It's Better than Mothing:
An Optimal Control Model of the Gypsy Moth Invasion with Heterogeneous Intensities

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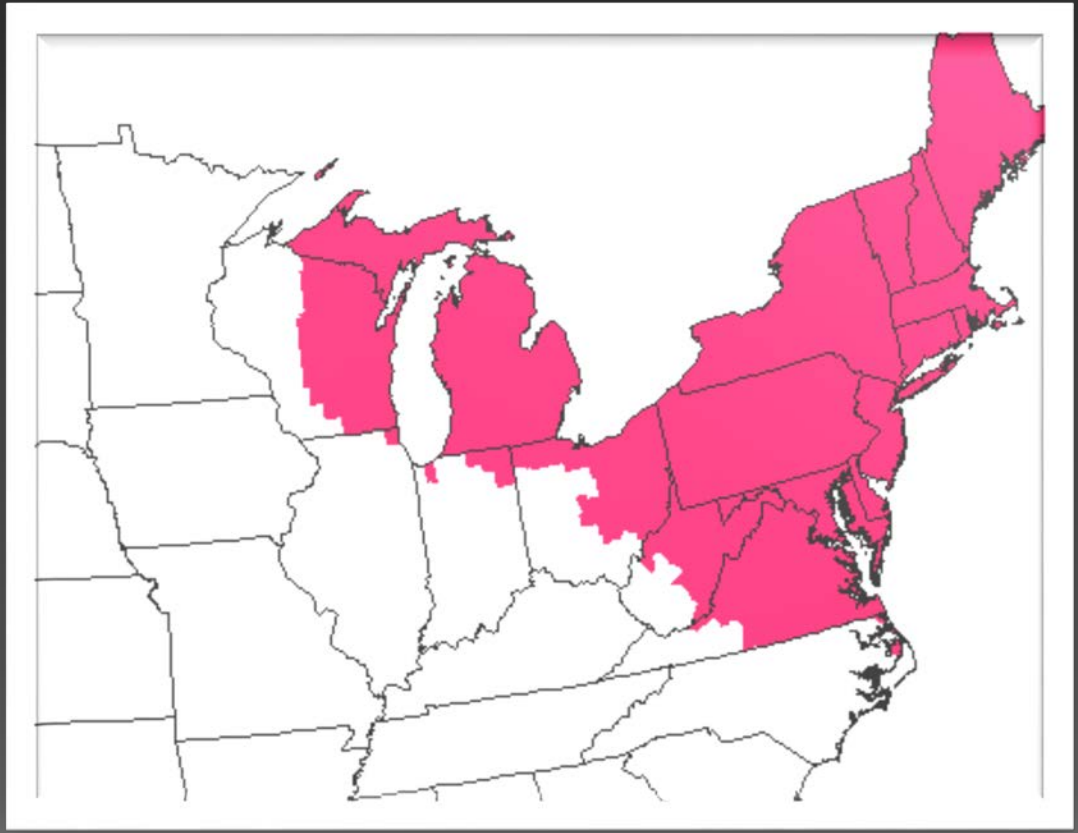
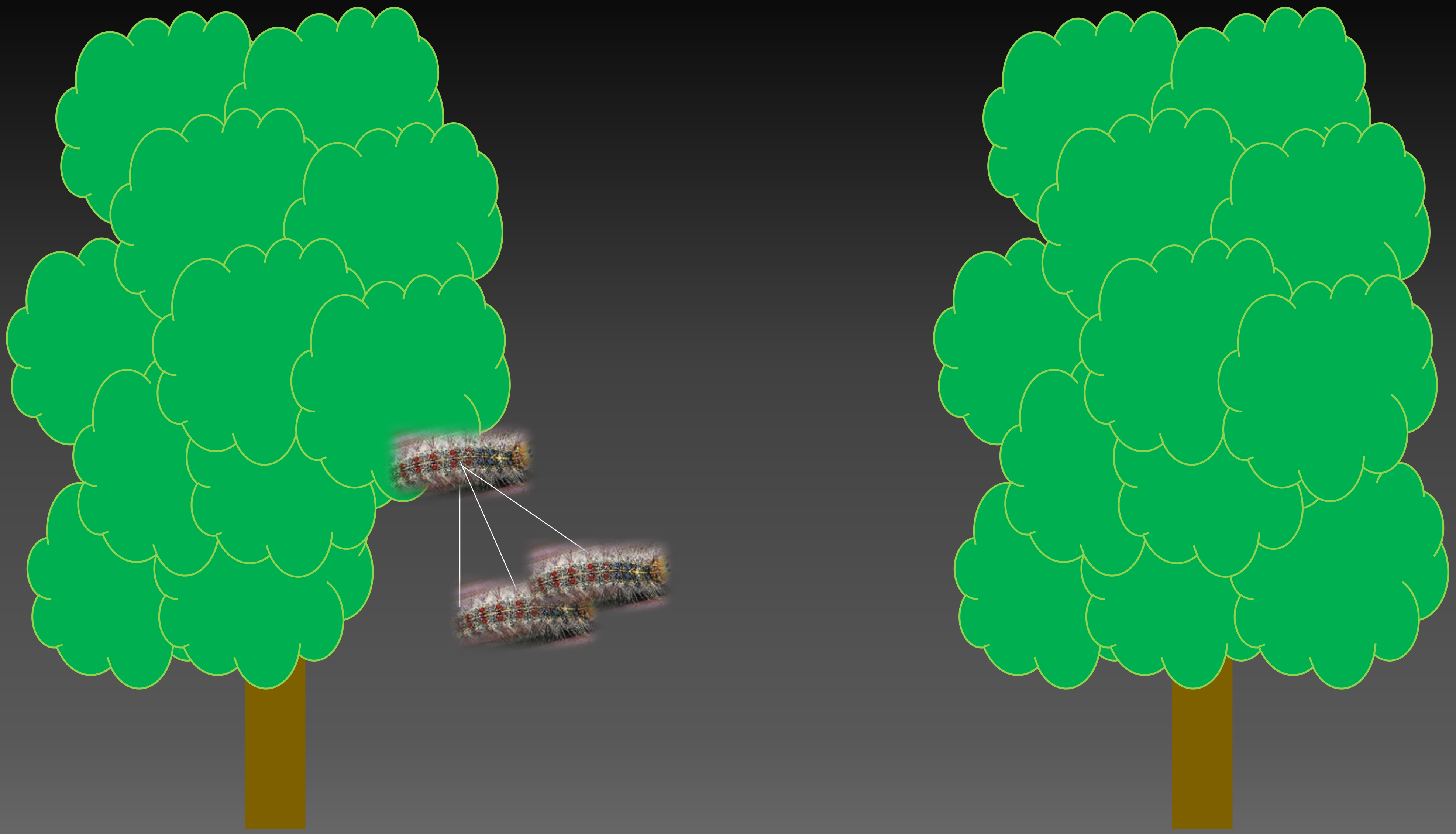
Gypsy Moth



Gypsy Moth

Larva

Adult

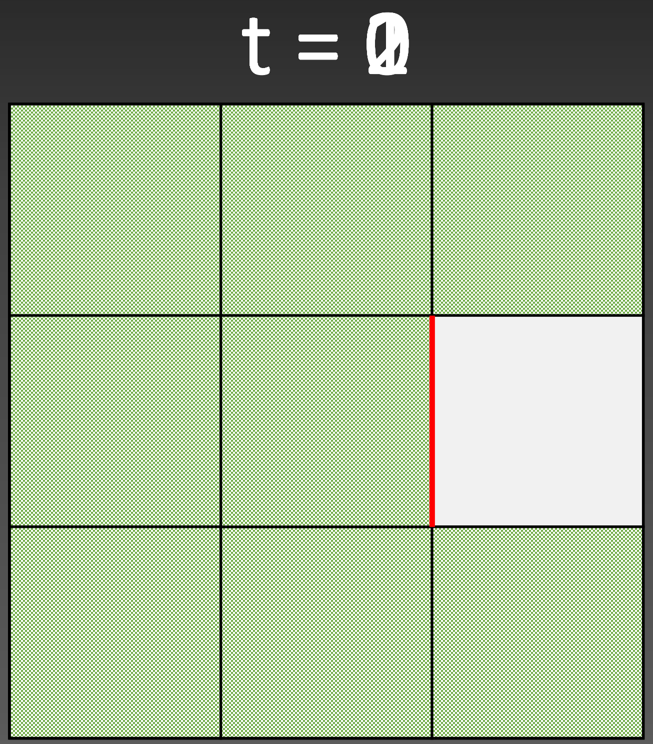


Epanchin-Niell and Wilen (2012)

- Two-Dimensional Cellular Automata
  - Each cell is invaded or uninvaded
    - Integer Programing

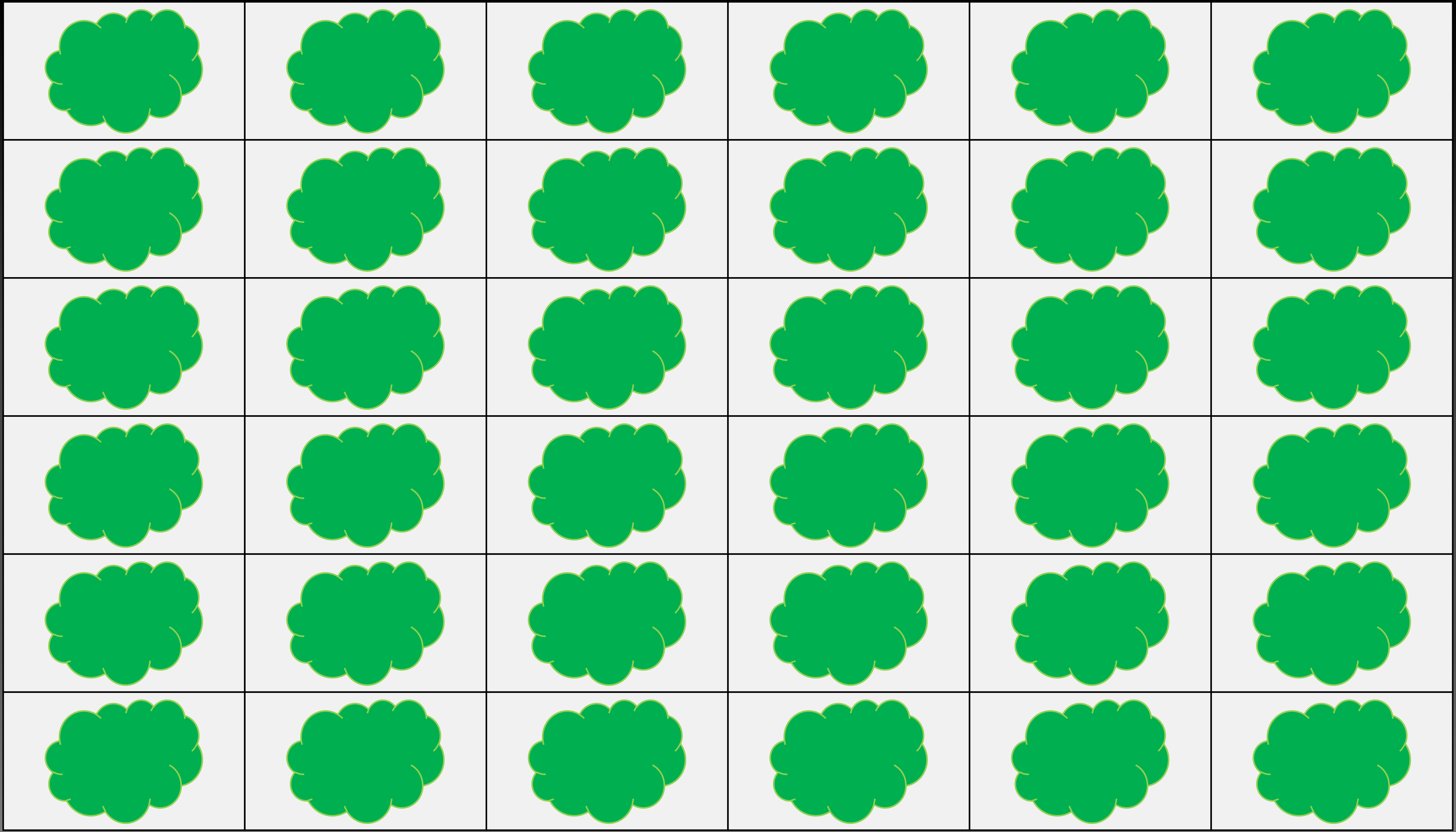
- Two Control Strategies
  - Eradication (Kill within a cell)
  - Block the Edge (Prevent spread to adjacent cell)

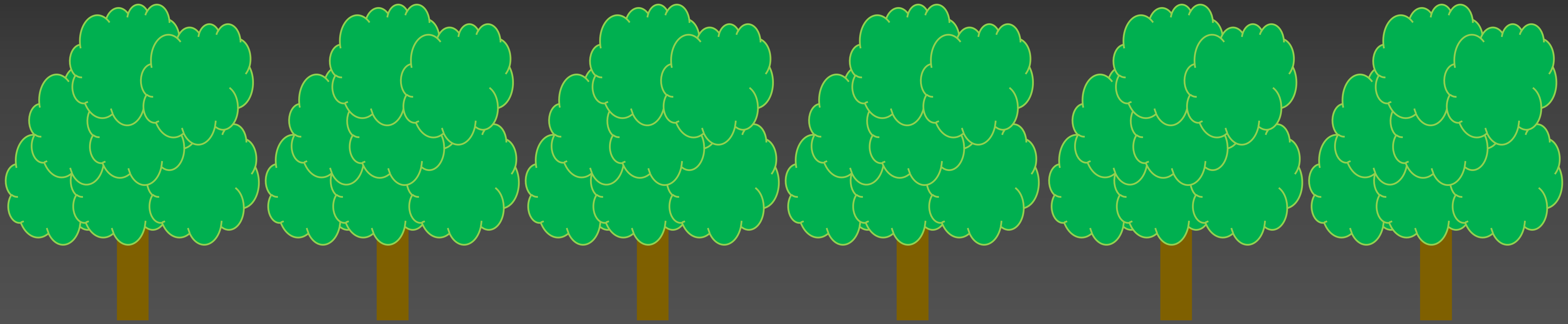
- Findings:
  - Optimal control strategy changes with the physical shape of the landscape (dimensions)



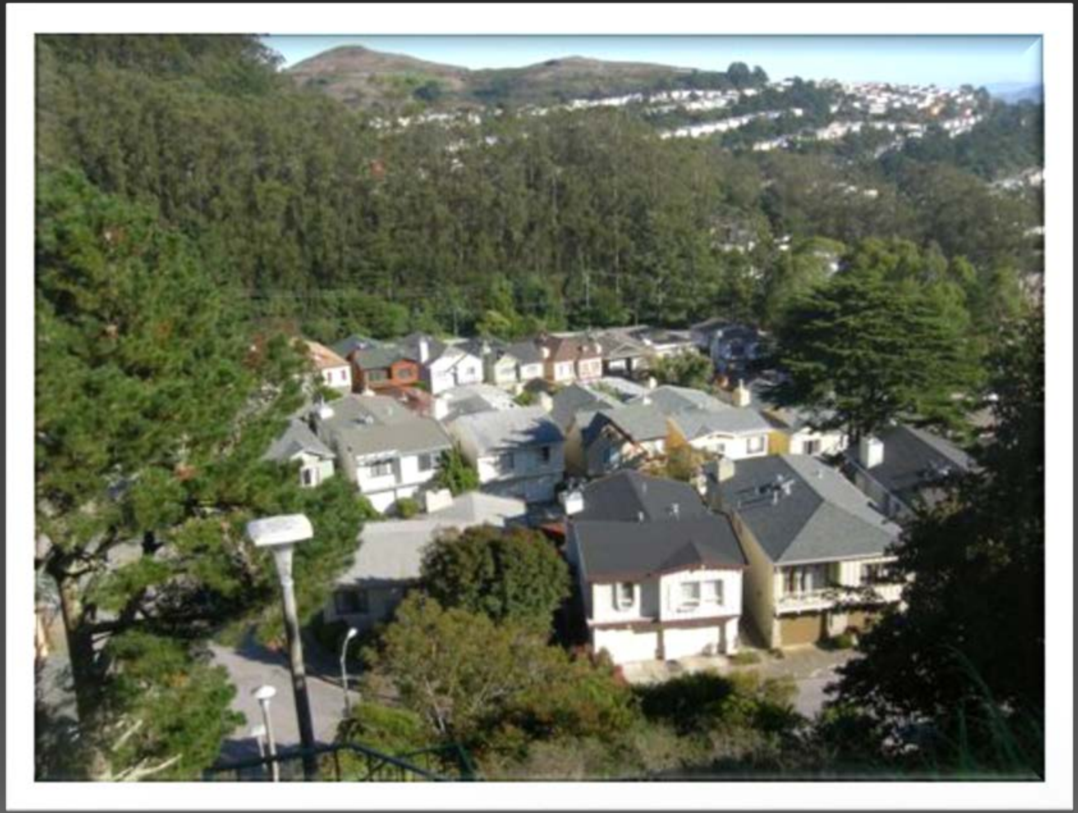
Key Assumption

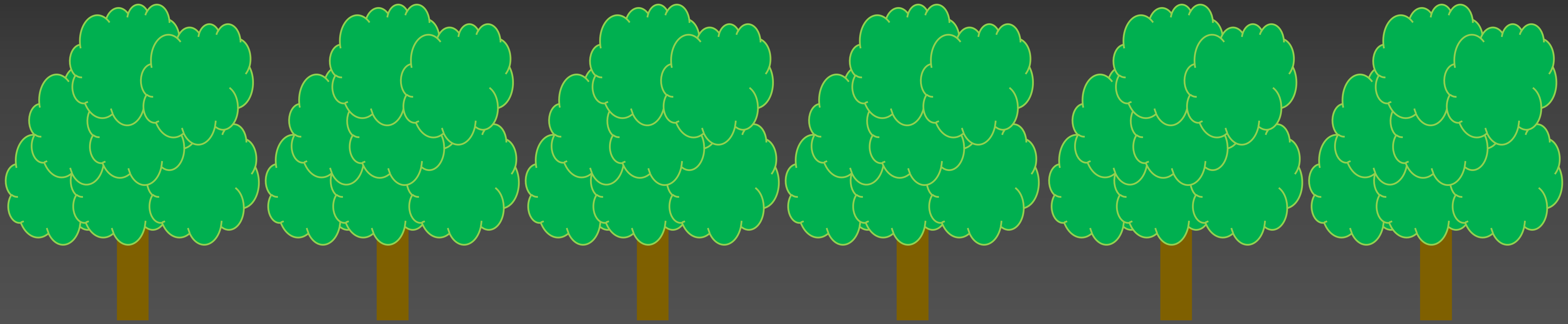
- Homogeneous Carrying Capacities:
    - Each patch of land has identical quantities of foliage

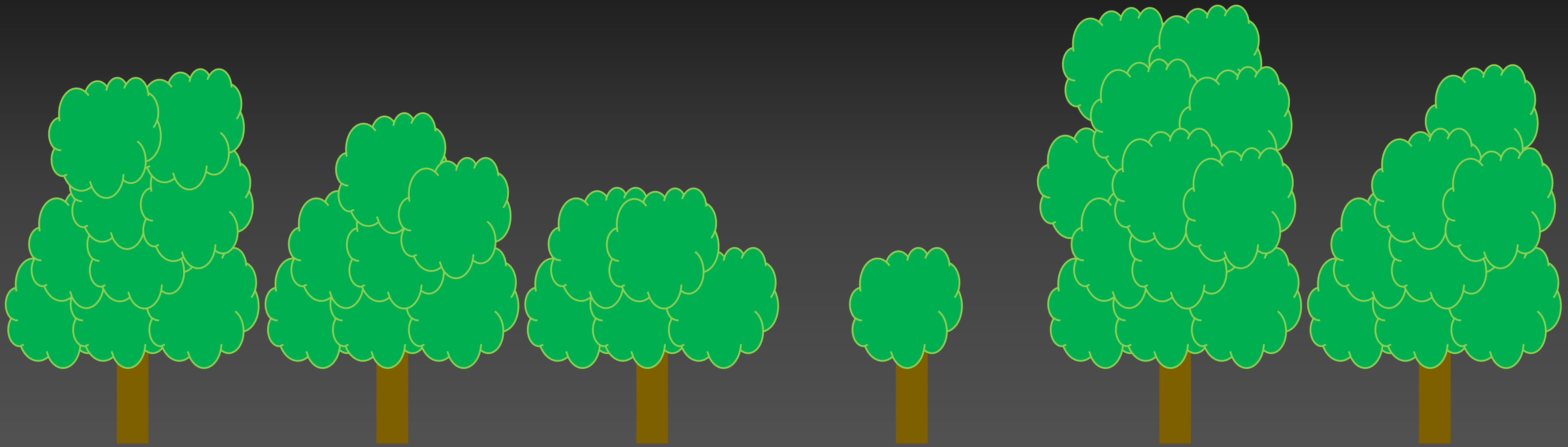


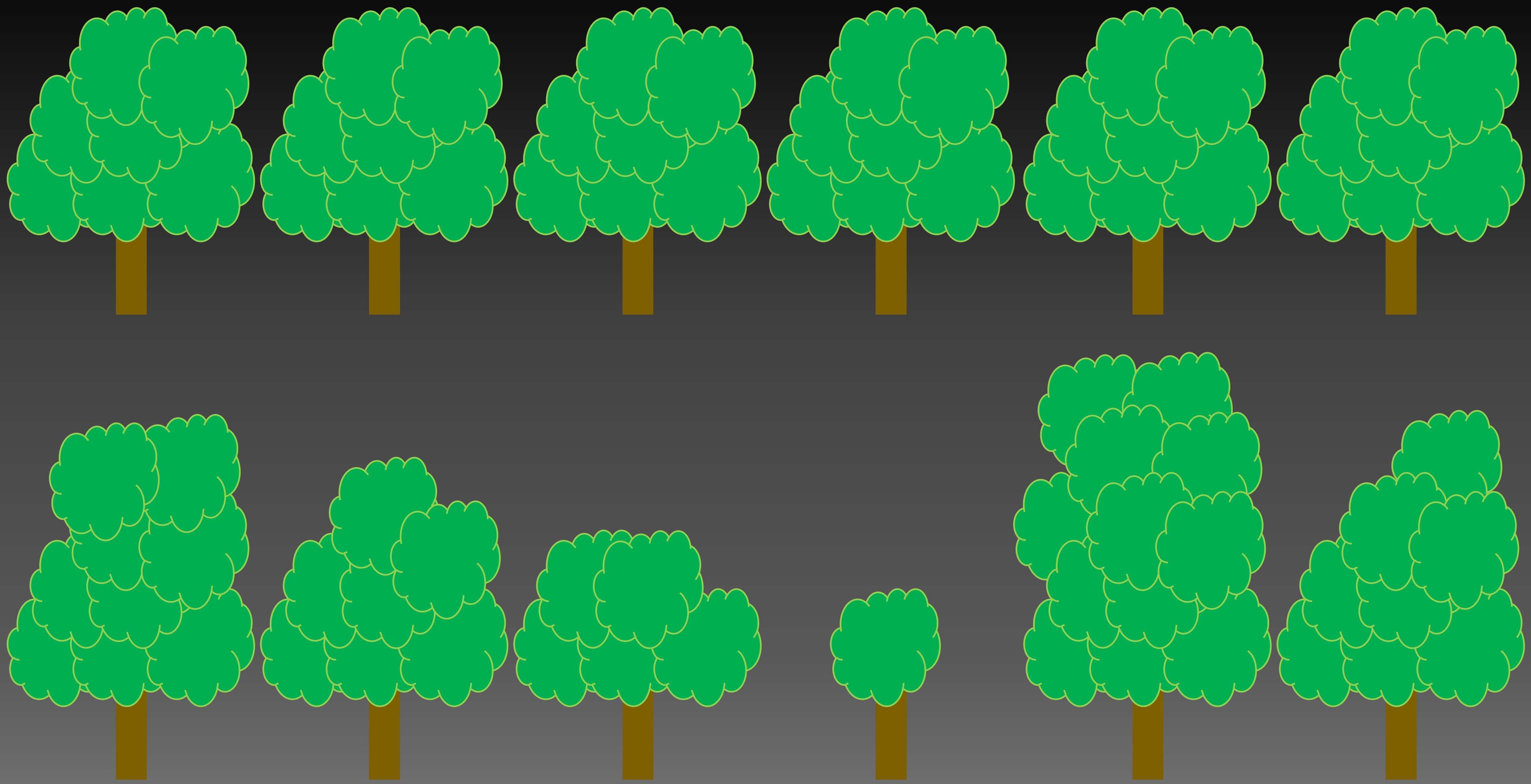


Spatially Varying Carrying Capacities





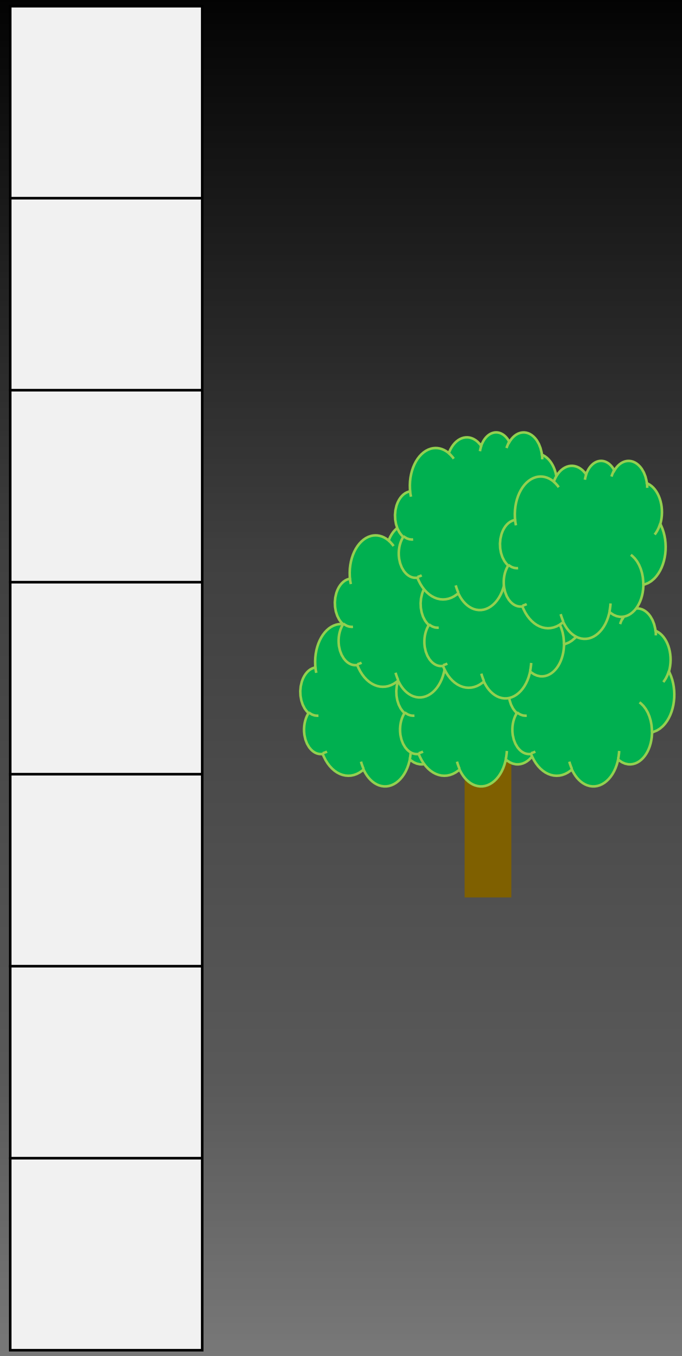


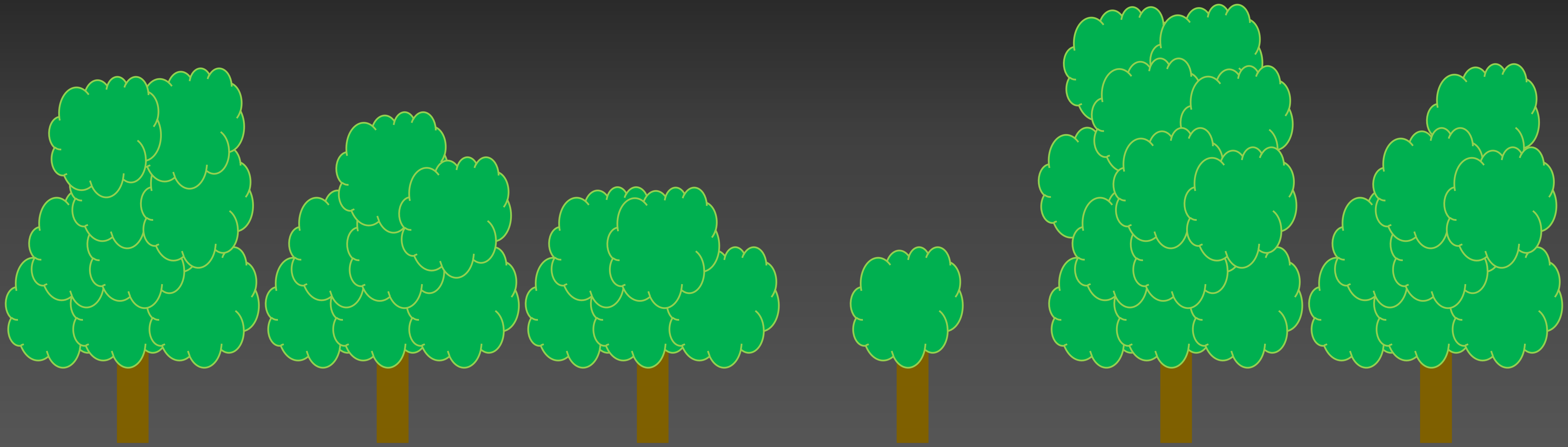


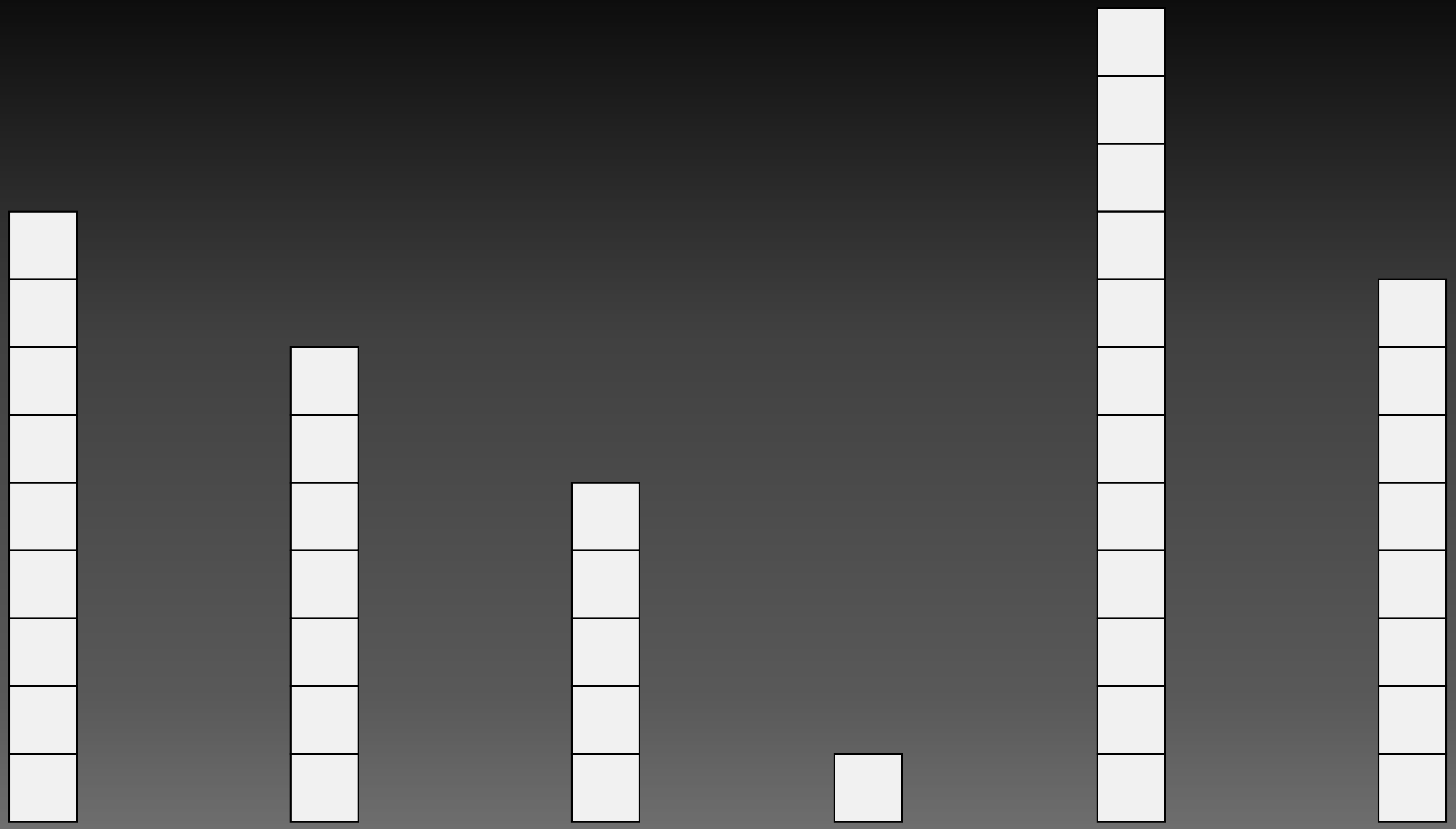
Do spatially varying carrying capacity configurations lead to different optimal control strategies?

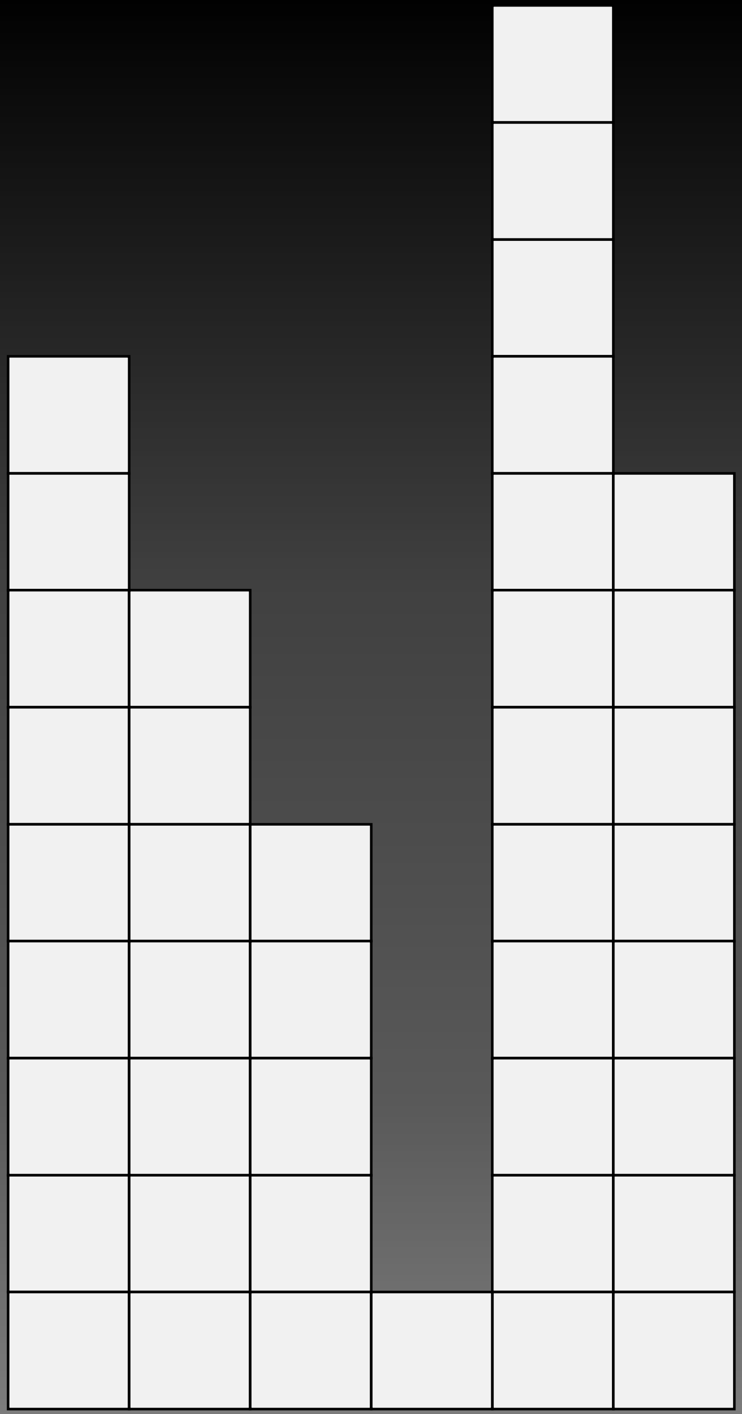
Our Research

- Introduce a new mechanism for invasive species control
  - Suppression
- Allow cost and damage parameters to be functions of carrying capacity instead of being constants
- New motivation for why spatially heterogeneous control policies are necessary



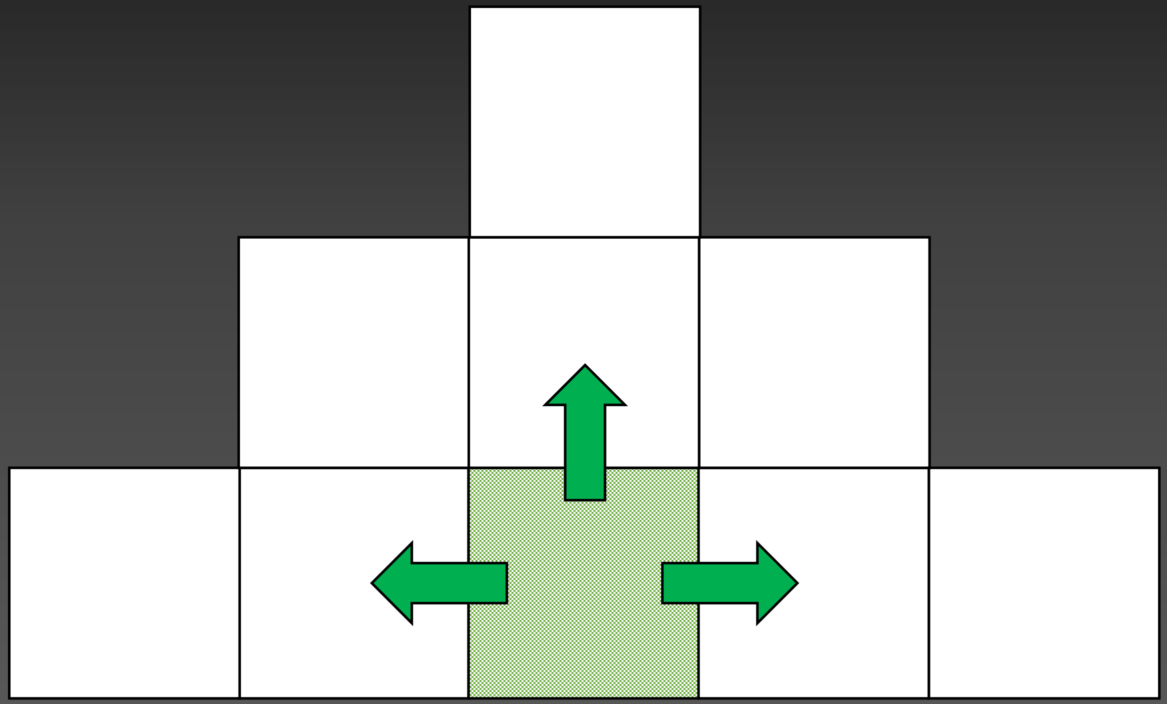






Spread Mechanism

- In each time period:
  - Spreads Left
  - Spreads Right
  - Grows Upward in Intensity



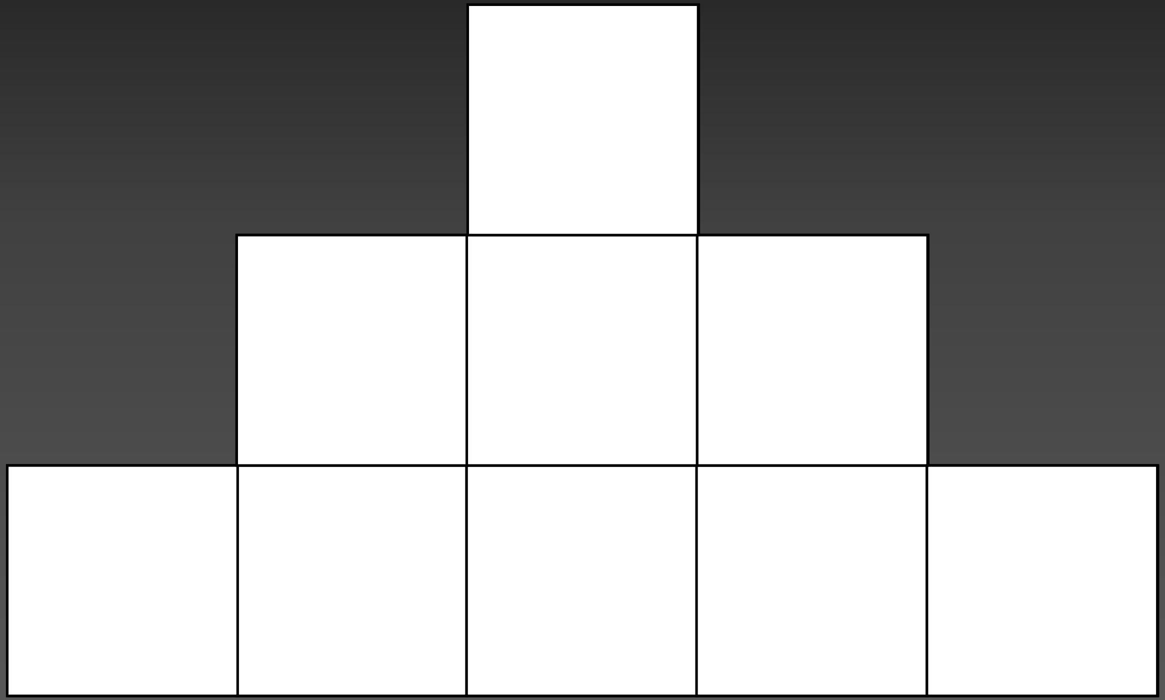
Two Distinct Control Mechanisms

- Eradication
- Suppression

Eradication

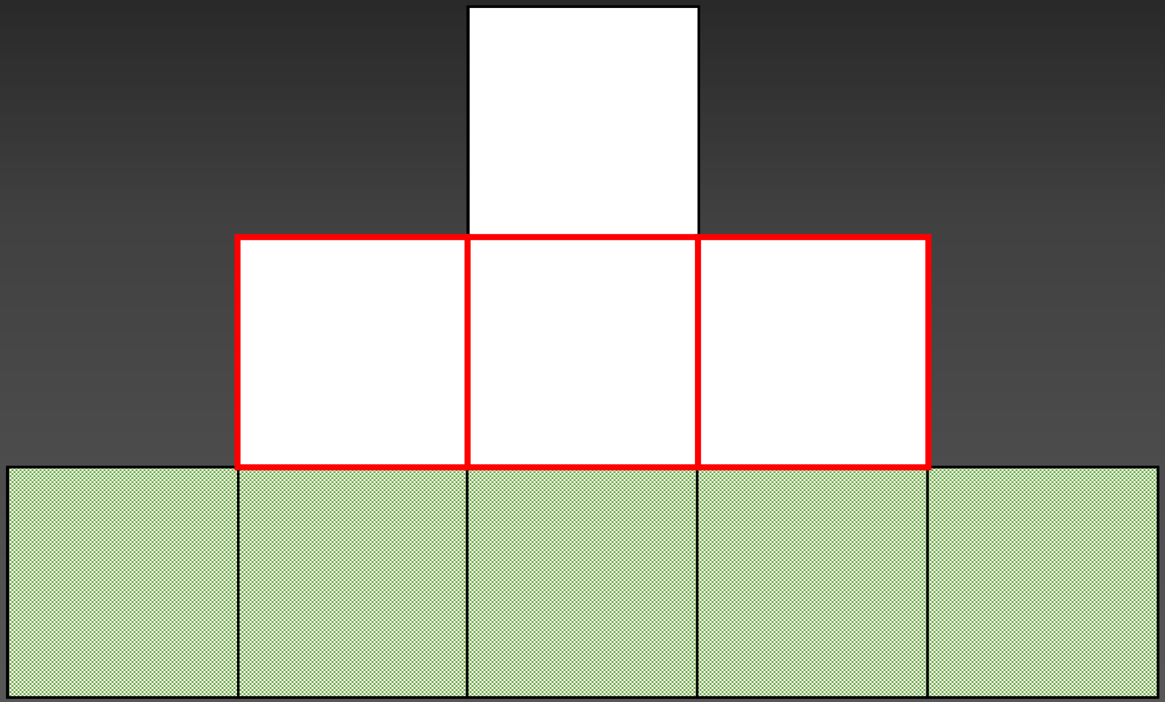
- Eliminates the invasive from an entire patch (column)
- Cost is a function of carrying capacity

t = 0



Suppression

t = 0



- Reduces the intensity within a parcel by one unit
- Cost is constant
- Invasive cannot be suppressed into extinction

Model

- Minimize the net present value of the damage caused by the invasive and the cost of control.

Objective Function

$$Min\left\{\sum_{t=1}^{T_{max}} r * \left(\sum_{(i,j)\in C} x_{ijt} * d_j(k) + \sum_{(i,j)\in C} y_{ijt} * e_j(k) + \sum_{(i,j)\in C} z_{ijt} * s\right)\right\}$$

- Total damage of all invaded cells
- Total cost of all eradication decisions
- Total cost of all suppression decisions

- We use branch and bound method to solve the IP problem

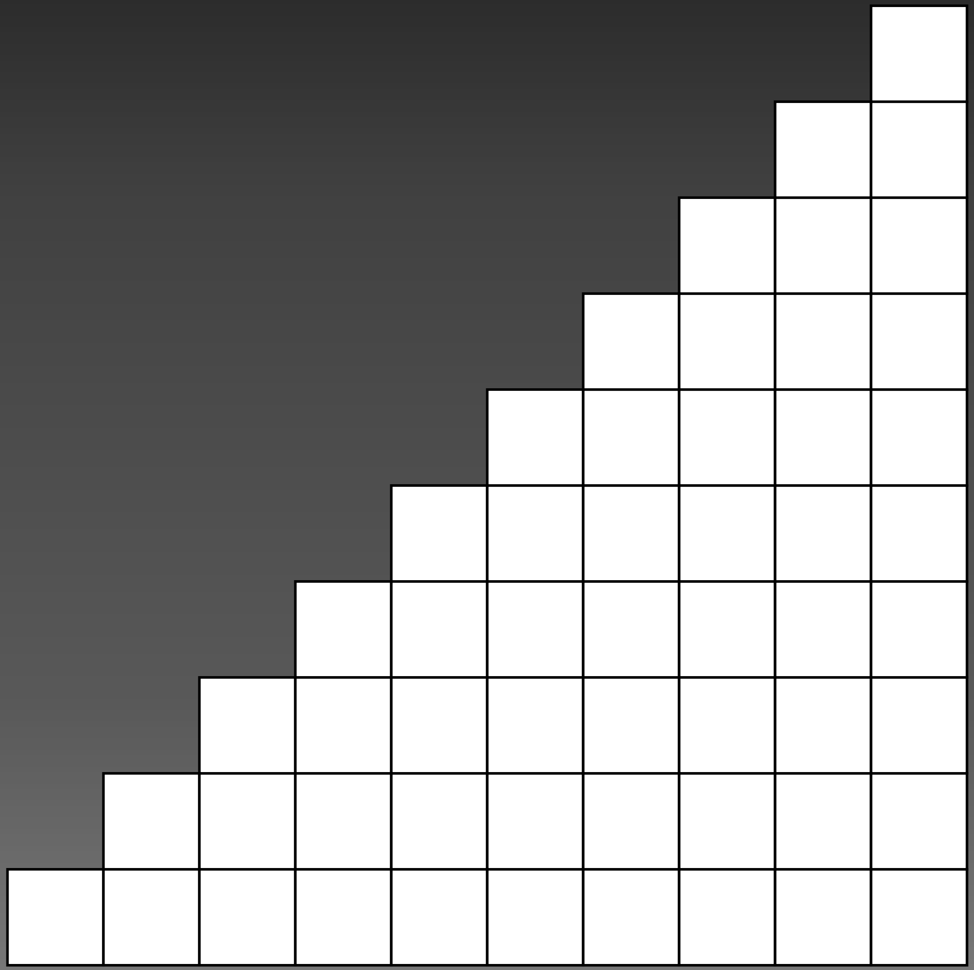
Results

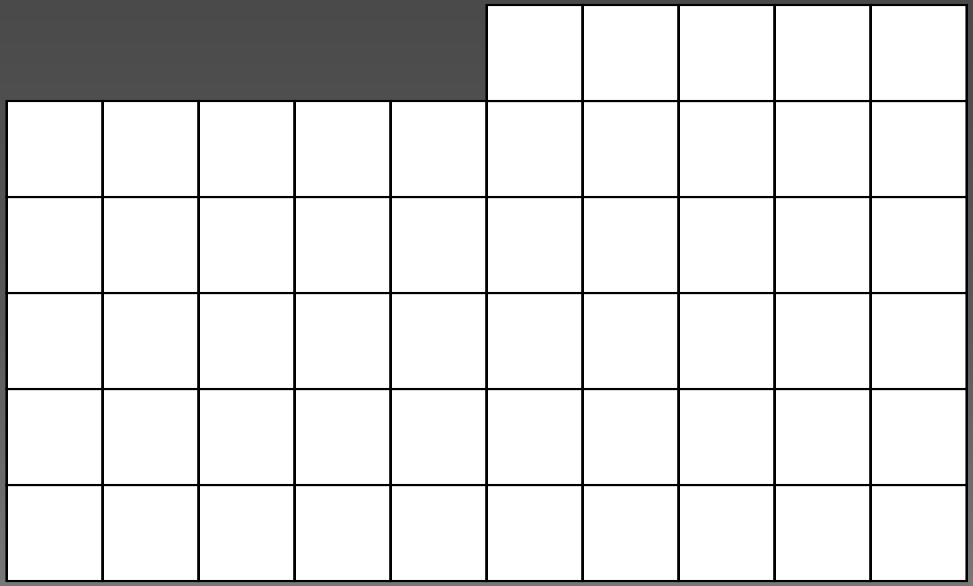
- Compare two landscapes with different carrying capacity configurations

- All parameters are kept the same
  - e = 40, s = 5, d = 1, r = .05, T = 50

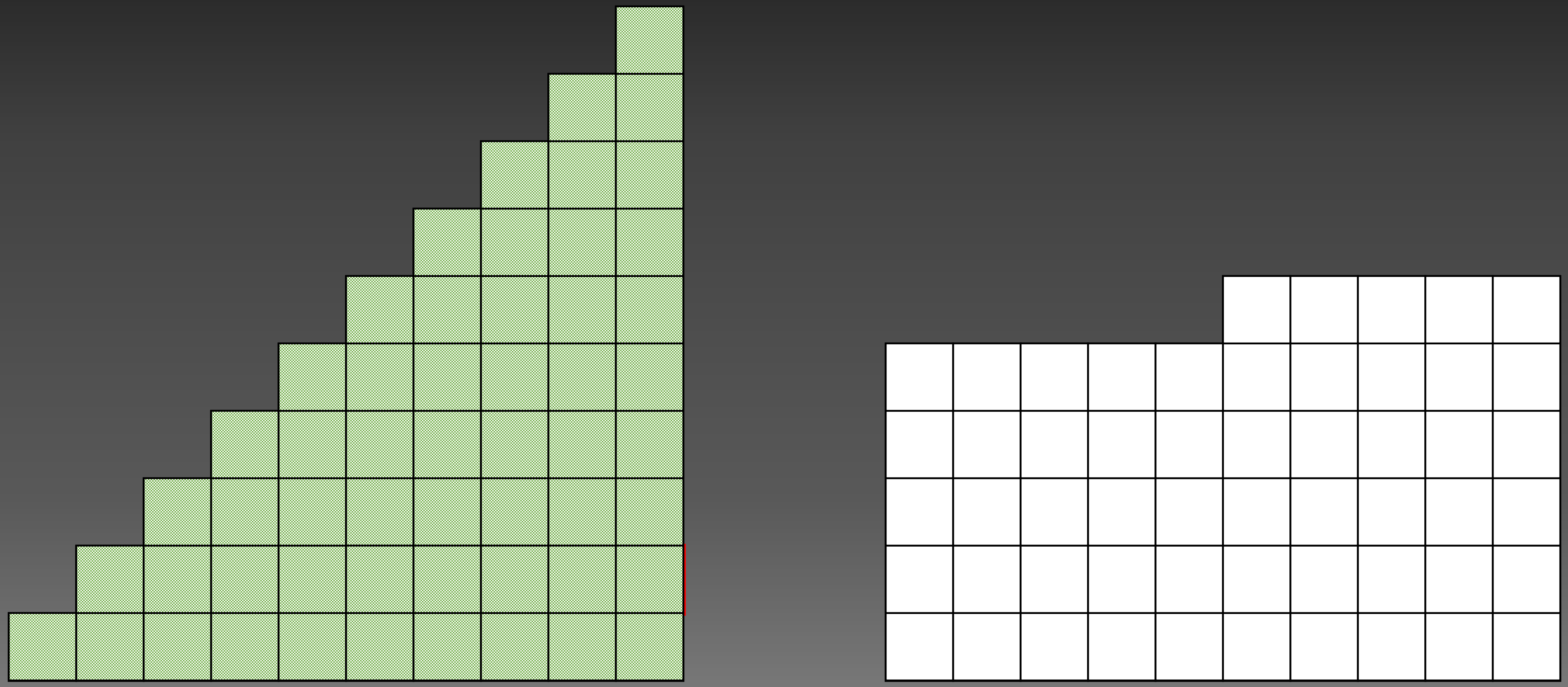
- Total number of cells in the landscape kept the same

Two Landscapes

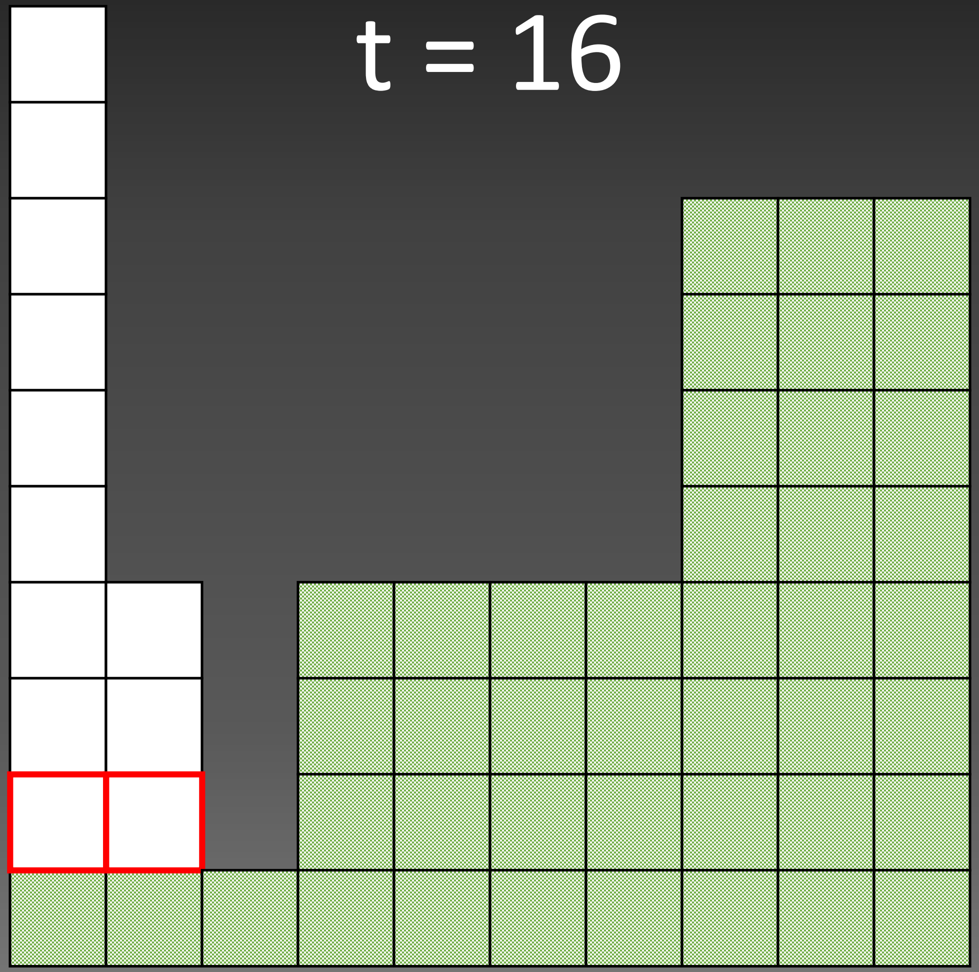




t = [illegible]



Another Equilibrium



Conclusions

- It is possible to introduce some ecological complexities into spatial dynamic optimal control models.

- Spatially varying carrying capacities are important for policy makers to consider as they try to combat invasive species.

- Ignoring ecological factors about landscapes under threat from biological invasions may lead to suboptimal control policies being put into practice.

Next Steps

- Estimate damage parameter (hedonic) and collect information on control costs.
- Empirically ground this model to the gypsy moth invasion in Ohio.
- Compare optimal control strategies found to the “Slow The Spread” program currently being implemented.

Thank You!

$e = 50, s = 0.7, d = 1/k, r = .05, T = 50$