Spatial Distribution in Competition

Project Module Associated with
2nd Edition, Introduction to Computational Science: Modeling and Simulation **by**

Angela B. Shiflet and George W. Shiflet
Wofford College

Cellular Automaton Simulation Techniques, such as in Chapter 10
or
Agent-Based Modeling Techniques, such as in Chapter 11

Overview of Model

Silvertown et al. (1992) considered competition among five grasses—*Lolium*, *Agrostis*, *Holcus*, *Poa*, *Cynosurus*. Because competition occurs mainly between neighbors, they employed a cellular automaton simulation to investigate the impact of different initial spatial configurations of the plants on the outcome of interspecific competition. Initial configurations included random arrangements and various arrangements of monospecific bands.

Table 1 gives the yearly rates of replacement of invading grasses (left column) to native species (top row). At each iteration of the model, we consider the four nearest neighbors (north, east, south, west) of each cell. Weighted by the number of these neighboring grasses, species *i* is randomly replace by a neighboring species *j* with the probability p_{ij} from Table 1. For example, suppose a cell contains *Lolium*, while the neighbors are one of *Poa*, two cells of *Agrostis*, and one of *Lolium*. At the next iteration, the cell in the center of this neighborhood will be replaced by *Poa* with a probability of $0.44 \times 1/4 = 0.11$. However, the cell changes its contents to *Agrostis* with a probability of $0.23 \times 2/4 = 0.115$. With a probability of 0.775 (= 1 – 0.11 – 0.115), the cell would continue to contain *Lolium*.

Table 1. Yearly rates of replacement of invading grasses (left column) to native grasses (top row) (Silvertown et al. 1992)

	Native Species				
Invasive Species	***Lolium***	***Agrostis***	***Holcus***	***Poa***	***Cynosurus***
Lolium	—	0.02	0.06	0.05	0.03
Agrostis	0.23	—	0.09	0.32	0.37
Holcus	0.06	0.08	—	0.16	0.09
Poa	0.44	0.06	0.06	—	0.11
Cynosurus	0.03	0.02	0.03	0.05	—

The projects below involve development of such a cellular automaton simulation. Moreover, experiments using the simulation will consider ramifications of various initial configurations.

Project

1. **a.** Develop a cellular automaton simulation for grass competition using the data above. Have the world be a 40-by-40 lattice with an additional one-cell inert boundary containing no grass around the edges. The user should be able to initialize the world with a random configuration so that each cell has an equal probability of having any grass species or with a configuration having *Cynosurus* grass bands, 8 cells in height, in one of the following orders: *Agrostis*-*Holcus*-*Lolium*-*Cynosurus*-*Poa*, *Agrostis*-*Lolium*-*Cynosurus*-*Holcus*-*Poa*, or *Agrostis*-*Holcus*-*Poa*-*Cynosurus*-*Lolium*. Have switches for the simulation to stop at the following time steps: 50, 100, 150, 200, and 300. The maximum length for the simulation should be 600 time steps. Besides an animation of the simulation, graph abundance (percentage) of each grass versus time.

The following parts of this project involve experimenting with your model. Run the simulation with each initial configuration, saving the plot and a picture of the animation at each time stop, 50, 100, 150, 200, 300, and 600.

b. Describe the plot and simulation result for each initial configuration.

c. Which initial aggregation has the greatest impact on the rate at which stronger competitors exclude weaker ones?

d. How does the initial configuration of the grasses and juxtaposition of the species affect community composition in the medium term?

e. Compare the behaviors of *Agrostis* and *Holcus* when these two dominants are adjacent to one another but in the presence of a third species. Does presence of the third species in the community have a long-lasting effect?

f. When only *Agrostis* and *Holcus* remain, how quickly does change to occur? What is the difference in the invasion rates of the two species on each other? Discuss the impact of this difference on how rapidly change occurs when only the two dominant species remain.

g. Use the results of your experiments to discuss spatial distribution as a factor in determining competitive outcome.

2. **a.** Refine your model to allow the user to specify any order of bands of grasses.

b. Design and perform a series of experiments to examine the impacts of initial spatial distribution. Discuss the results.

References

Silvertown, Jonathan, Senino Holtier, Jeff Johnson, and Pam Dale. "Cellular automaton models of interspecific competition for space - the effect of pattern on process." *J. of Ecolog*y, 1992, 80, 527-534