Modeling, Simulation, and Analysis: Final Project

Due on Dec 16, 2015 at 10:30am

Professor Eric Aaron Section 1

Jayce Rudig-Leathers

Proposal

I propose to construct a cellular automata based model of a forest to answer questions about forest dynamics, including competition among different species for resources such as light and space. I believe that a cellular automata model will allow my project to have the furthest scope in the time I have available to it. Some examples of what I'd like to find out with my model are: how a forest regrows after clear cutting, which type of trees are more apt to grow back. What effect does the max height/width of a tree have on its competitive ability.

The model

I am using Lett's model as a basis for my own [1]. Presented here are the equations and constants I used in my simulation. In the interest of time I will only state the differences between my model and Lett's. Lett's model does not contain values for the last seven values in the Constants table. These I intuited or found in the case of k which I found as online as the average yearly light extinction for all biomes.

Species Specific parameters

	Description	White birch	Yellow birch	Beech
G	Parameter that determines how early in its age (or size) a tree achieves most of its growth	190.1	143.6	87.7
Dmax	Maximum diameter at breast height (cm)	76	100	160
Hmax	Maximum height (cm)	3050	3050	3660
AGEmax	Maximum age (years)	140	300	366
C	Constant of proportionality relating leaf area to tree diameter	0.486	0.486	2.200
Almin	Minimum proportion of incident sunlight needed for regeneration	0.99	0.90	0.00
Almax		1.00	0.99	0.90
b2		76.6	58.3	44.0
b3		0.504	0.291	0.137

Equations

Equation	Description
$\Delta D_{opt} = \frac{GD\left(1-\frac{DH}{D_{max}H_{max}}\right)}{274+3b_2D-4b_3D^2}$	Optimal Growth for a tree
$AL = AL_0 exp(-kSLAI)$	Available Light
$BAR = \sum_{neighborhood} \frac{\pi D^2}{4}$	Total Basal Area Equation
$f(AL)_{1-2} = 2.24(1 - exp(-1.136(AL - .08)))$	Shade response for shade intolerant and shade intermediat species
$f(AL)_3 = 1 - exp(-4.64(AL - .05))$	Shade response for shade tolerant species
$s(BAR) = 1 - \frac{BAR}{BAR_{max}}$	Response to space competition
$\Delta D = \Delta D_{opt} * f(AL) * s(BAR)$	Change in diameter
$D(t + 1) = D(t) + \Delta D$	Equation for Diameter
$H(t + 1) = 137 + b_2D(t + 1) - b_3D(t + 1)^2$	Equation for height
$LA(t + 1) = CD(t + 1)^2$	Equation for leaf area

Constants

Parameter	Value	Descripton
dt	1	timestep in years
$simulationLength$	200	simulation length
$numIterations$	$simulationLength/dt$	number of iterations
m	25	size of forest in cells
n	25	size of forest in cells
R	6	neighborhood radius meters
s_{cell}	2	size of cell in meters
$AL0$	.99	light incident above canopy
k	.56	light extinction coefficient
$BARmax$	150	maximum basal area
$ageDeathFraction$	.001	fraction of trees to reach species dependent maximum age
$competitionDeathFraction$	.01	fraction of trees which should die if growth is below AINC
$AINC$	.001	minimum D increment to not have a chance of death
$competitiveDeathProbability$	$1 - competitionDeathFraction^{(}1/10)$	chance of competitive death

Validation of Model

I'm currently in the process of model validation. My main method of validation is to get results in line with Lett's. Currently I'm experiencing unpredictable results from my simulation. There's an error somewhere and I'm trying to find it. I believe it's to do with my choice of constants and how I'm utilizing them.

Evaluation of Model

It's too early to truly evaluate the model but some initial thoughts I've had on the structure of Lett's model as I've been working are as follows.

1. The other two trees within a cell are not taken into account within the neighbor equation. It seems to me that for any tree in a cell, the other two trees in that cell should be its neighbors as well as those within the radius.

References

[1] Christophe Lett, Catherine Silber, and Nicolas Barret. Comparison of a cellular automata network and an individual-based model for the simulation of forest dynamics. *Ecological Modelling*, 121(2–3):277 – 293, 1999.