Controlling Invasive Species in an Urban-Wildland Interface

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October 22-23, 2009
Economic Research Service, USDA
1800 M Street NW Washington, DC
Typical Sonoran Desert vegetation is poorly adapted to fire.

Perennial buffelgrass forms dense stands, crowds out native vegetation, and readily carries fire.
Spraying with Glyphosate is the most effective control method.

But, glyphosate only effective when plants have “greened up” after rainfall.

Rains uncertain & infrequent.

Timing and mobilizing labor is a major constraint.

Treatment is Leontief function of Labor, Chemicals, Equipment.
Conclusions First

- Annual treatment budget determines damage path
- Treatment start year does not affect trajectory of this path, just how soon you get on it
- “Rules of thumb” used by land managers provide significant damage reductions
- Resource sharing not necessarily beneficial if agencies have different objectives
- Stakeholder response to results:
  - Revisit local eradication as strategy
  - Does possibility of eradication change gains to cooperation?
Objective Function: Minimize Damage Index subject to

- Resource constraints (Budget & Labor)

- Buffelgrass population dynamics equations
  - Calibrated based on historical observations of Tumamoc Hill Desert Research Lab (DRL)

- Treatment (time) cost function
  - Estimated via OLS based on DRL treatment data
  - Labor time the binding constraint
  - Cost depends on plant density, distance from road, slope
Tumamoc Hill & ‘A’ Mountain Simulation Site

UA/USGS Desert Lab
Damage Function

- Damage caused by buffelgrass in a cell depends on:
  - Population density in cell
  - Cells proximity to resources at risk (exponential decay)

- \[ D = \lambda_S \text{Saguaro} + \lambda_R \text{Riparian} + (1 - \lambda_S) \text{House} \]
  - Saguaro = risk to saguaros
  - Riparian = risk to riparian vegetation
  - House = fire risk to housing
Buffelgrass population dynamics

- Pre-treatment population at \( t \) depends on
  - Population at \( t - 1 \)
  - Population in surrounding cells at \( t - 1 \)
  - Carrying capacity (\( K \))

- Post-treatment population
  - Pre-treatment population \( x (1 - k) \)
  - \( k = 0.9 \) based on Desert Research Lab data
  - Local eradication (population driven to 0) doesn’t occur
    (we’ll come back to this)

- 2,000 interrelated, non-linear state equations
  - This is rocket science!
Control Strategies
(given binding labor constraint)

- Full dynamic optimization difficult

- Static optimization (rank based on D/C ratio)

- Rules of thumb
  - “Treat twice” give priority to acres treated in previous year for the first time
  - Weight treatment priority based on carrying capacity, K
  - Rules of thumb introduce dynamic considerations into static optimization
“Teach your parents well . . .”
-Crosby, Stills and Nash

STOP THE MORBUZAKH
The Morbuzakh is threatening the Ta-Metru foundry. Can you help Vakama stop it before the protodermis rises out of control?
Download the game and try your skill on your desktop!

Can heuristics & strategies be developed by running simulations?
Data Layers

- **Cost function**
  - Plant Density
  - Distance from Road
  - Slope

- **Resources at Risk**
  - Riparian Vegetation
  - Houses
  - Saguaro
  - Others Possible
Data Layers

- Carrying capacity, $K$
  - Aspect
  - Soil Type
  - Disturbance
  - Altitude

- Damage
  - Population Density
  - Proximity to Resources at Risk
Tumamoc / A Mountain as Test Site

- 2,000 acre site
  - Multiple entities managing land
  - U of A, USGS, DOT, City Parks & Rec, Homeowners’ Association

- Data layers are Excel worksheets
  - Each acre on map represented by Excel cell
  - Excel keeps track of spatial relationships
  - Automatically generates maps
Disadvantages

- Not full dynamic optimization
  - Static optimization is a lower bound of effectiveness
  - Rules of thumb improve results
  - Don’t know how far we are from optimum
Advantages

- People can input spatial data into Excel
- Excel Solver generates maps of where to spray
- Alternative to using Solver
  - Damage / Cost ratio maps
  - This just another linked spreadsheet
  - Using “Surface” option in Charts can be used to create maps of priority areas for treatment
- Recommendations easy to interpret
Damage / Cost Ratio & Treatment (under labor time constraint)

Recommended treatment area
Based on Excel Solver

D/C ratio obtained from simple spreadsheet formulas
Labor lowers damage trajectory
Saguaro Damage as a Function of Start Year
Damage Converging to New, Lower Trajectory
Population rebounds because $k = 0.9$

Should we model possibility of local eradication?
Housing Damage as a Function of Start Year
Riparian Vegetation Damage as a Function of Start Year
Buffelgrass Population, $t = 30$
Treatment start $t = 20$

Minimize Saguaro Risk: Saguaro stand protected

Minimize Housing Risk: Population lower near residential periphery
Gains from Cooperation?

- Suppose
  - Player 1 wants to minimize damage to environmental resources
  - Player 2 wants to minimize fire risk to houses
  - Each manages land within their own boundaries

- Can each be better off by sharing resources?
  - Not so far, in preliminary simulations
  - Better to “go it alone” if you have different objects than neighbors?
Recap

- **Approach allows for laptop-based decision support**
  - Develops easy to implement decision rules
  - “Rules of thumb” currently used
    - Better than static optimization
    - How close to dynamic optimum?

- **Ongoing work**
  - Strategic behavior by different land management entities
  - Under what circumstances might there be gains from cooperation
  - Is local eradication feasible?
  - How might that change results?
Questions?