Controlling Invasive Species in an Urban-Wildland Interface

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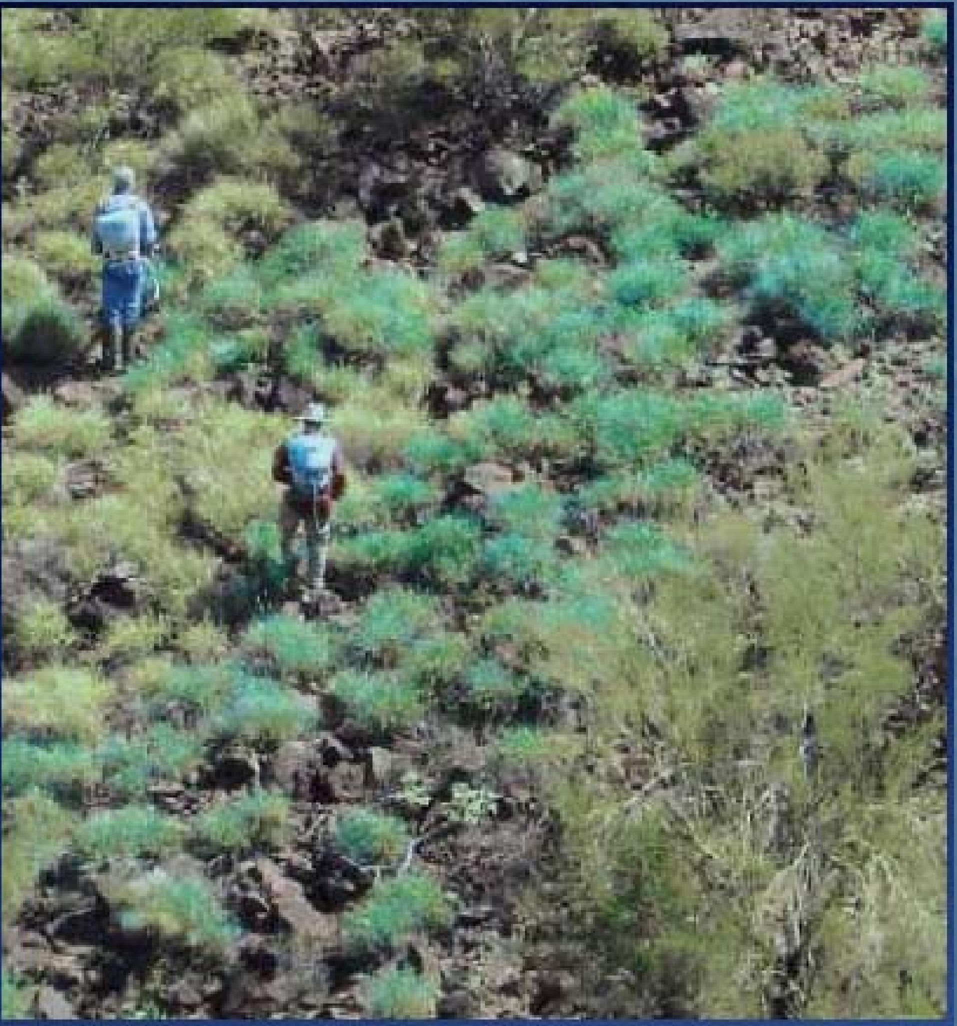
Typical Sonoran Desert vegetation is poorly adapted to fire.

Perennial buffelgrass forms dense stands, crowds out native vegetation, and readily carries fire.

Spraying with Glyphosate 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

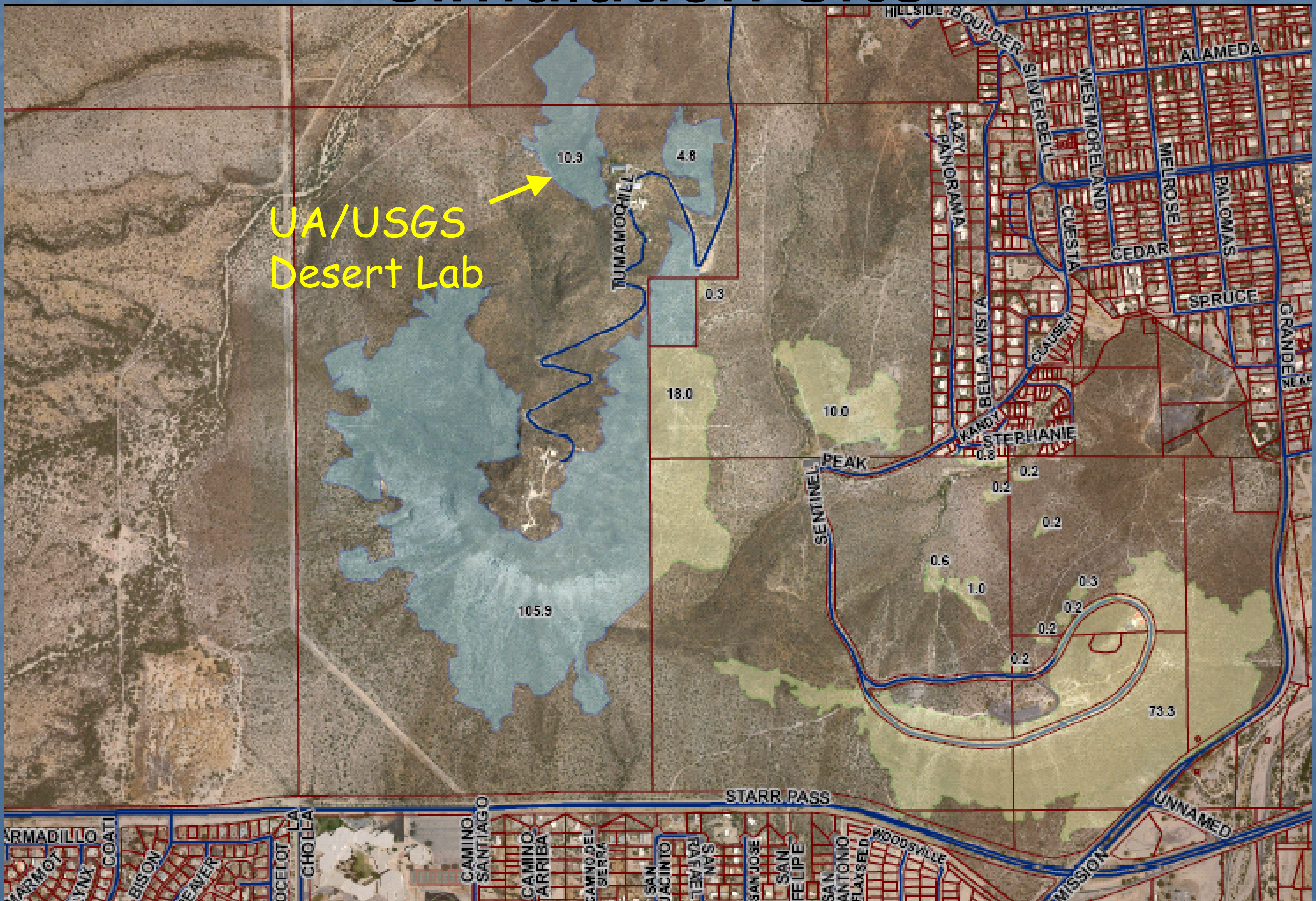
Conclusions First

- 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 possibilty 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



Damage Function

- Damage caused by buffelgrass in a cell depends on
  - Population density in cell
  - Cells proximity to resources at risk (exponential decay)
- $D = \lambda_S$ Saguaro $+\lambda_R$ Riparian $+ (1 - \lambda_S)$ 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 <u>is</u> 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

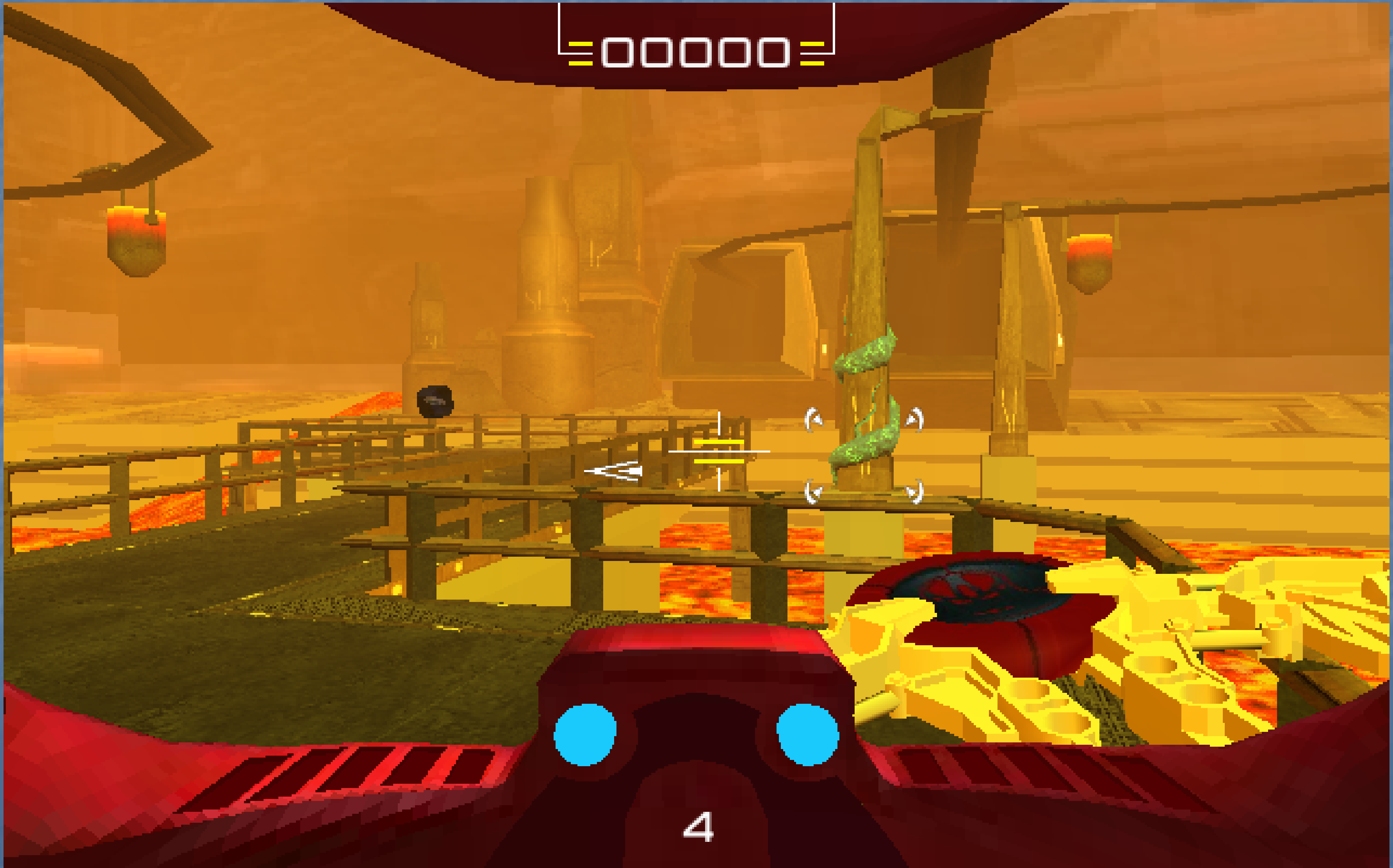
“Teach your parents well . . .”
-Crosby, Stills and Nash

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!

http://www.lego.com/eng/bionicle/games/morbuzak.aspx

Can heuristics & strategies be developed by running simulations?



Data Layers

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

- Resources at Risk
  - Riparian Vegetatin
  - Houses
  - Saguaros
  - 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

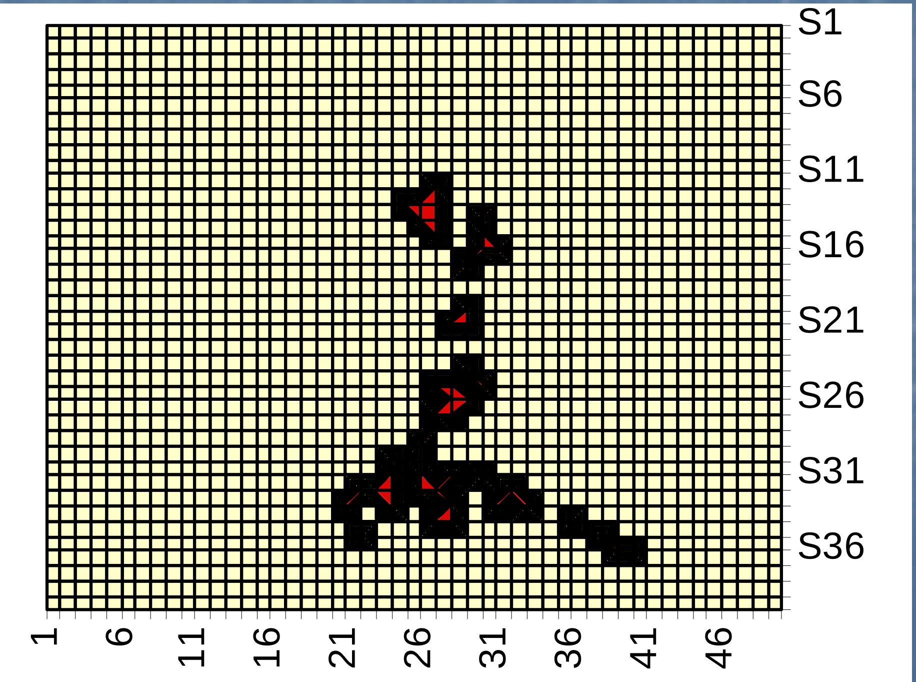
- Not full dynamic optimization
  - Static optimization is a lower bound of effectiveness
  - Rules of thumb improve results
  - Don’t know how far we are from optimum

Advantages

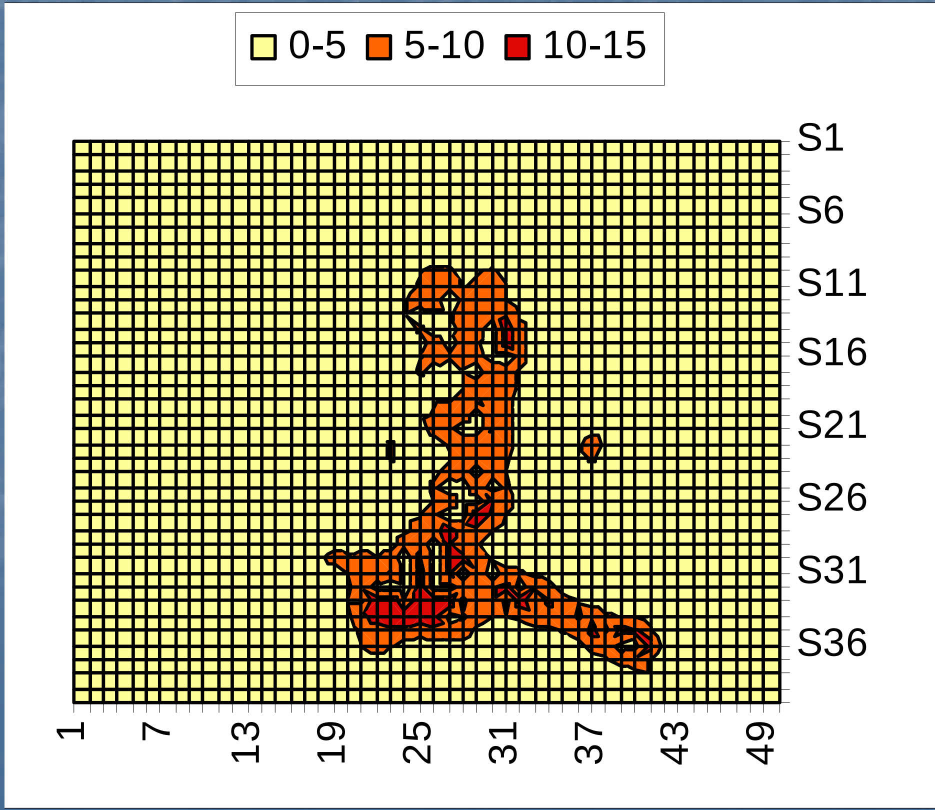
- People can input spatial data into Excel
- Excel Solver generates maps of where to spray
- Alternative to using Solver
  - Damage / Cost ratio maps
  - This just another linked spreadsheet
  - Using "Surface" option in Charts can be used to create maps of priority areas for treatment
- Recommendations easy to interpret

Damage / Cost Ratio & Treatment (under labor time constraint)

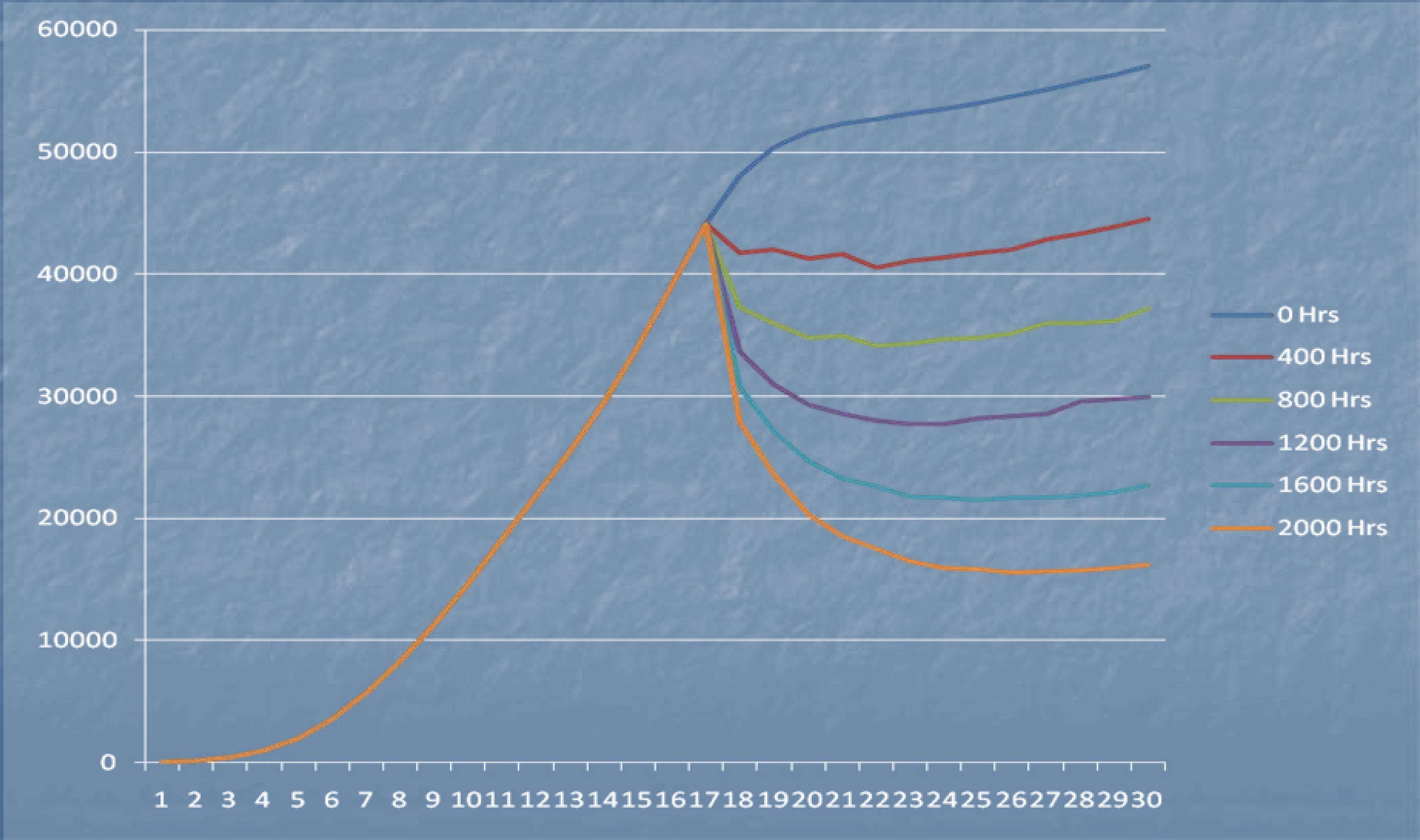
Recommended treatment area
Based on Excel Solver



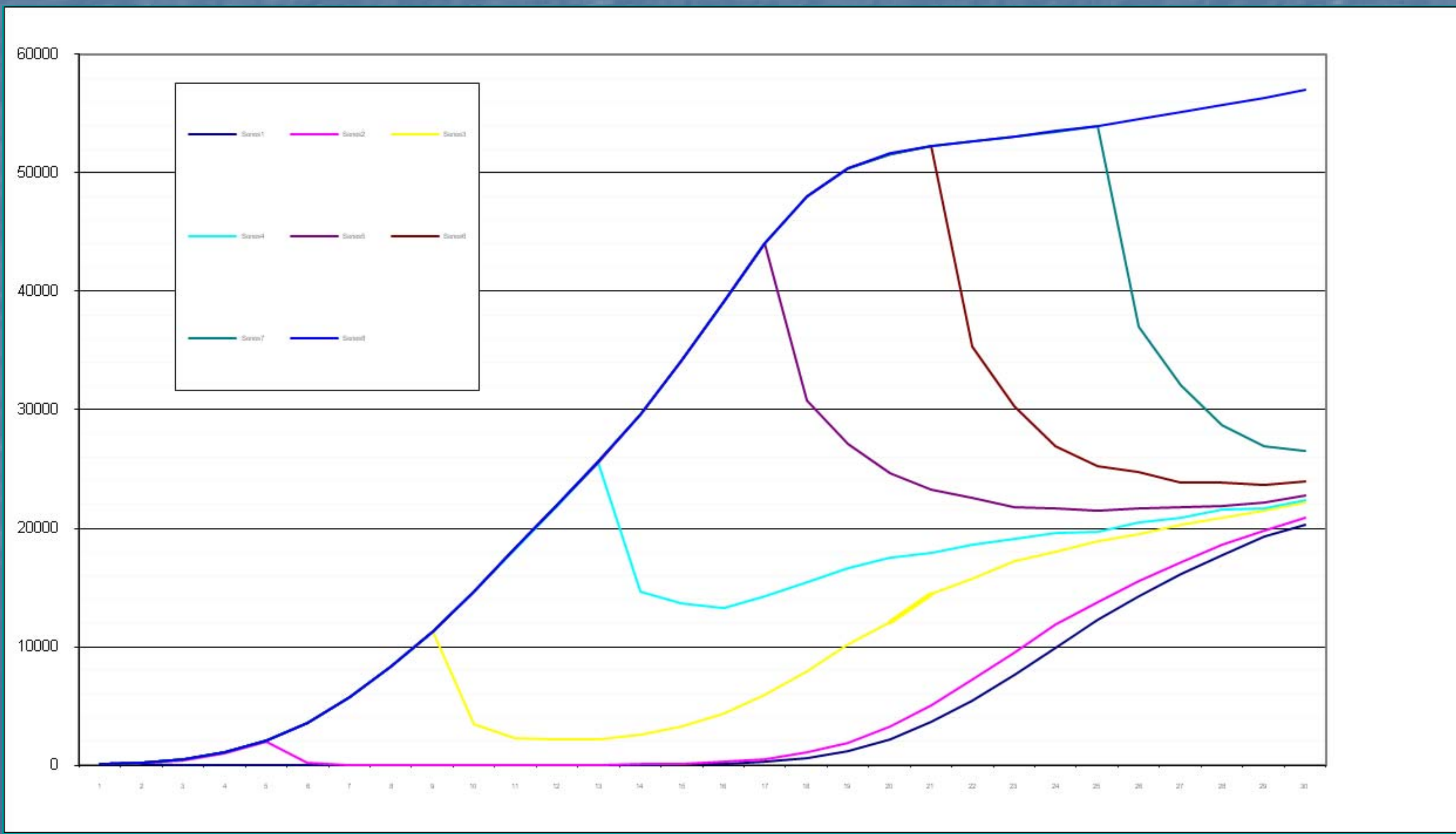
D/C ratio obtained from simple spreadsheet formulas



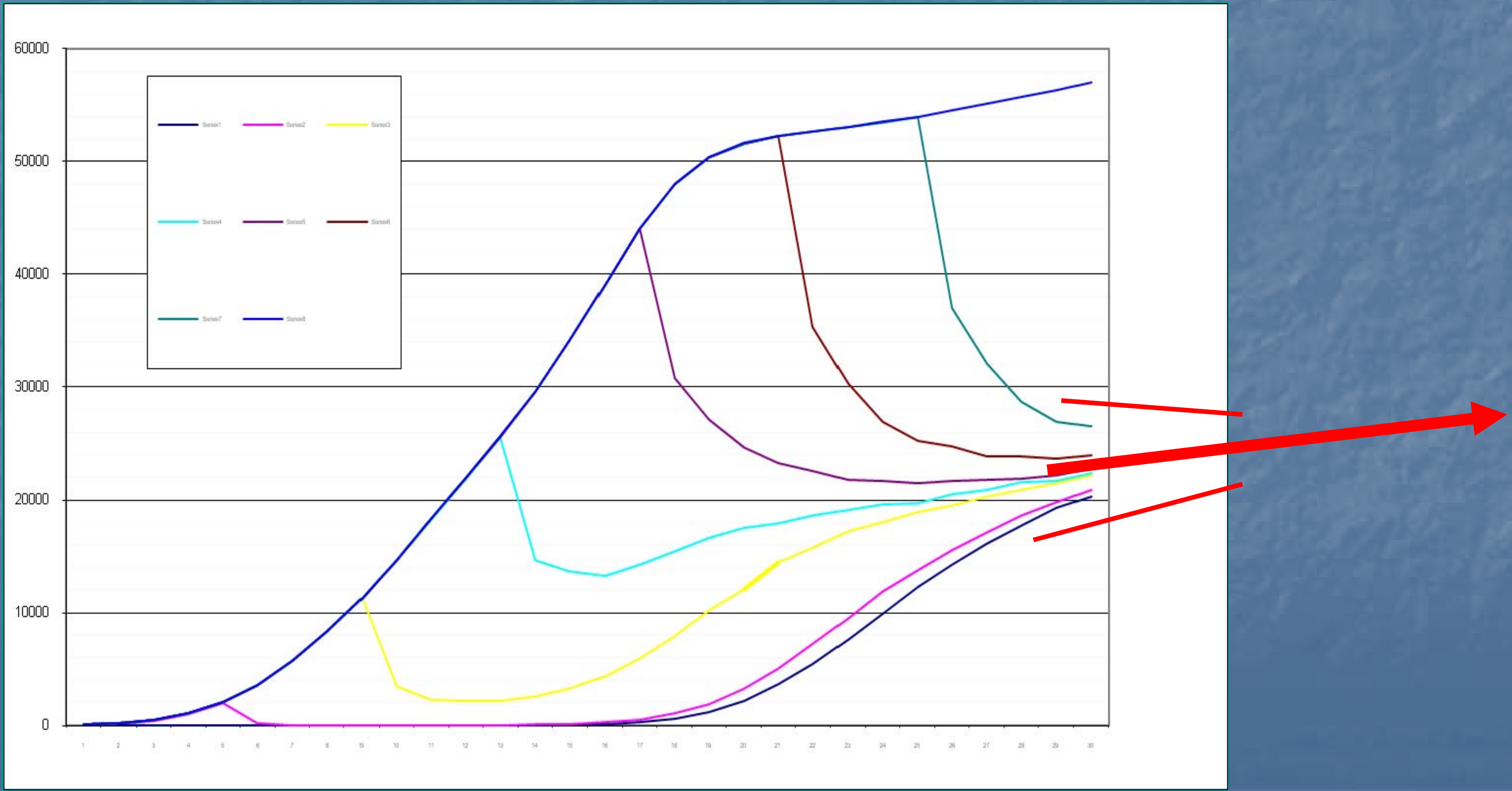
Labor lowers damage trajectory



Saguaro Damage as a Function of Start Year

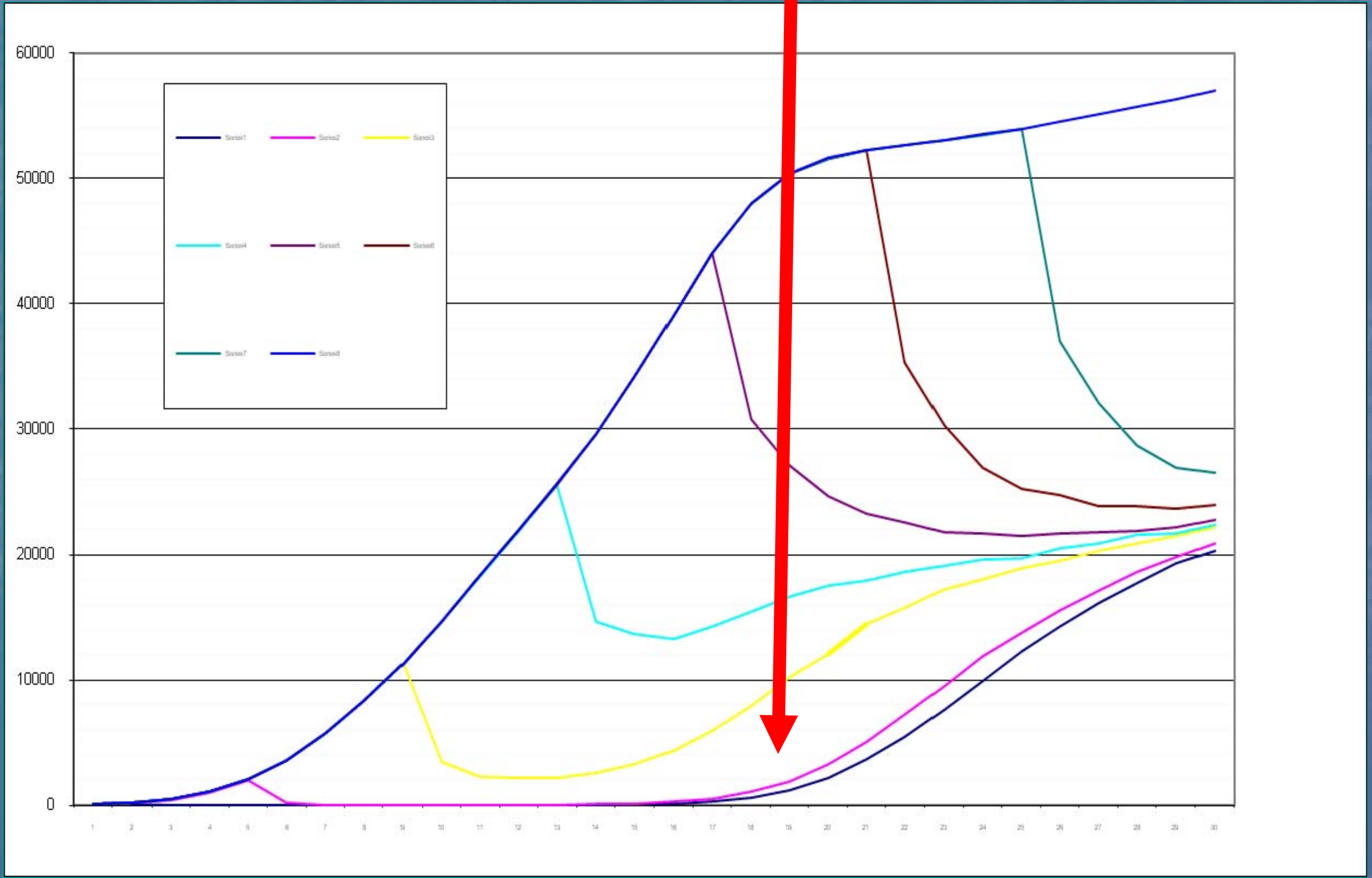


Damage Converging to New, Lower Trajectory

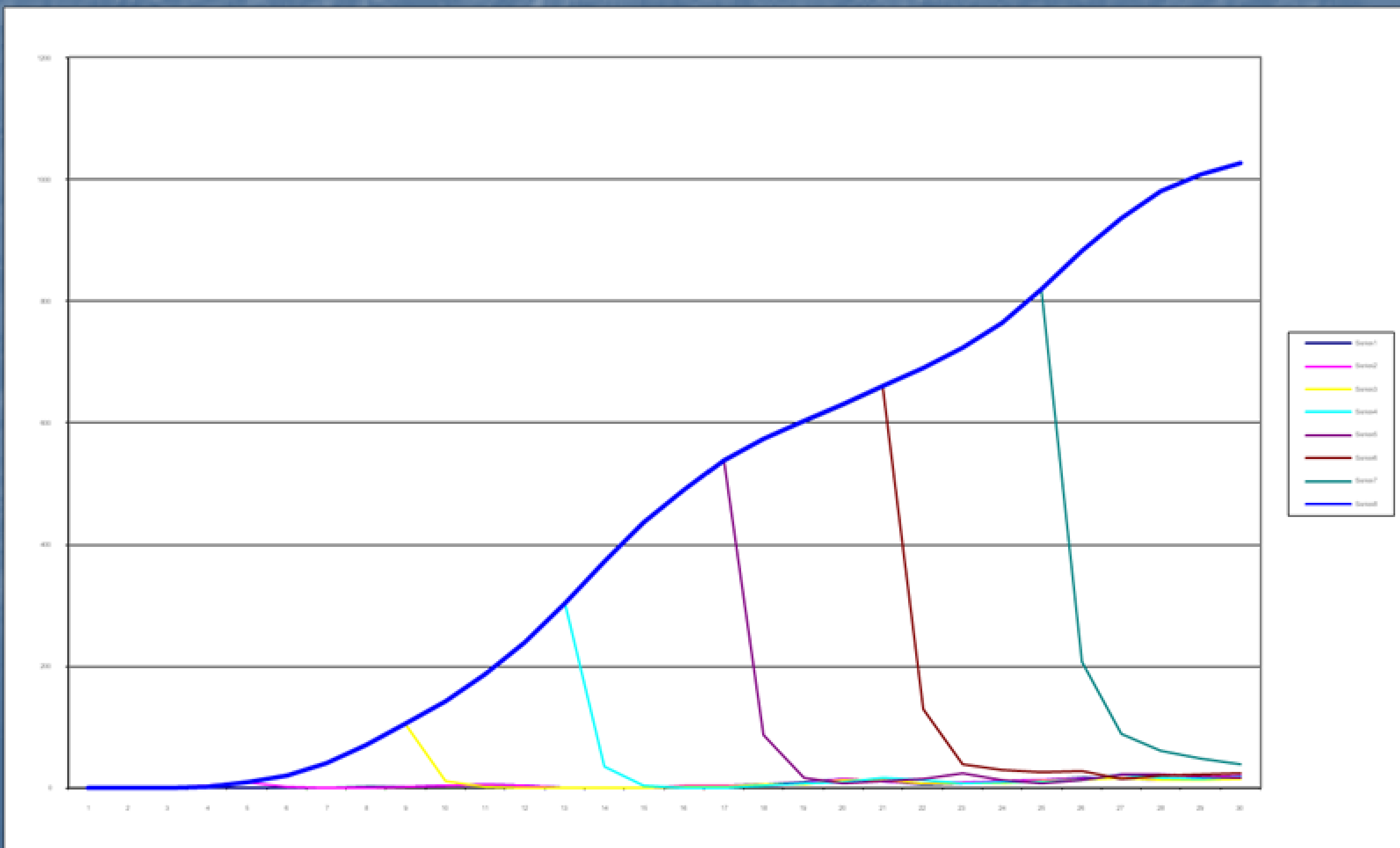


Population rebounds because k = 0.9

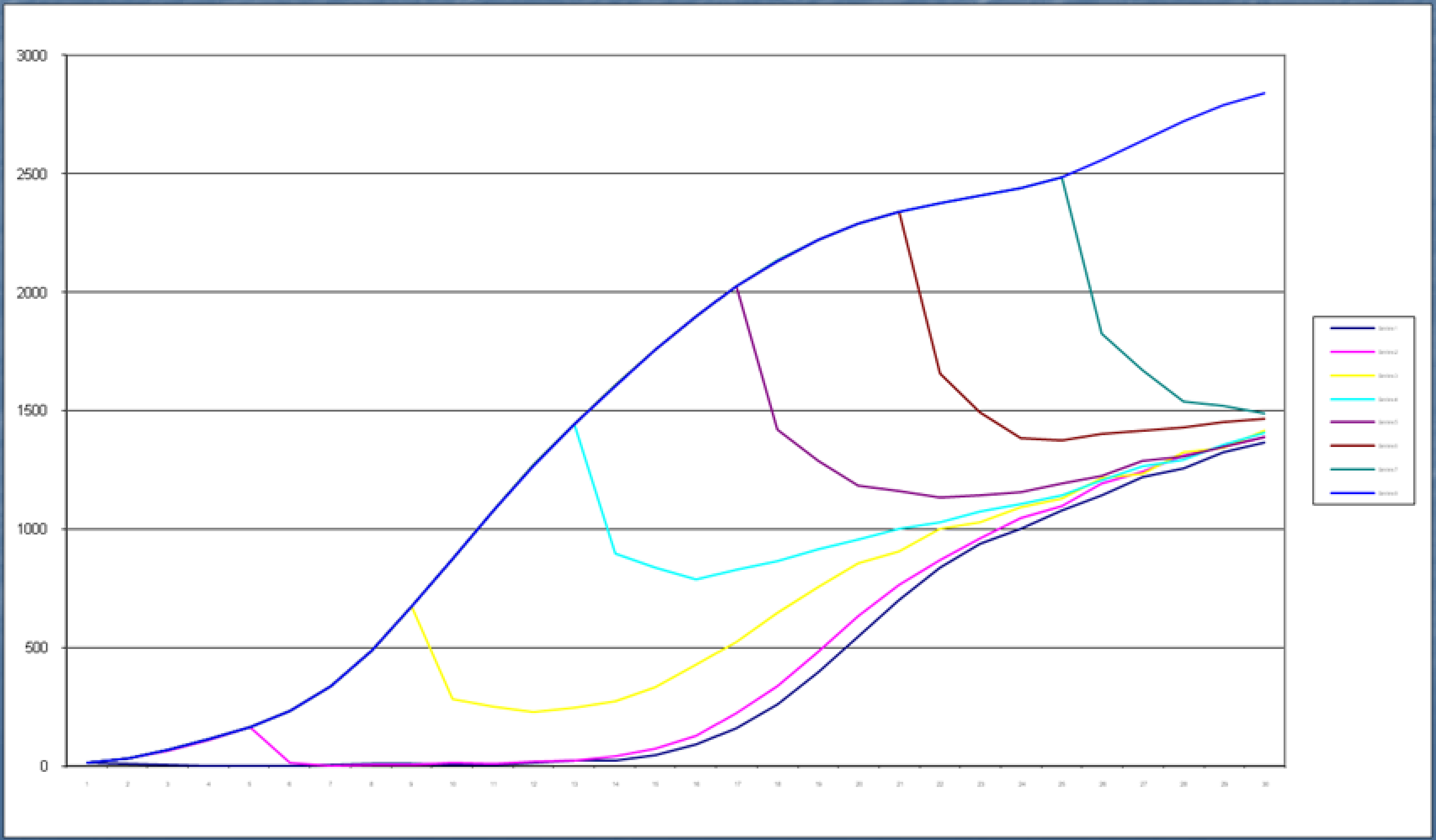
Should we model possibility of local eradication?



Housing Damage as a Function of Start Year



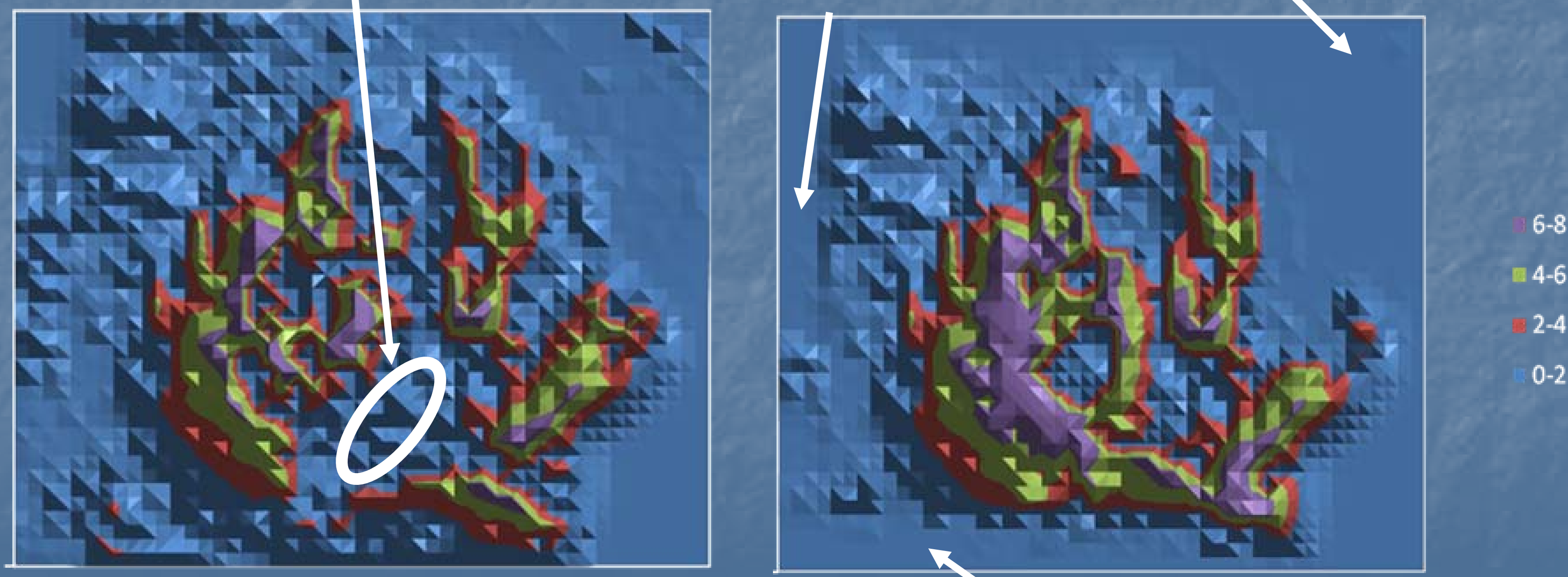
Riparian Vegetation Damage as a Function of Start Year

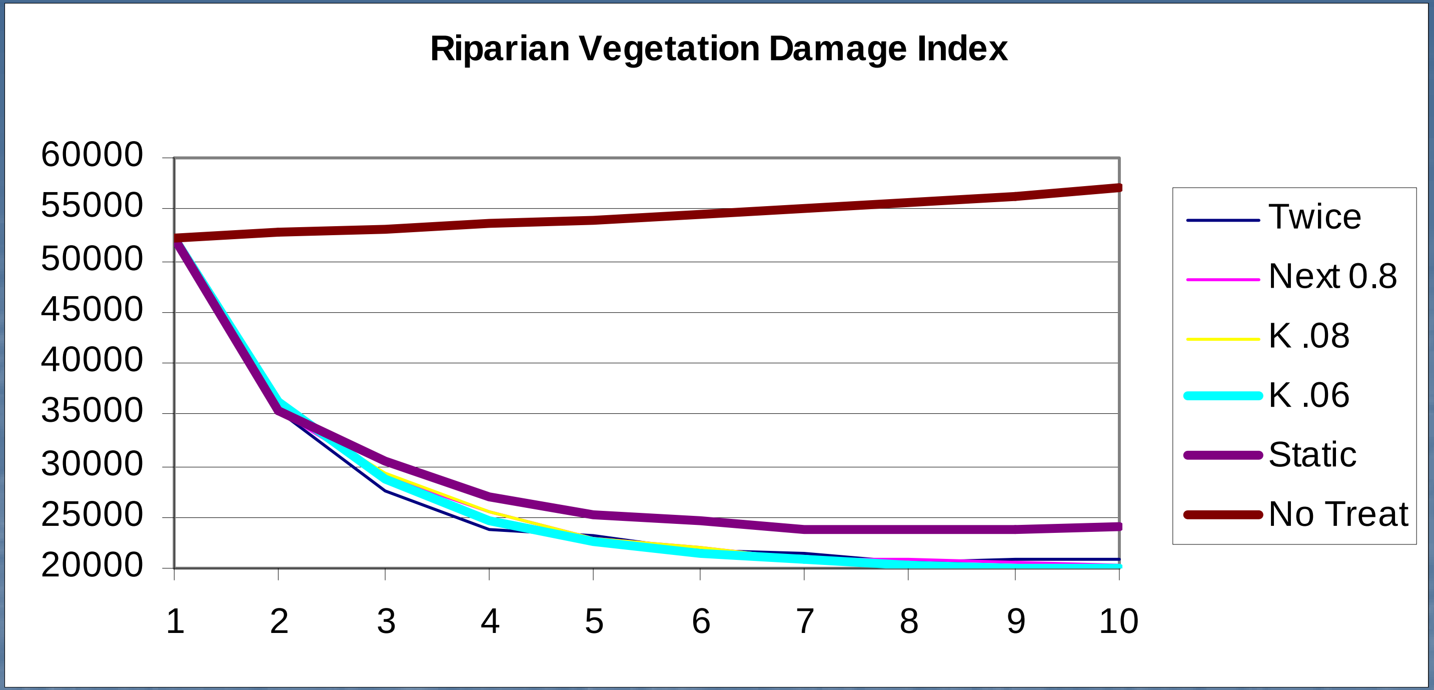


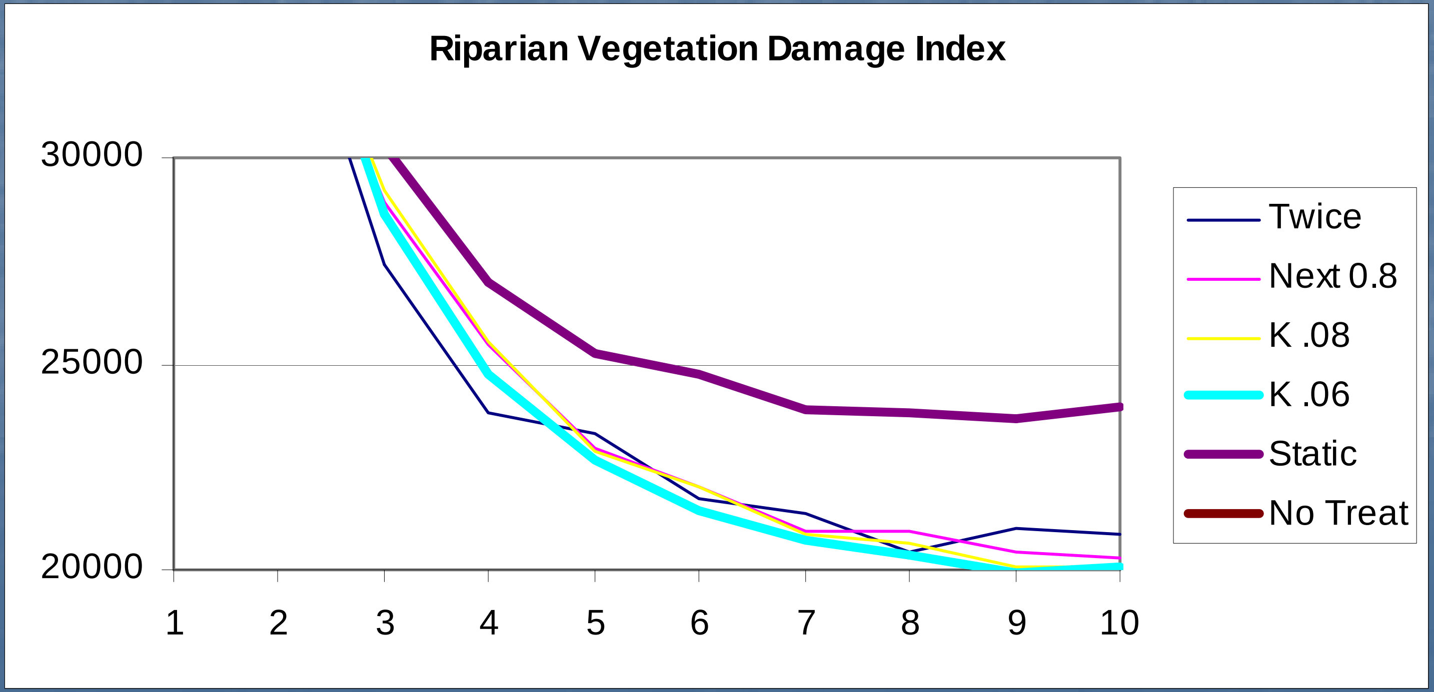
Buffelgrass Population, t = 30
Treatment start t = 20

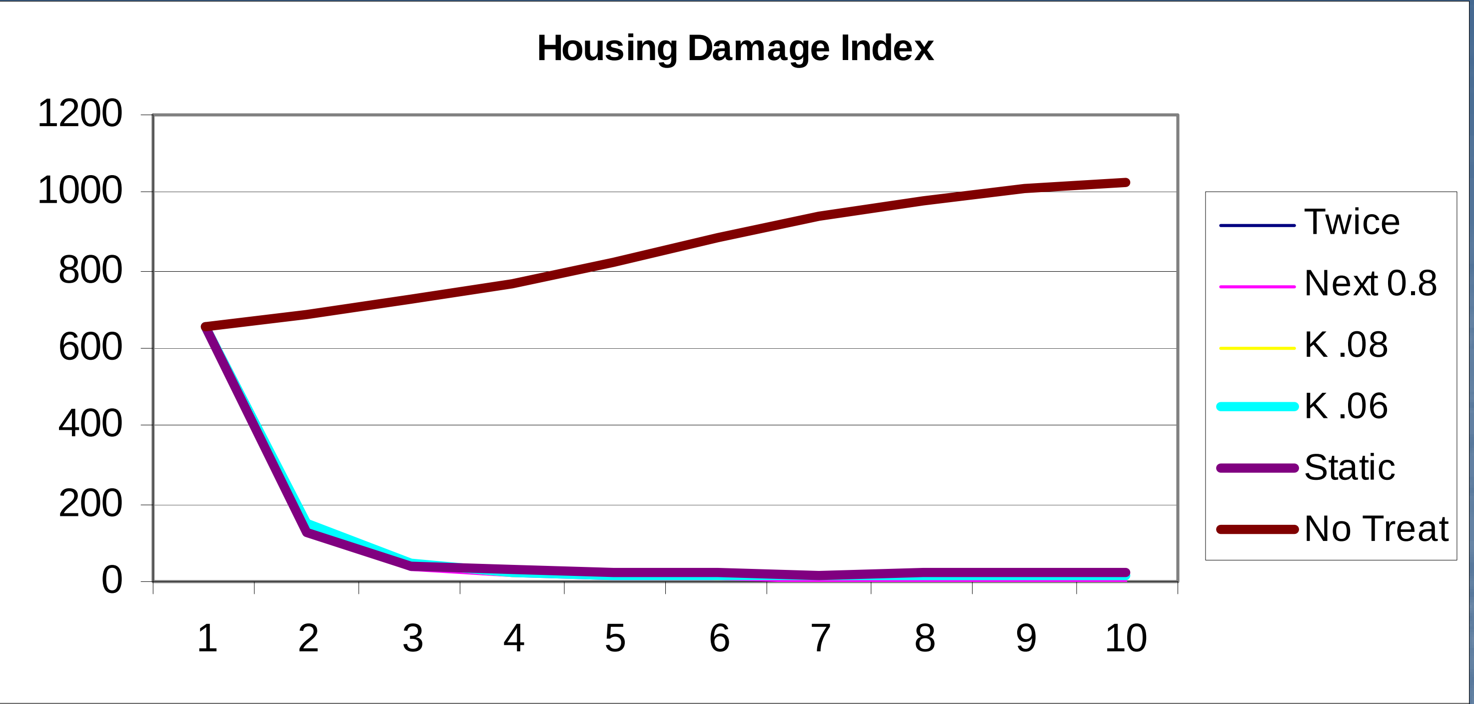
Minimize Saguaro Risk:
Saguaro stand protected

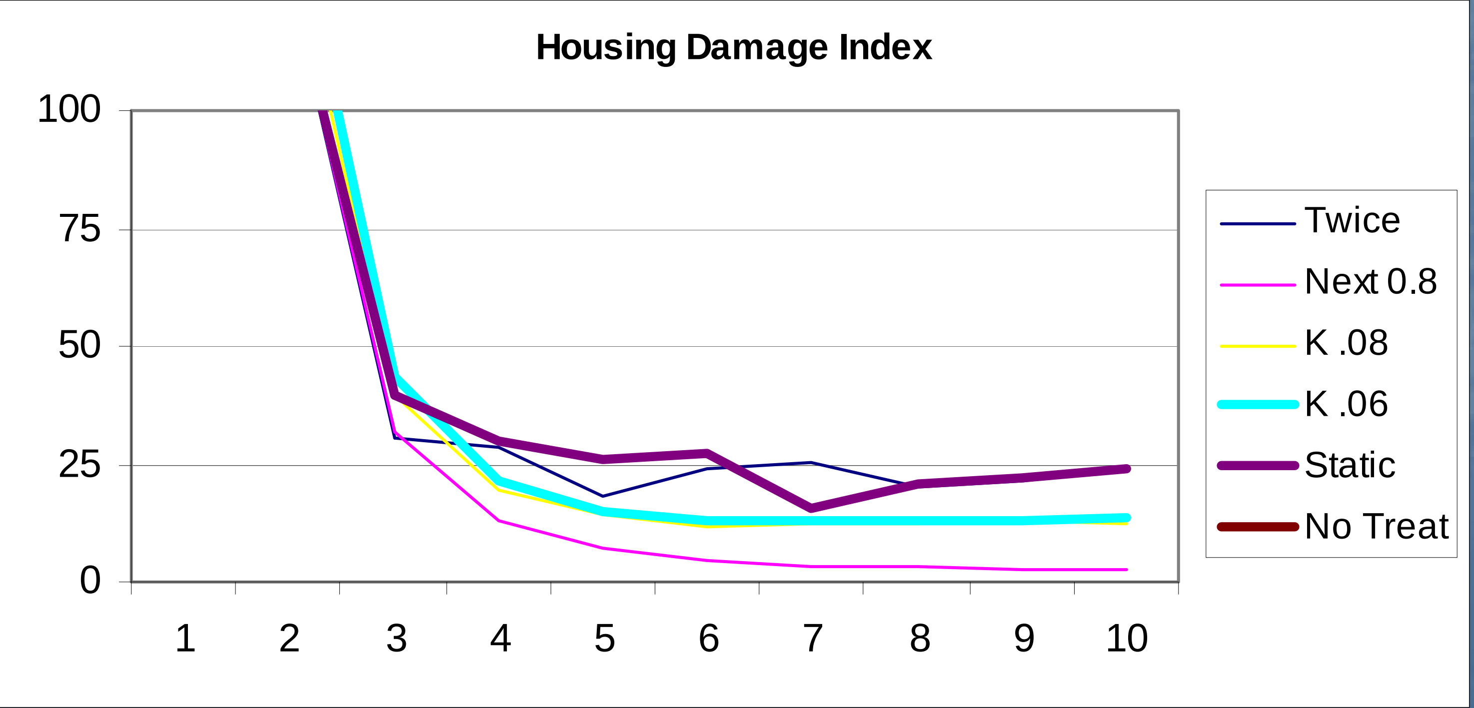
Minimize Housing Risk:
Population lower near residential periphery

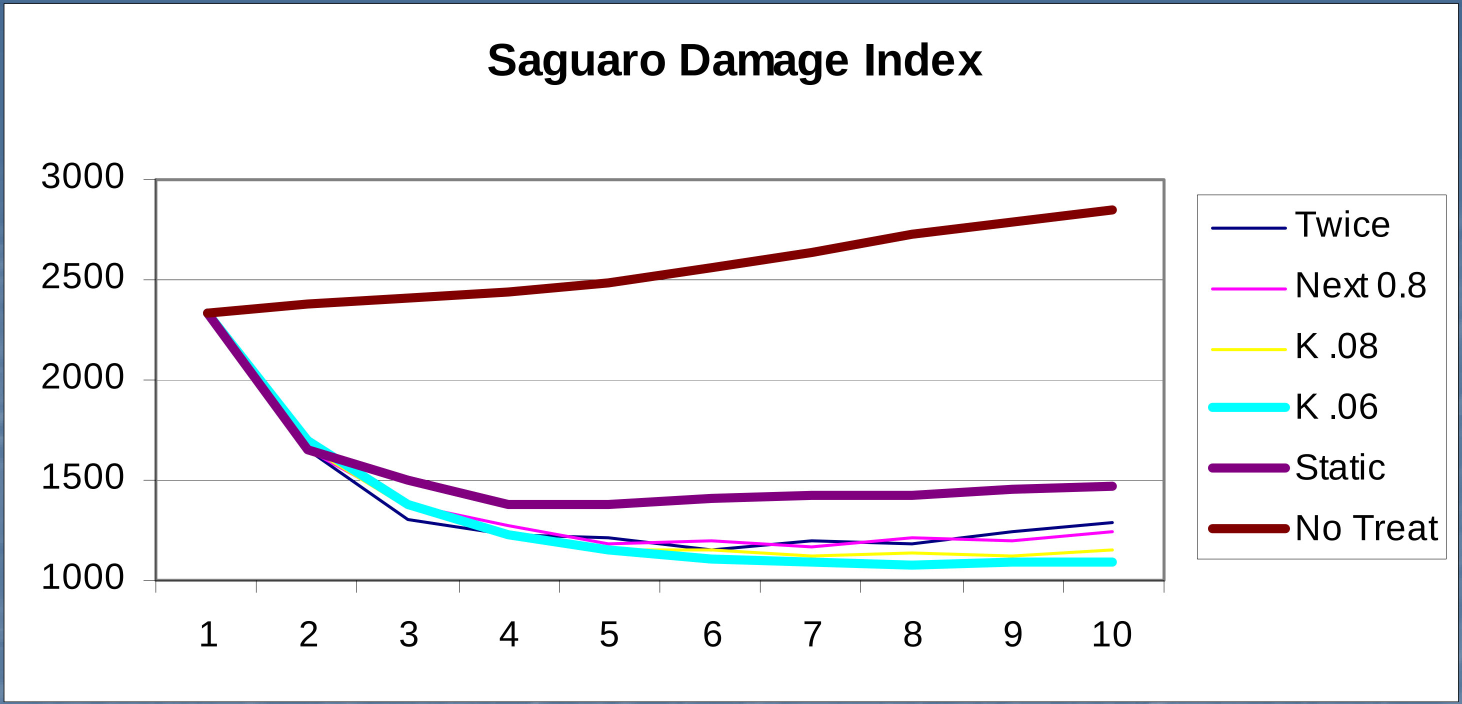



Riparian Vegetation Damage Index
60000
55000
50000
45000
40000
35000
30000
25000
20000
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat

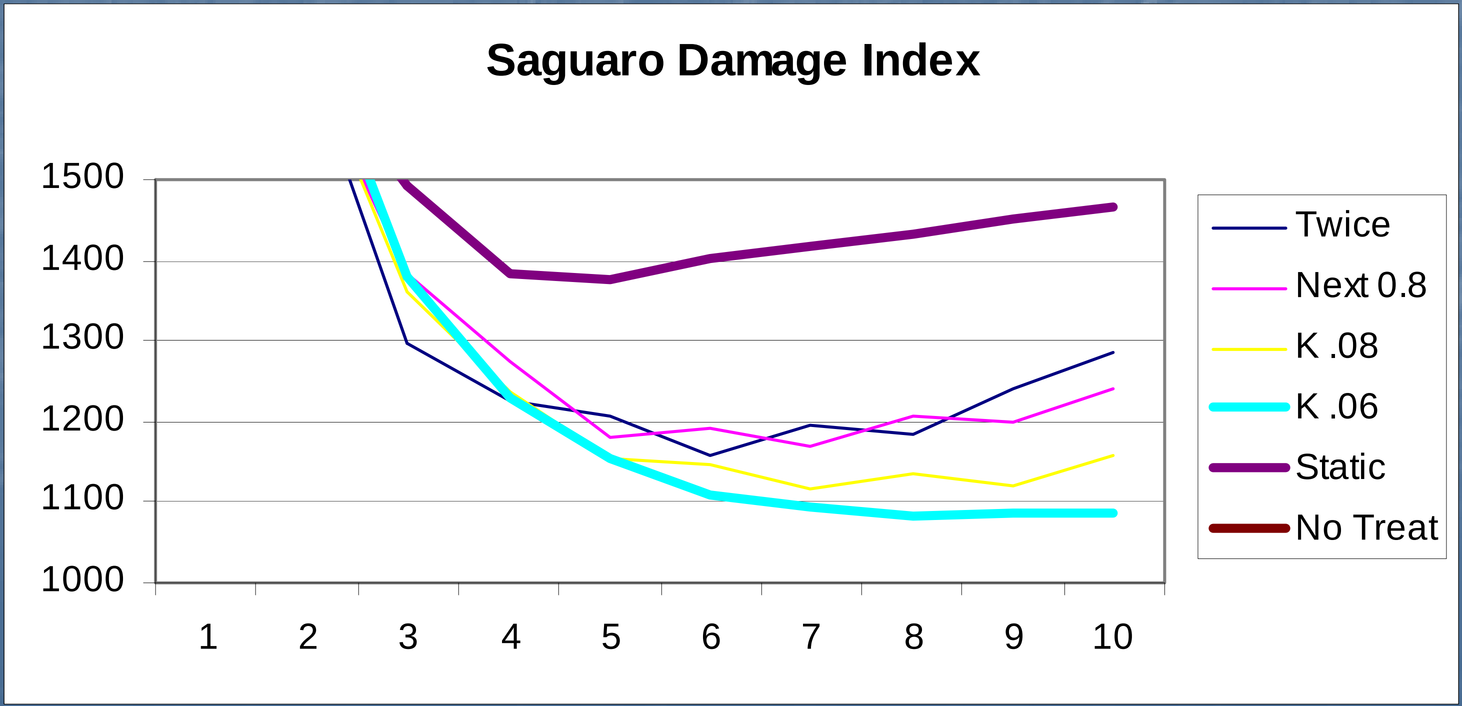

Riparian Vegetation Damage Index
30000
25000
20000
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat


Housing Damage Index
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat


Housing Damage Index
100
75
50
25
0
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat



Saguaro Damage Index
3000
2500
2000
1500
1000
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat



Saguaro Damage Index
1500
1400
1300
1200
1100
1000
1
2
3
4
5
6
7
8
9
10
Twice
Next 0.8
K .08
K .06
Static
No Treat

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 prelimary 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 their be gains from cooperation
  - Is local eradication feasible?
  - How might that change results?


Questions?