Optimal Temporal-Spatial Control of an Invasive Species over a Heterogeneous Landscape: Exploratory exercises for the case of *Mimosa pigra* in Puerto Rico

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Content

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Introduction

- Invasive species move over time and space
- Not all space is suitable for the survival of an invasive species
- Suitable space has certain geometric and topological properties

Objective

We want to see how the characteristics of the space that is suitable for an invasive plant *Mimosa pigra* and the spatial location and dispersal pattern of the species can affect its optimal control.

Approach

- We tried Dynamic Programming but the dimension of the problem was overwhelming.
- We decided to use instead Integer Programming along the lines of Epanchin et al. (2011).

Model

$$\text{Min} \sum_{t \in T, t>0} \beta_t * \left(\sum_{(i,j) \in C} x_{(i,j,t)} * d + \sum_{(i,j) \in C} y_{(i,j,t)} * e + \sum_{(i,j,k,l) \in N} z_{(i,j,k,l,t)} * b \right)$$

Subject to

$$x_{(i,j,t)} \geq x_{(i,j,t-1)} - y_{(i,j,t)} \quad \text{remains invaded}$$

$$x_{(i,j,t)} \geq x_{(k,l,t-1)} - z_{(i,j,k,l,t)} - y_{(i,j,t)} \quad \text{invaded if invaded neighbor}$$

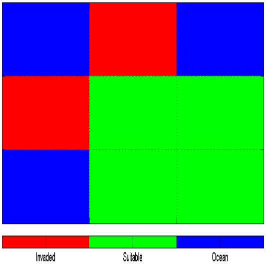
where:

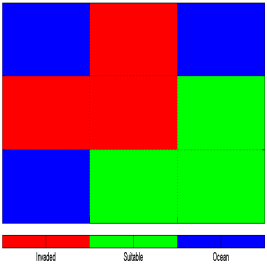
x:	State of cell	d:	Damage cost (per cell per time period)
y:	Eradication policy	e:	Eradication cost
z:	Barrier policy	b:	Barrier cost
		β_t:	Discount factor

Damage Cost

Cost at time t :
$d + d$

Cost at time $t + 1$:
$d + d + d$

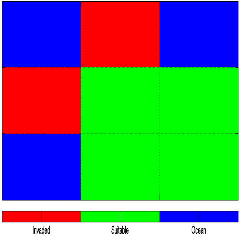


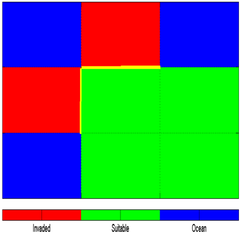


Barrier Cost

Cost at time t :
$d + d$

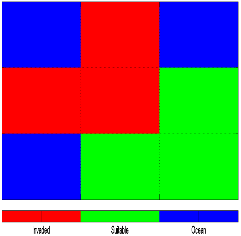
Cost at time $t + 1$:
$d + d + b + b$



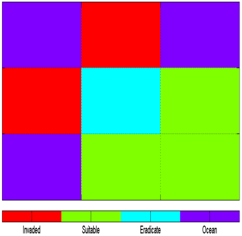


Eradication Cost

Cost at time t :
$d + d + d$

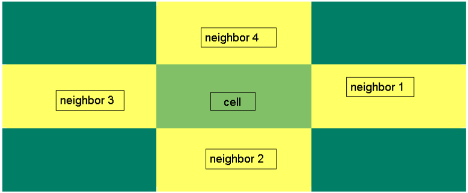


Cost at time $t + 1$:
$d + d + e$



Dispersion

If *cell* were invaded at time t, then neighbor cells 1, 2, 3, and 4 would be invaded at time $t + 1$.



Suitability map

We start with suitability map for *Mimosa pigra* (Barragán et al.)

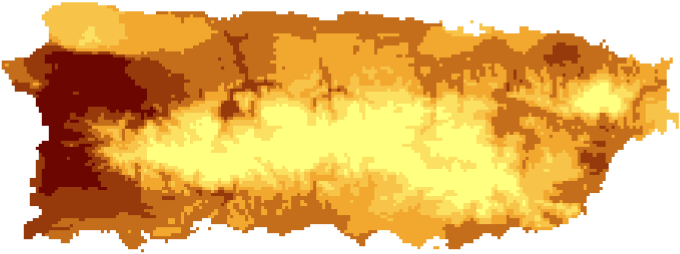
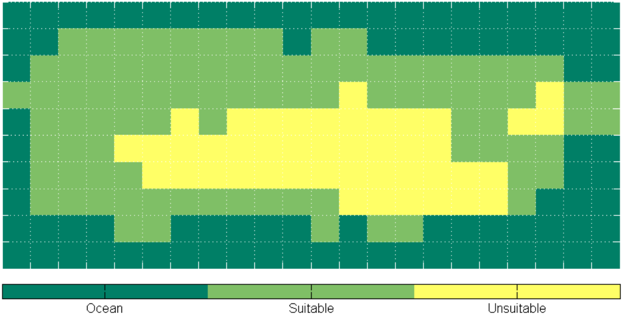


Figure : Probability of presence

Suitable Space C

A grid on of square cell over which the invader could spread, bounded by the sea and the mountains (unsuitable).

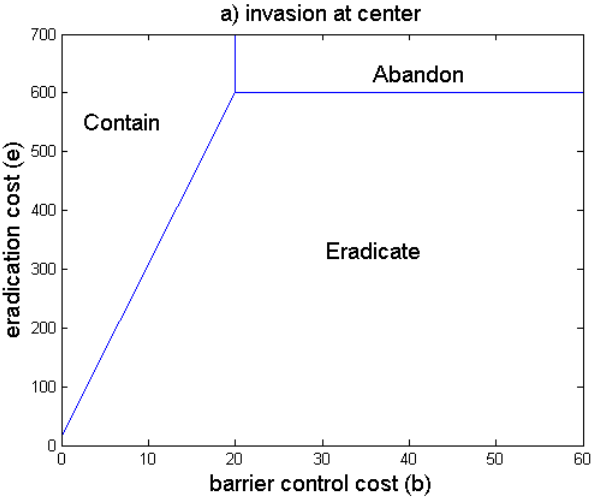


Exploratory exercise

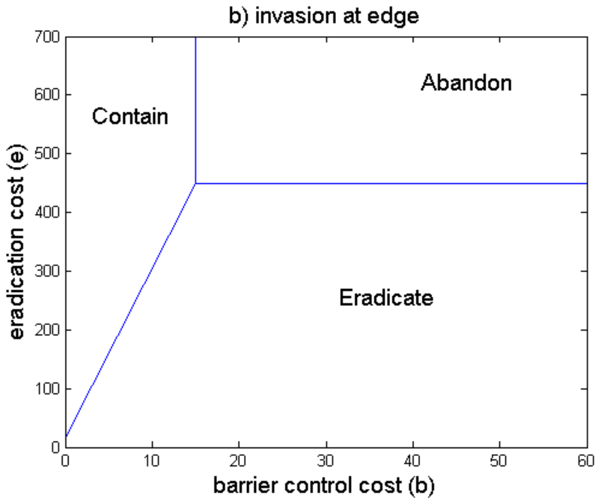
Scenarios

- At the center, at an edge, and at a corner of the landscape.
- For different barrier and eradication control costs.

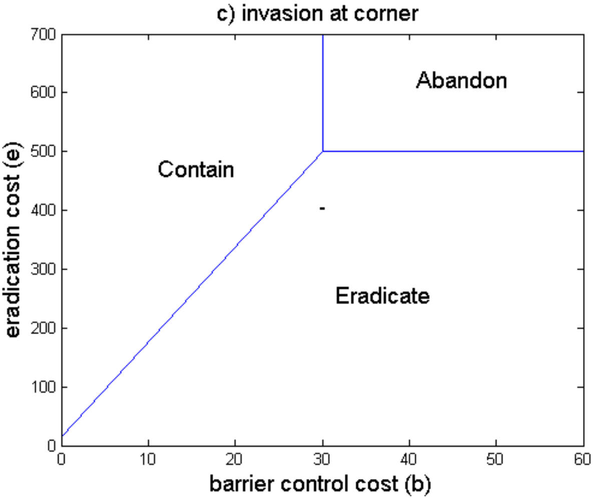
Control strategies for **center** cell invasion



Control strategies for **edge** cell invasion



Control strategies for **corner** cell invasion



Corner cell invasion (with $e >> b$)

Center cell invasion (with $e >> b$)

Edge cell invasion (with $e >> b$)

Erradication cost greater than barrier cost ($e >> b$)

Here optimal control strategy is to contain with barriers.

When we increase barrier cost

Here optimal control strategy is to eradicate.

When both barrier and eradication costs are high

Here optimal decision is to abandon control.

Conclusions

- Other things equal, we saw that corner invasions are easier to contain, while center invasions are easier to erradicate.
- Low barrier costs will result in containing invasion, low eradication costs will result in eradication, and high controls costs (barrier and eradication) will result in abandoning invasion.

Suggestions

Some ideas we would like to try next:

- Increase number of cells.
- estimate real control and eradication costs for *Mimosa pigra*.