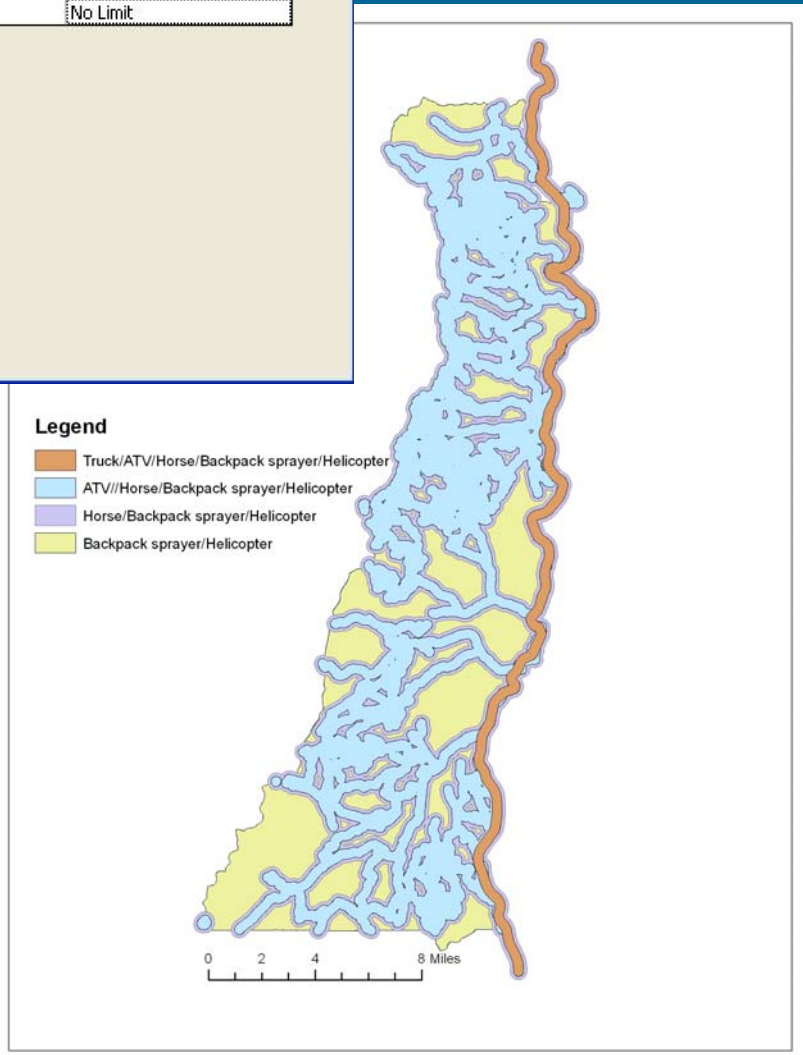
User Interfaces

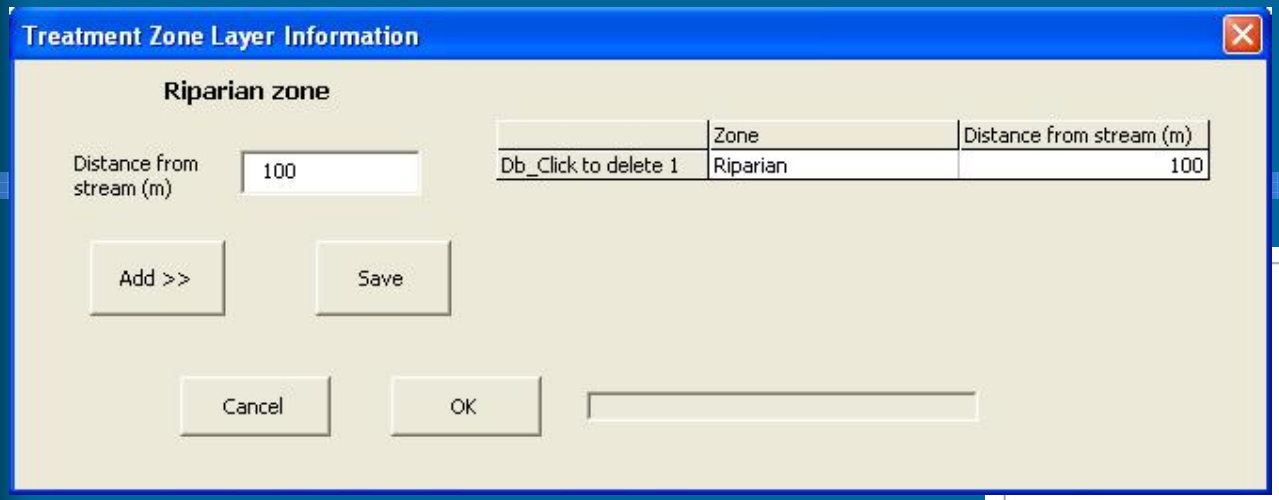


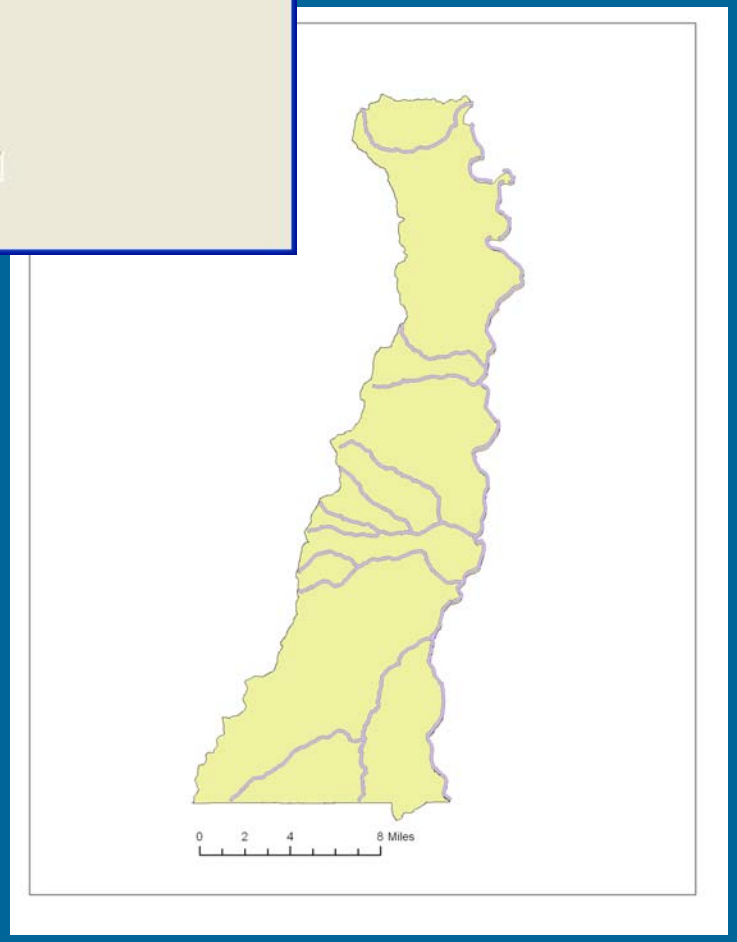

Weed Treatment
Treatment cost and effectiveness
Weed rank and spread rate
1. Add cost and effectiveness for each treatment
Weed
Common crupina
Weed re-establishment Duration (years)
3
Treatment
Tordon
Applicable for riparian zones
Rate
1
pt
oz
(per acre)
Surfactants
% v/v NIS
qt MSO
Add >>
Treatment Cost ($/acre)
11.47
Save
Cancel
Db_Click to delete 1 Common crupina Tordon 1 pt 11.47 3 No
Db_Click to delete 2 Common crupina Escort 1 oz + 0.25% v/v NI 15.06 1 Yes
Db_Click to delete 3 Common St. Johnswort Tordon 3 pt 34.41 2 No
Db_Click to delete 4 Common St. Johnswort Escort 1 oz + 0.25% v/v NI 15.06 1 Yes
Db_Click to delete 5 Dalmatian toadflax Tordon 4 pt 45.88 1 No
Db_Click to delete 6 Dalmatian toadflax Telar 2 oz + 0.25% v/v NIS 37.56 1 Yes
Db_Click to delete 7 Diffuse knapweed Transline 0.67 pt 28 3 No
Db_Click to delete 8 Diffuse knapweed Milestone 7 oz 17.22 3 Yes
Db_Click to delete 9 Hoary cress 2_4-D 4 pt 5.32 1 No
3. Add cost and maximum treatment size for each application method
Application Method
Backpack sprayer
Add >>
Cost ($/acre)
225
Save
Minimum Treatment Size (acres)
0
Cancel
Db_Click to delete 1 ATV 100 2
Db_Click to delete 2 Truck 40 10
Db_Click to delete 3 Horse 100 5
Db_Click to delete 4 Helicopter 15 100
Db_Click to delete 5 Backpack sprayer 225 0
4. Select treatment and application method for each weed
Weed
Common crupina
Add >>
Treatment
Tordon 1 pt
Save
Application Method
Backpack sprayer
Cancel
Show Alternatives
Db_Click to delete 1 Common crupina Tordon 1 pt Backpack sprayer
Db_Click to delete 2 Common crupina Tordon 1 pt ATV
Db_Click to delete 3 Common crupina Tordon 1 pt Truck
Db_Click to delete 4 Common crupina Tordon 1 pt Horse
Db_Click to delete 5 Common crupina Tordon 1 pt Helicopter
Db_Click to delete 6 Common crupina Escort 1 oz + 0.25% v/v NI Backpack sprayer
Db_Click to delete 7 Common crupina Escort 1 oz + 0.25% v/v NI ATV
Db_Click to delete 8 Common crupina Escort 1 oz + 0.25% v/v NI Truck
Db_Click to delete 9 Common crupina Escort 1 oz + 0.25% v/v NI Horse
Db_Click to delete 10 Common crupina Escort 1 oz + 0.25% v/v NI Helicopter
OK


Weed Treatment
Treatment cost and effectiveness
Weed rank and spread rate
2. Add weed rank to be treated and spread rate
Weed
Rush skeletonweed
Add >>
Rank (1 - 5)
1: highest
5: lowest
1
Save
Spread rate
(m/year)
1000
Cancel
Db_Click to delete 1 | Rush skeletonweed | 1 | 1000
Db_Click to delete 2 | Russian knapweed | 2 | 10
Db_Click to delete 3 | Yellow starthistle | 1 | 10
Db_Click to delete 4 | Spotted knapweed | 1 | 10
Db_Click to delete 5 | Scotch thistle | 1 | 1000
Db_Click to delete 6 | Toothed spurge | 4 | 10
Db_Click to delete 7 | Japanese knotweed | 5 | 10
Db_Click to delete 8 | Common crupina | 2 | 10
Db_Click to delete 9 | Hoary cress | 2 | 10
Db_Click to delete 10 | Mediterranean sage | 3 | 100
3. Add cost and maximum treatment size for each application method
Application Method
Backpack sprayer
Add >>
Cost ($/acre)
225
Save
Minimum Treatment
Size (acres)
0
Cancel
Db_Click to delete 1 | ATV | 100 | 2
Db_Click to delete 2 | Truck | 40 | 10
Db_Click to delete 3 | Horse | 100 | 5
Db_Click to delete 4 | Helicopter | 15 | 100
Db_Click to delete 5 | Backpack sprayer | 225 | 0
4. Select treatment and application method for each weed
Weed
Common crupina
Add >>
Treatment
Tordon 1 pt
Save
Application
Method
Backpack sprayer
Cancel
Show Alternatives
Db_Click to delete 1 | Common crupina | Tordon 1 pt | Backpack sprayer
Db_Click to delete 2 | Common crupina | Tordon 1 pt | ATV
Db_Click to delete 3 | Common crupina | Tordon 1 pt | Truck
Db_Click to delete 4 | Common crupina | Tordon 1 pt | Horse
Db_Click to delete 5 | Common crupina | Tordon 1 pt | Helicopter
Db_Click to delete 6 | Common crupina | Escort 1 oz + 0.25% v/v NI | Backpack sprayer
Db_Click to delete 7 | Common crupina | Escort 1 oz + 0.25% v/v NI | ATV
Db_Click to delete 8 | Common crupina | Escort 1 oz + 0.25% v/v NI | Truck
Db_Click to delete 9 | Common crupina | Escort 1 oz + 0.25% v/v NI | Horse
Db_Click to delete 10 | Common crupina | Escort 1 oz + 0.25% v/v NI | Helicopter
OK

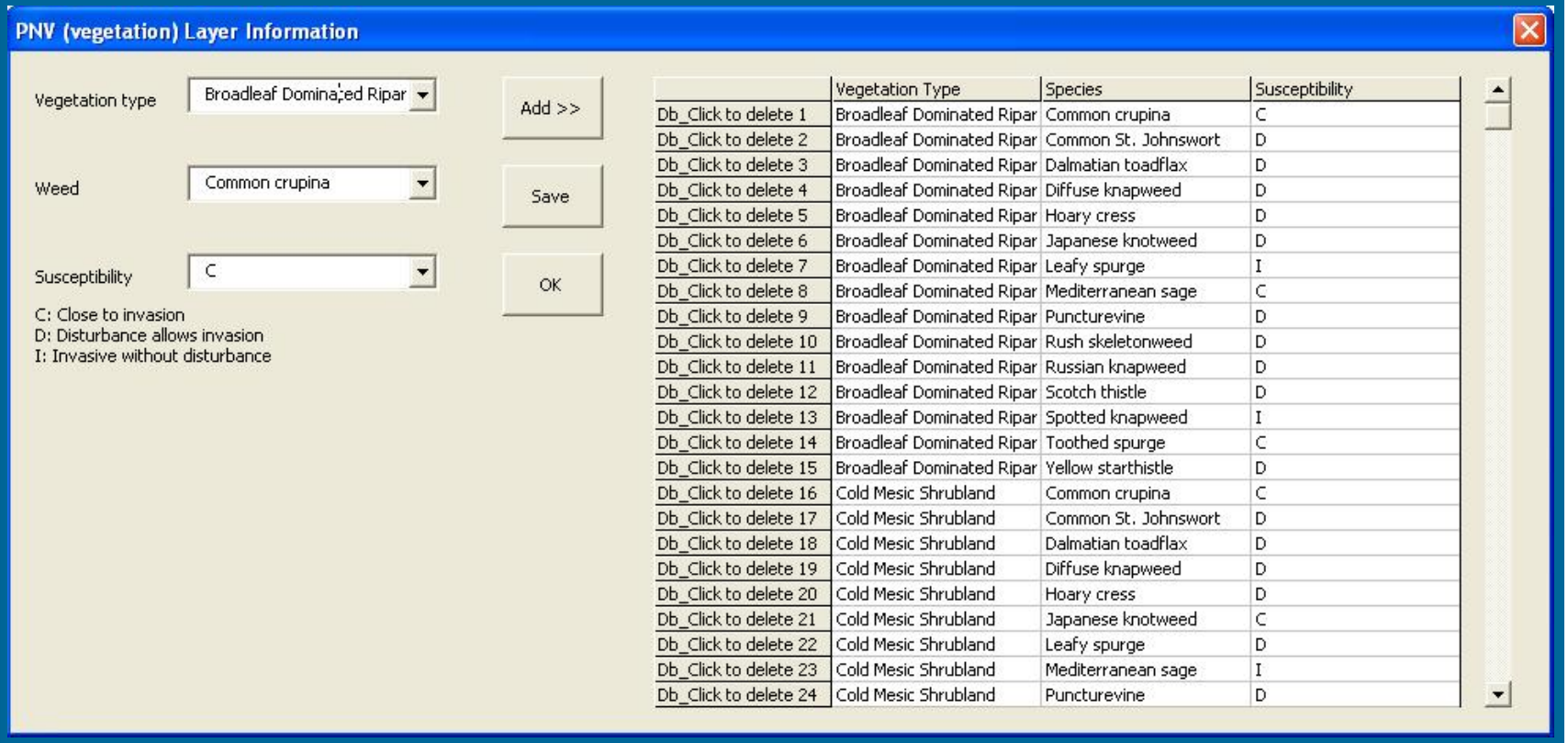

Accessibility Layer Information
Application Method
Helicopter
Distance from road (m)
No Limit
Save
Add >>
Cancel
OK
Db_Click to delete 1
Db_Click to delete 2
Db_Click to delete 3
Db_Click to delete 4
Db_Click to delete 5
Application Method
Distance from road (m)
Backpack sprayer
No Limit
ATV
300
Truck
300
Horse
500
Helicopter
No Limit


Legend
Truck/ATV/Horse/Backpack sprayer/Helicopter
ATV//Horse/Backpack sprayer/Helicopter
Horse/Backpack sprayer/Helicopter
Backpack sprayer/Helicopter
0
2
4
8 Miles

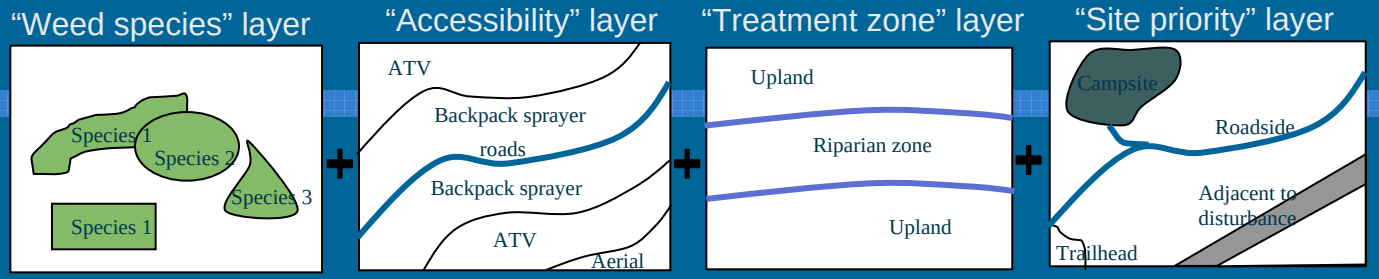

Treatment Zone Layer Information
Riparian zone
Distance from stream (m)
100
Add >>
Save
Cancel
OK
Zone
Distance from stream (m)
Db_Click to delete 1
Riparian
100


0
2
4
8 Miles

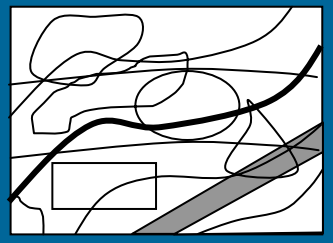

Vegetation and Weed Fields Selection
Select Vegetation Field
COVER_TY_N
Select Weed Field
SP_NAMES
Continue ...


PNV (vegetation) Layer Information
Vegetation type
Broadleaf Dominated Ripar
Weed
Common crupina
Susceptibility
C
C: Close to invasion
D: Disturbance allows invasion
I: Invasive without disturbance
Add >>
Save
OK
Vegetation Type
Species
Susceptibility
Db_Click to delete 1 Broadleaf Dominated Ripar Common crupina C
Db_Click to delete 2 Broadleaf Dominated Ripar Common St. Johnswort D
Db_Click to delete 3 Broadleaf Dominated Ripar Dalmatian toadflax D
Db_Click to delete 4 Broadleaf Dominated Ripar Diffuse knapweed D
Db_Click to delete 5 Broadleaf Dominated Ripar Hoary cress D
Db_Click to delete 6 Broadleaf Dominated Ripar Japanese knotweed D
Db_Click to delete 7 Broadleaf Dominated Ripar Leafy spurge I
Db_Click to delete 8 Broadleaf Dominated Ripar Mediterranean sage C
Db_Click to delete 9 Broadleaf Dominated Ripar Puncturevine D
Db_Click to delete 10 Broadleaf Dominated Ripar Rush skeletonweed D
Db_Click to delete 11 Broadleaf Dominated Ripar Russian knapweed D
Db_Click to delete 12 Broadleaf Dominated Ripar Scotch thistle D
Db_Click to delete 13 Broadleaf Dominated Ripar Spotted knapweed I
Db_Click to delete 14 Broadleaf Dominated Ripar Toothed spurge C
Db_Click to delete 15 Broadleaf Dominated Ripar Yellow starthistle D
Db_Click to delete 16 Cold Mesic Shrubland Common crupina C
Db_Click to delete 17 Cold Mesic Shrubland Common St. Johnswort D
Db_Click to delete 18 Cold Mesic Shrubland Dalmatian toadflax D
Db_Click to delete 19 Cold Mesic Shrubland Diffuse knapweed D
Db_Click to delete 20 Cold Mesic Shrubland Hoary cress D
Db_Click to delete 21 Cold Mesic Shrubland Japanese knotweed C
Db_Click to delete 22 Cold Mesic Shrubland Leafy spurge D
Db_Click to delete 23 Cold Mesic Shrubland Mediterranean sage I
Db_Click to delete 24 Cold Mesic Shrubland Puncturevine D

Work Completed



Union



Small polygons within infested areas become unique treatment units

Rasterization

Tabular data
- Species priority index
- Treatment site priority index
- Spread rates
- Treatment effects
- Treatment costs

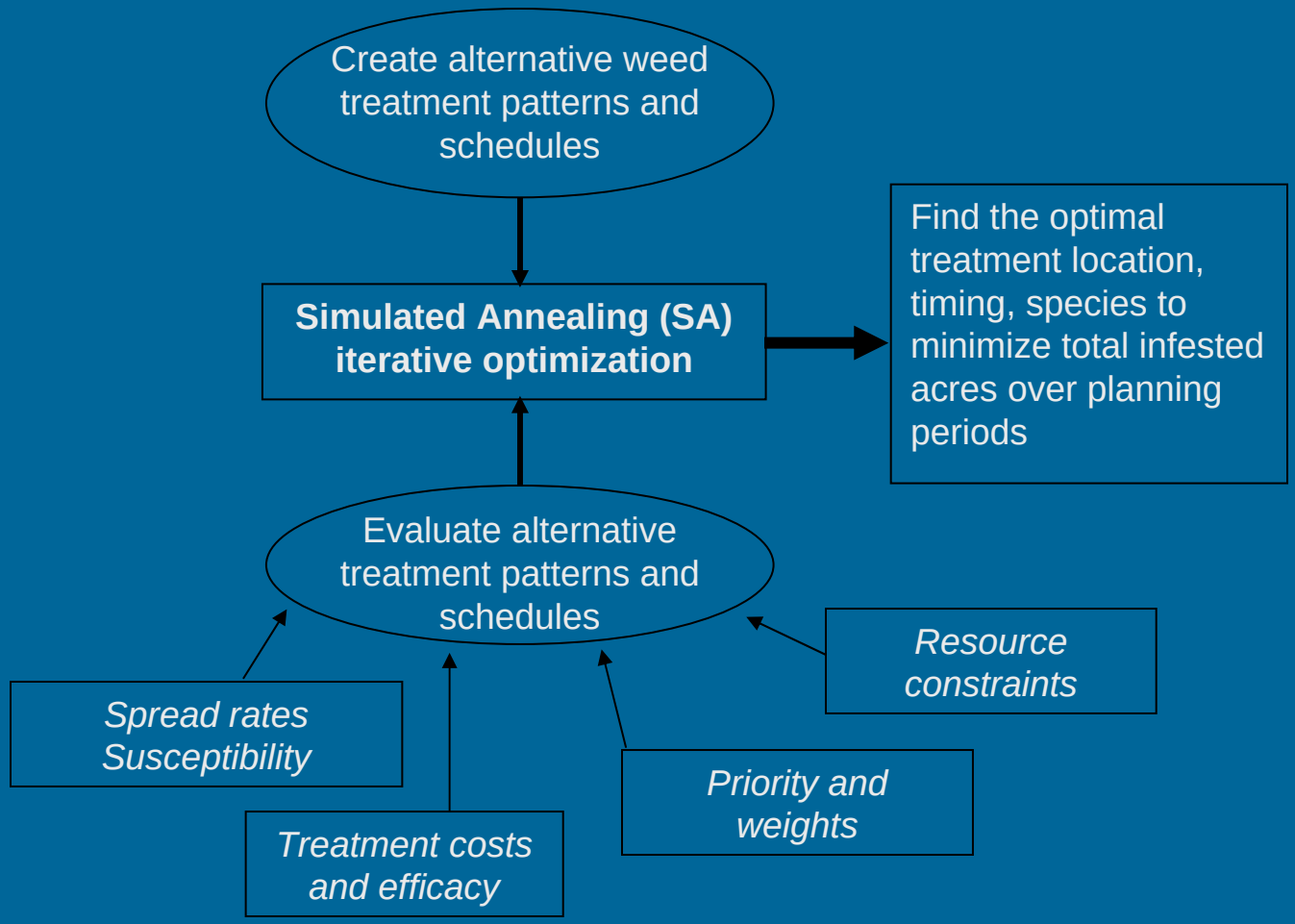
Simulated Annealing (SA) iterative optimization

Constraints
- Budget
- …

Outputs

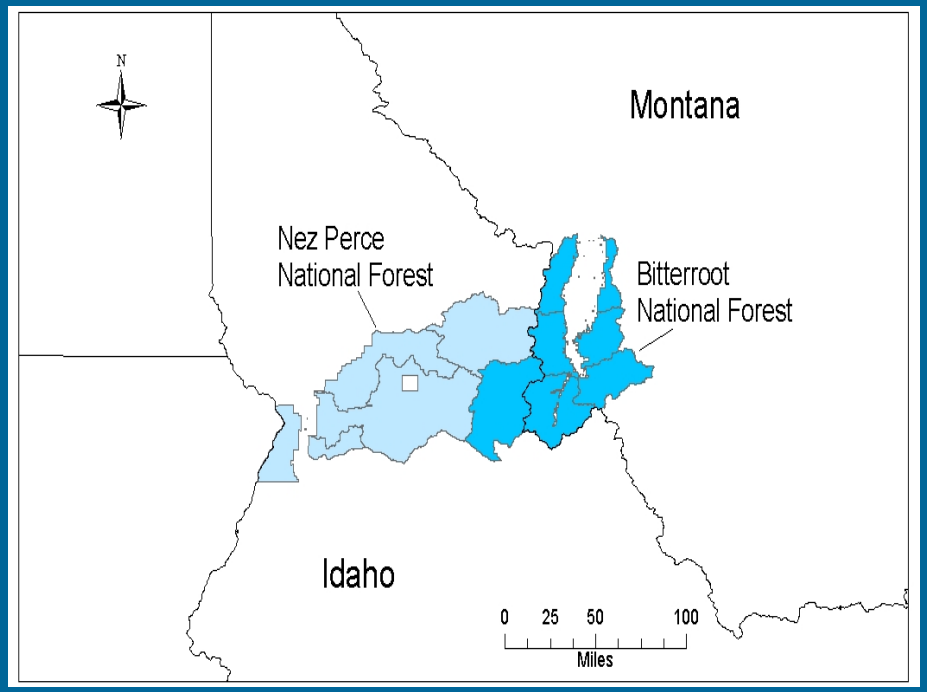
- Treatment plans for next 5 years
- Costs and other information of selected treatments
- Estimated treatment effects over next 10 years

Heuristic Optimizer



Applications

- The system will be tested on two national forests
- Developed system will be applicable for weed control planning on other forests and ownerships



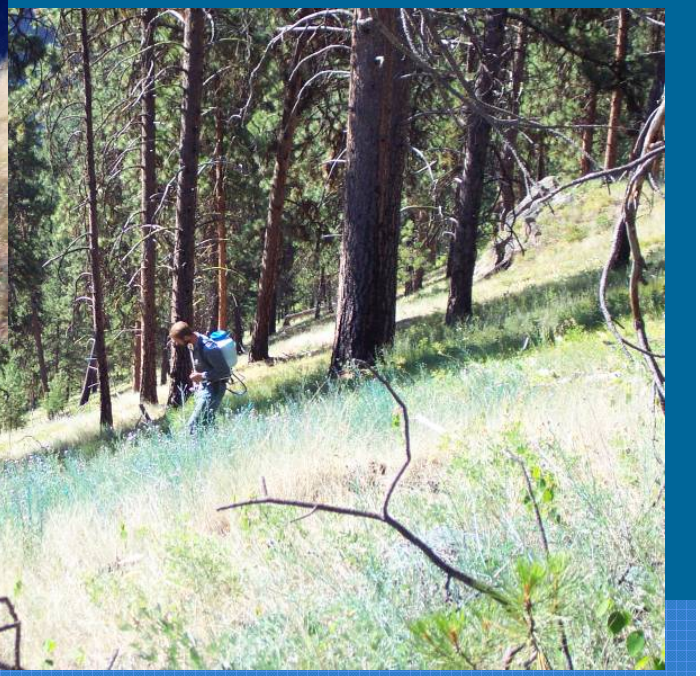
Deliverables

- The system will be public domain
- Online tutorials will be developed with case study examples

Significance

- Helps national forests and other public land management agencies achieve the maximum amount of weed control for a limited budget (optimally place treatments)
- Facilitates what-if and trade-offs analyses
  - Which of multiple invasive species to treat (weed priorities, locations, etc.)
  - How to treat (various treatment methods, herbicides, biological control, grazing, etc.)
  - Where to treat (site priorities, along road or trail networks, main infestation areas, satellite infestations, etc.)

Questions?



Example Data Collection

Results of likelihood of occurrence model
(Rush Skeletonweed)

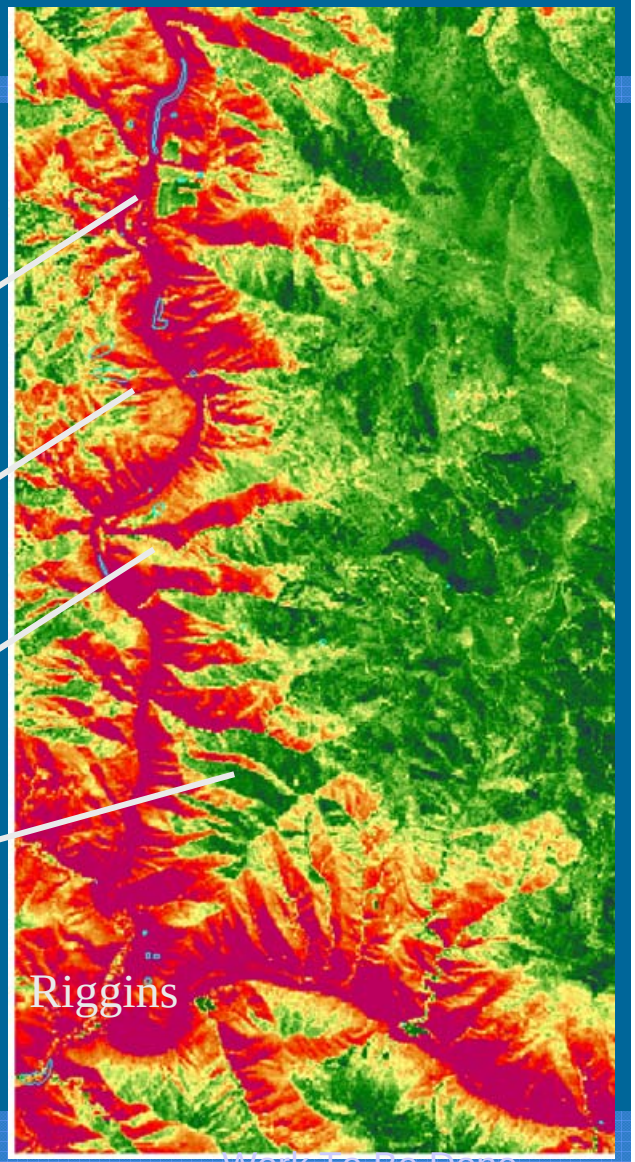
ROC = 87%
(100% = perfect fit)

Very high probability (purpre)

High probability (red)

Moderate probability (yellow)

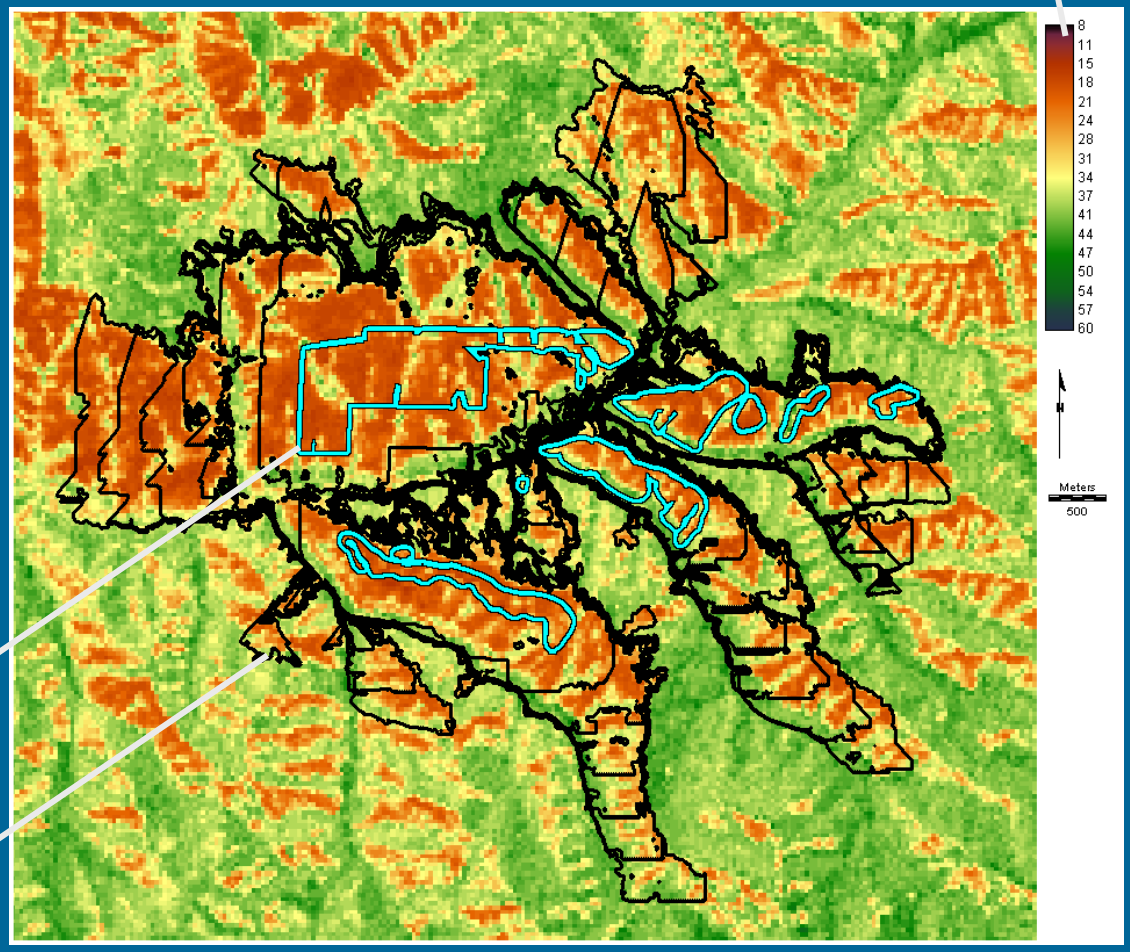
Low probability (green)



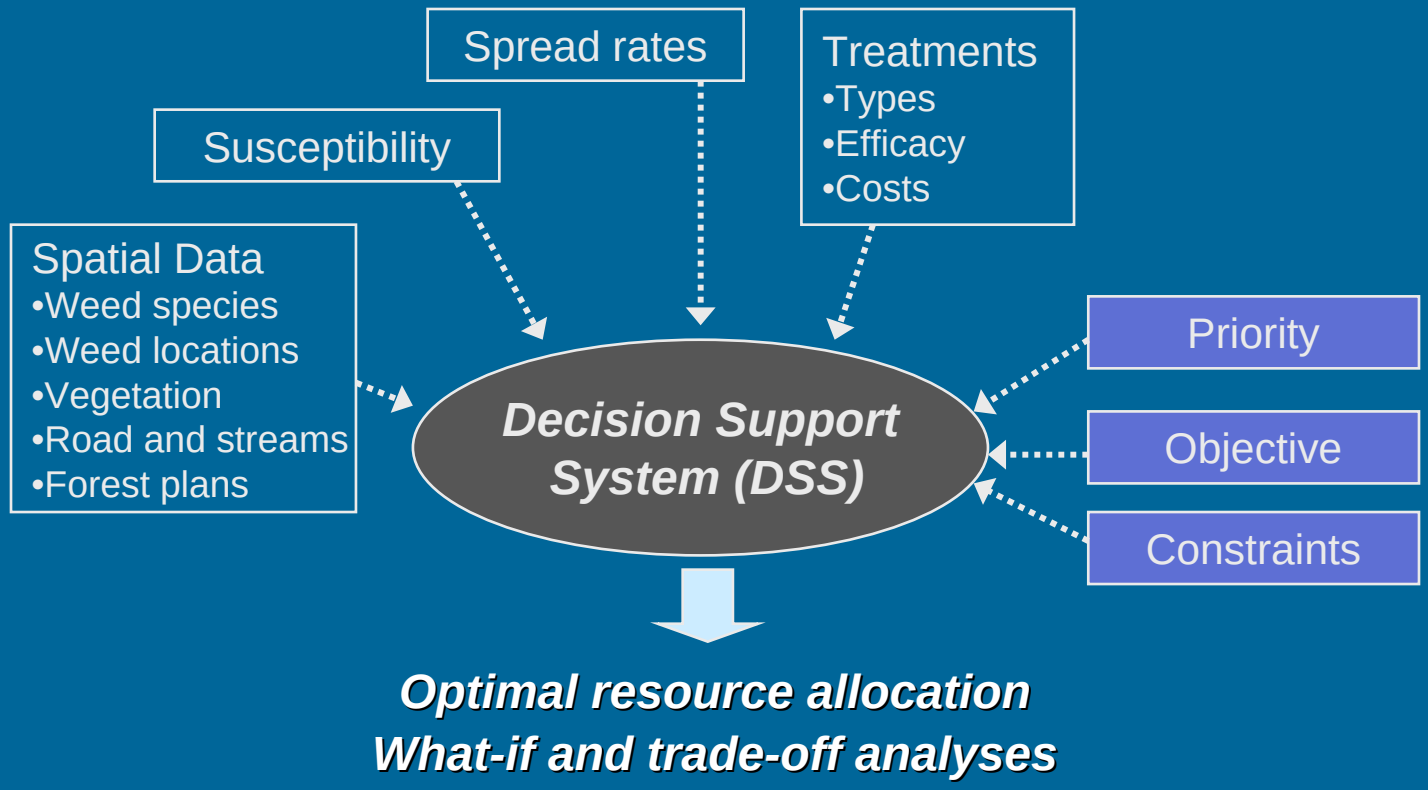
Likelihood of occurrence has been completed for all species in the Nez Perce National Forest

Example Data Collection

Results of dispersal model (yellow starthistle)



Conceptual Model of DSS



Conceptual Model of DSS

- 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

User Interfaces

Site Priority Information

Treatment site: LTA99

Add >>

Save

Rank (1 - 5)
1: highest
5: lowest

1

OK

	Treatment Site	Rank (1-5)
Db_Click to delete 1	LTA99	1
Db_Click to delete 2	LTA7	2
Db_Click to delete 3	LTA12	5
Db_Click to delete 4	LTA18	3
Db_Click to delete 5	LTA3	3
Db_Click to delete 6	LTA16	4
Db_Click to delete 7	LTA13	1
Db_Click to delete 8	LTA0	4
Db_Click to delete 9	LTA15	4