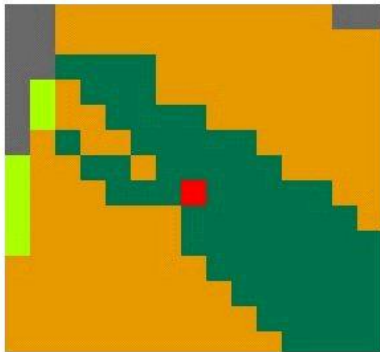
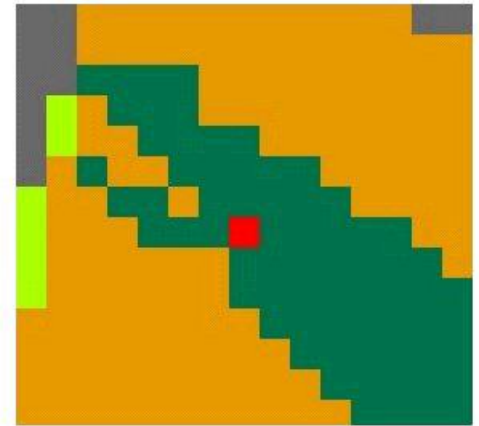


Modelling Landscape Dynamics with Cellular Automata and Agent-Based Models

Dr. James Millington



What is a Cellular Automaton?



Grids of cells (pixels) that change state dependent on rules about their neighbours

What is an Agent-Based Model?

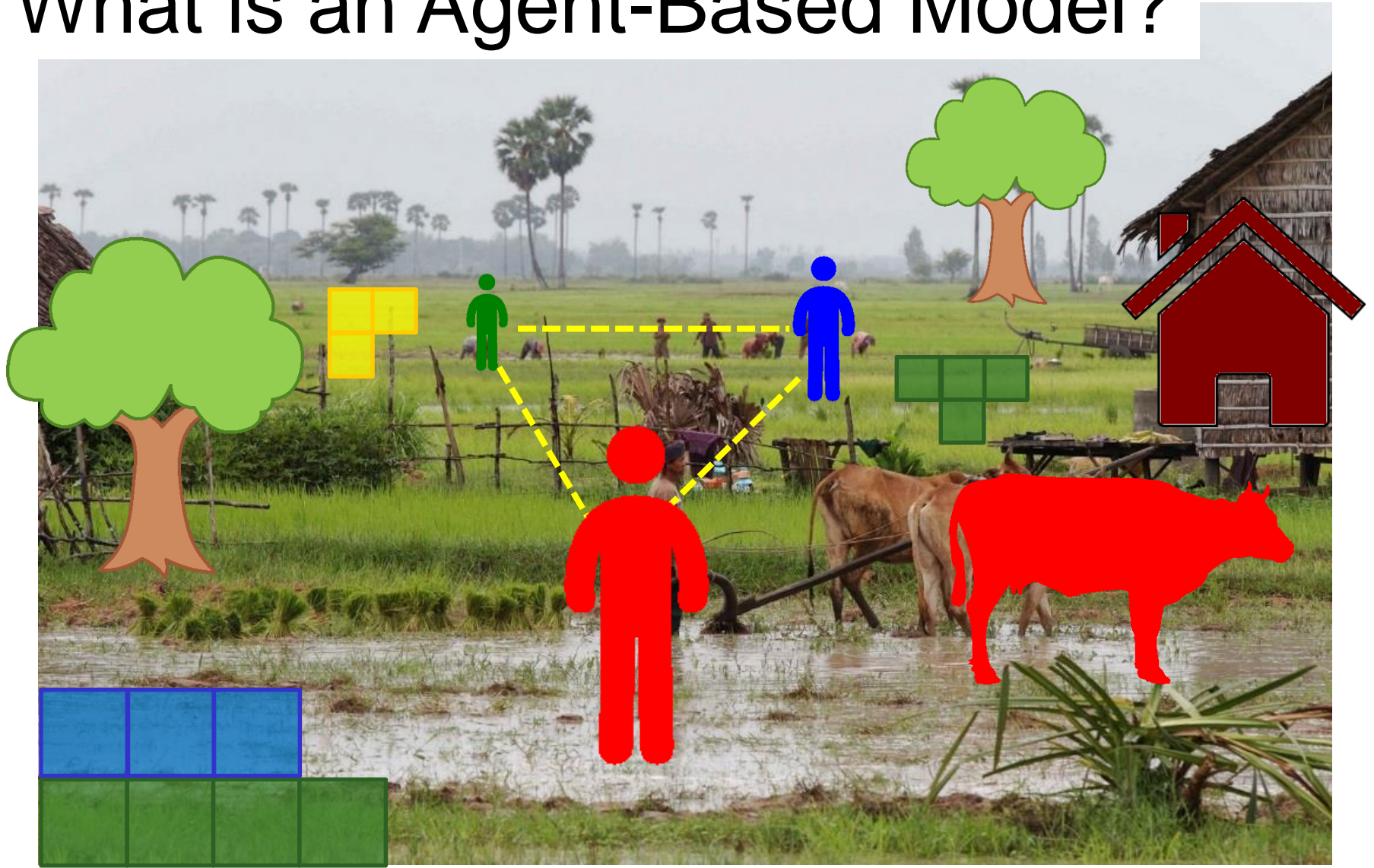


Image: [Sophie et Fred](#), flickr

'Bottom Up' Simulation

■ ***Discrete Element Models***

- Geomorphology
- e.g. gravel-bed rivers, avalanches, debris flows

■ ***Individual-Based Models***

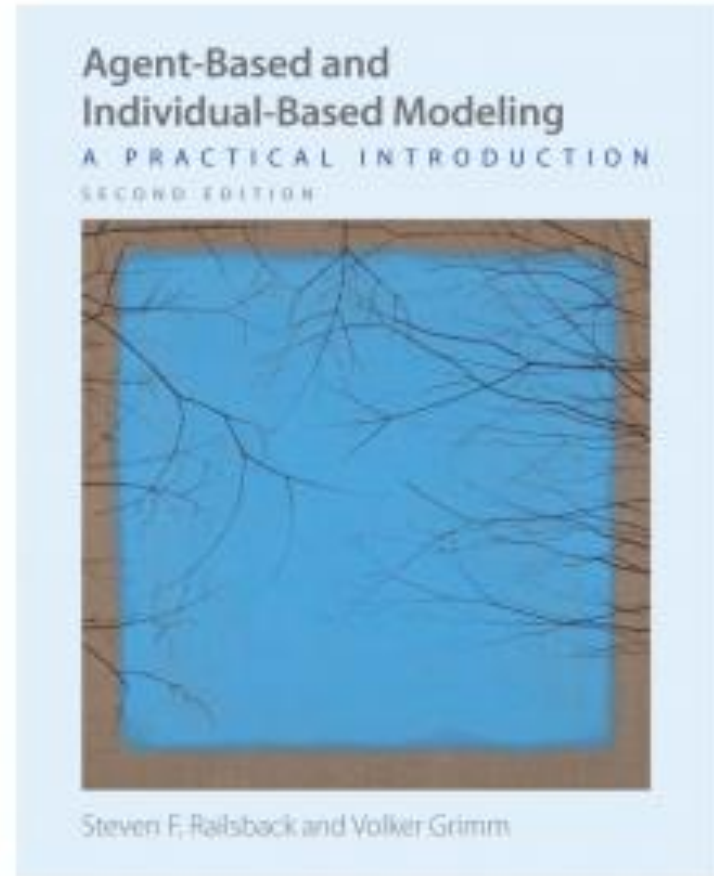
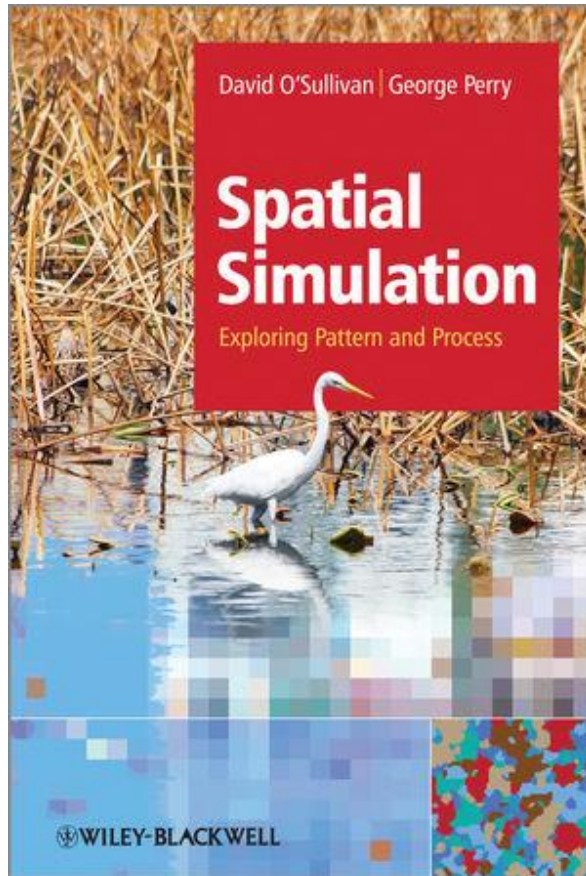
- Ecology
- e.g. foraging animals, forest growth/senescence

■ ***Agent-Based Models***

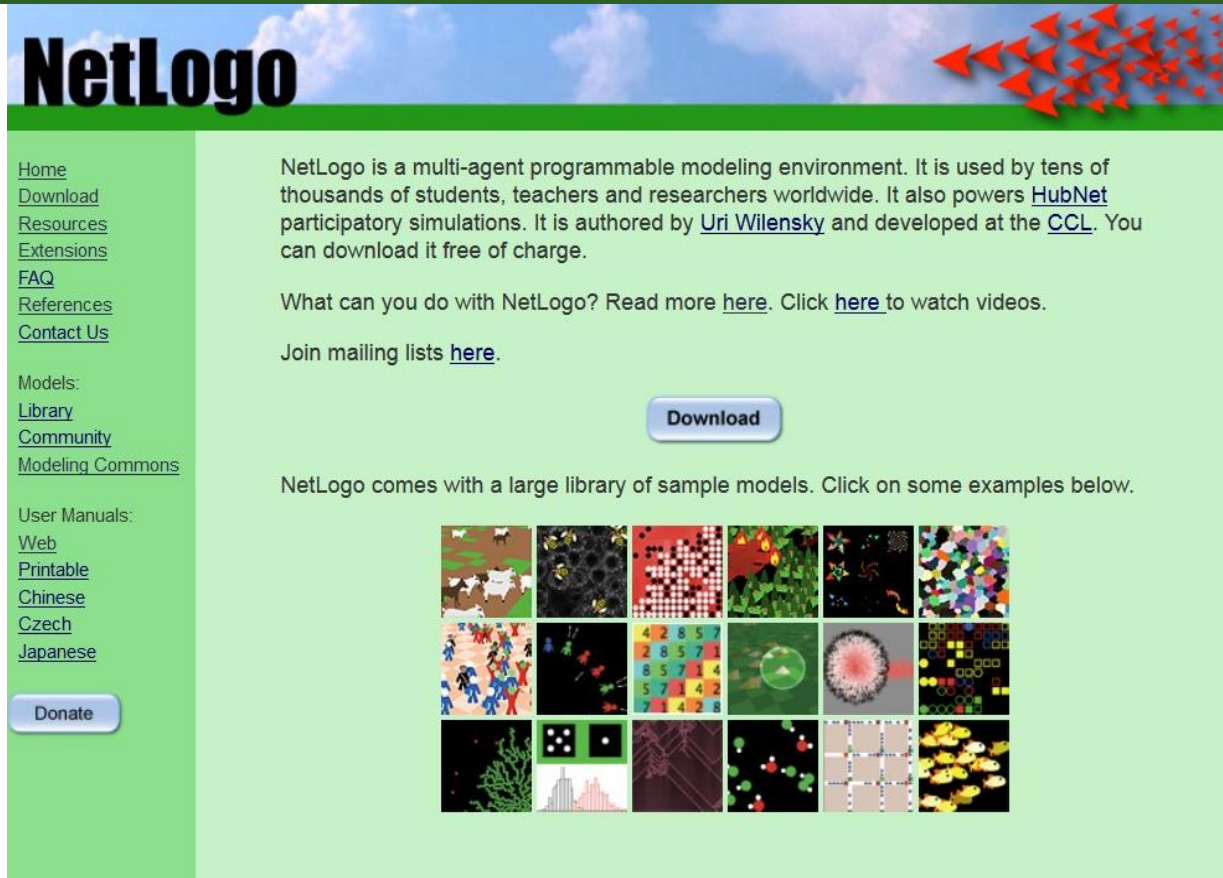
- Social Science
- e.g. subsistence farming, urban populations

See Bithell *et al.* (2008) for review

Resources



<http://ccl.northwestern.edu/netlogo/>

A screenshot of the NetLogo website. The header features the "NetLogo" logo in large black text on a blue sky background with clouds. To the right of the logo is a decorative graphic of red arrows pointing left. Below the header, the page is divided into a green sidebar on the left and a main content area on the right. The sidebar contains a list of links: Home, Download, Resources, Extensions, FAQ, References, Contact Us, Models: Library, Community, Modeling Commons, User Manuals: Web, Printable, Chinese, Czech, Japanese, and a blue "Donate" button. The main content area has a light green background. It contains a paragraph about NetLogo being a multi-agent programmable modeling environment, used by thousands of students, teachers, and researchers, and powered by HubNet. It mentions it is authored by Uri Wilensky and developed at the CCL, and that it is free of charge. Below this, it says "What can you do with NetLogo? Read more here. Click here to watch videos." and "Join mailing lists here." There is a blue "Download" button. Further down, it says "NetLogo comes with a large library of sample models. Click on some examples below." and displays a 4x6 grid of 24 small thumbnail images representing various models, such as a flock of birds, a forest, a city, and a game board.

Download *NetLogo* yourself for free and try it at home.
There's lot's of other resources online to help you get your
own models going...

Landscapes 'Tutorial'

Go to guide and models online:

bit.ly/CA-ABM-landscapes

Forest Fire Cellular Automata

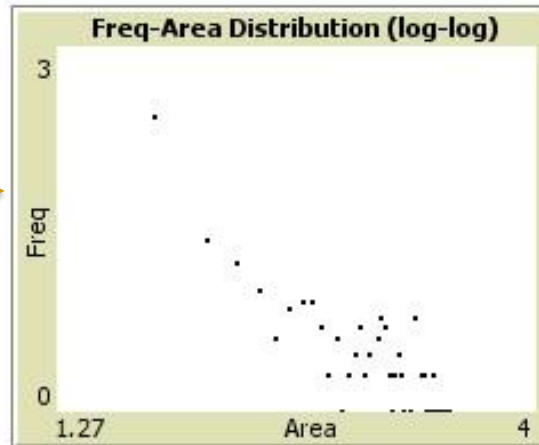
Buttons



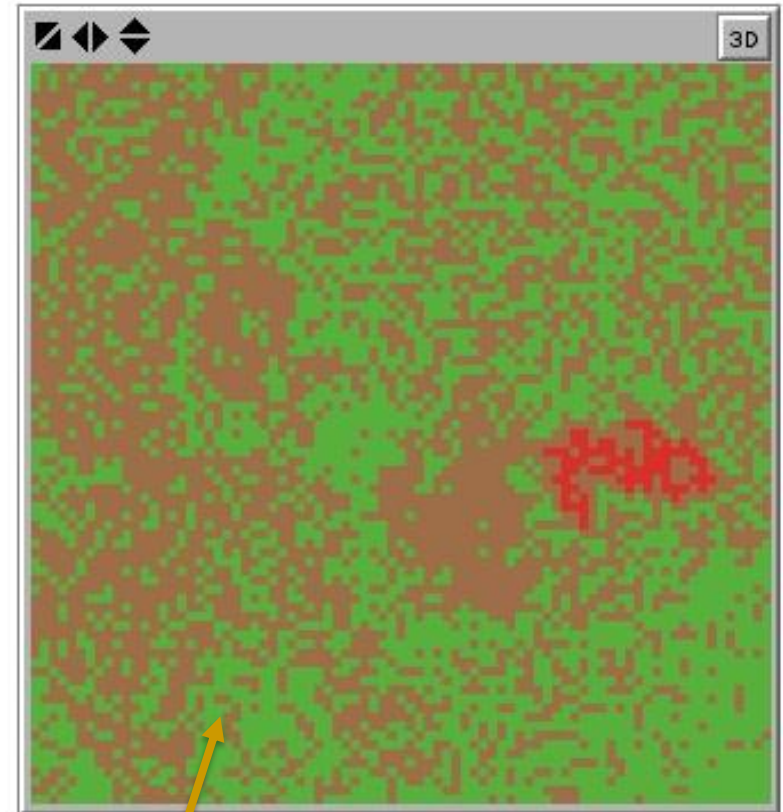
Parameter
(‘slider’)



Plot



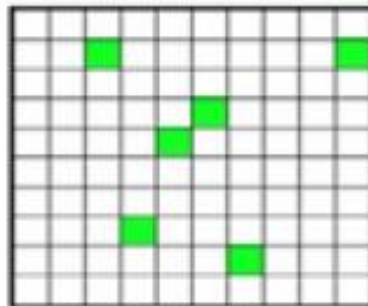
Monitors



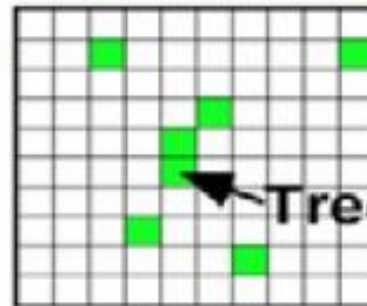
Model ‘Environment’

00	01	02	03	04	05	06	07	08	09
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69
70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89
90	91	92	93	94	95	96	97	98	99

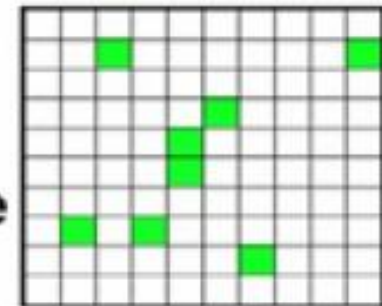
10 x 10 grid



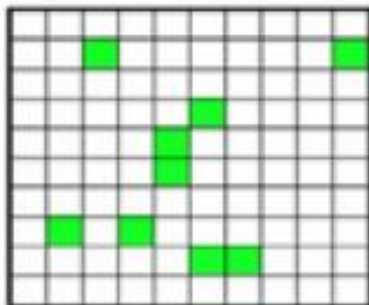
Beginning Configuration



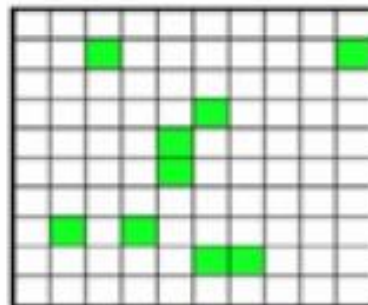
step 1
(tree on cell 54)



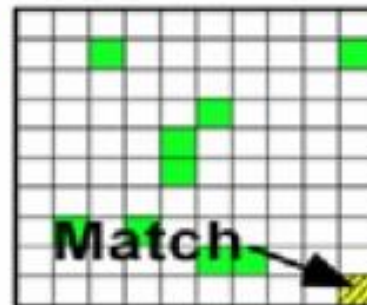
step 2
(tree on cell 71)



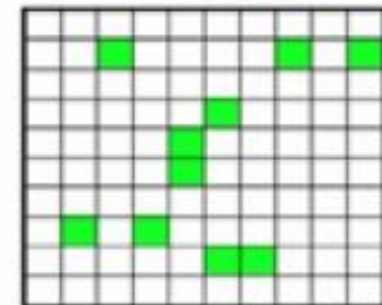
step 3
(tree on cell 85)



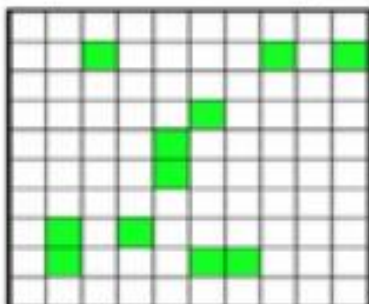
step 4
(tree on cell 19)



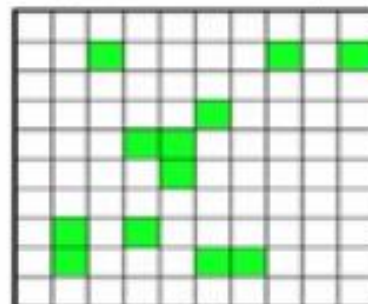
step 5
(match on cell 99, $A_F = 0$)



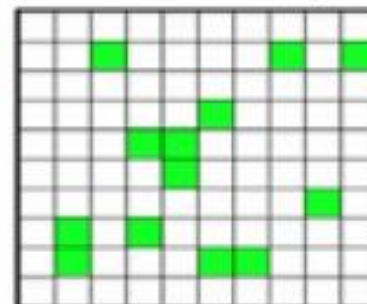
step 6
(tree on cell 17)



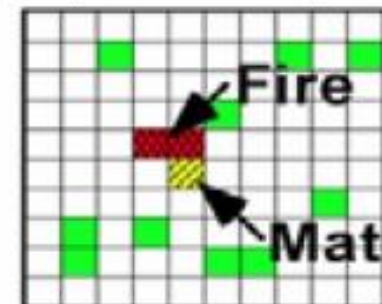
step 7
(tree on cell 81)



step 8
(tree on cell 43)



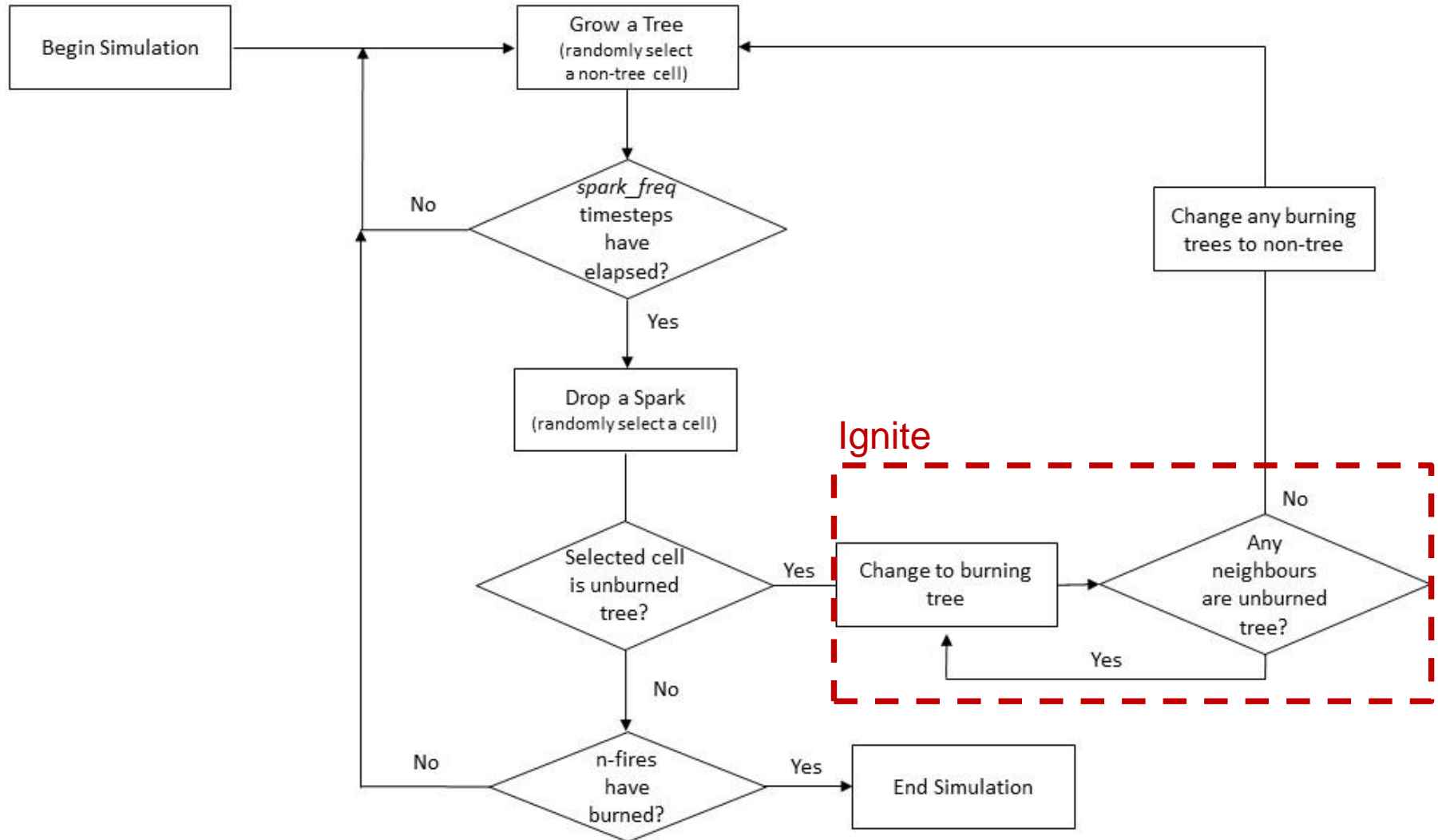
step 9
(tree on cell 68)



step 10
(match on cell 54, $A_F = 3$)

Millington *et al.* (2006)

FFCA flowchart



Power-Law Frequency-Area

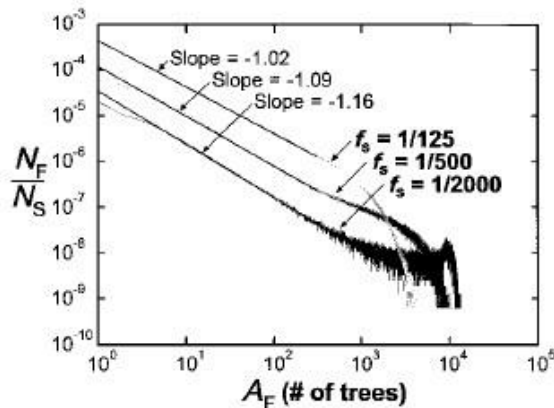


Fig. 1. Noncumulative frequency-area distributions of model forest fires for a grid size of 128 by 128 squares at three sparking frequencies. $f_s = 1/125$, $1/500$, and $1/2000$. The number of fires per time step (N_F/N_S) with area (A_F) is given as a function of A_F , the number of trees that were burned in each fire. For each sparking frequency, the model is run for $N_S = 1.638 \times 10^9$ time steps. The small and medium fires correlate well with the power-law relation (Eq. 1) with $\alpha = 1.02$ to 1.18 ; $-\alpha$ is the slope of the best-fit line in log-log space and is shown for each sparking frequency. The finite grid-size effect can be seen at the smallest sparking frequency, $f_s = 1/2000$. At about $A_F = 2000$, fires begin to span the entire grid.

Malamud *et al.* (1998)

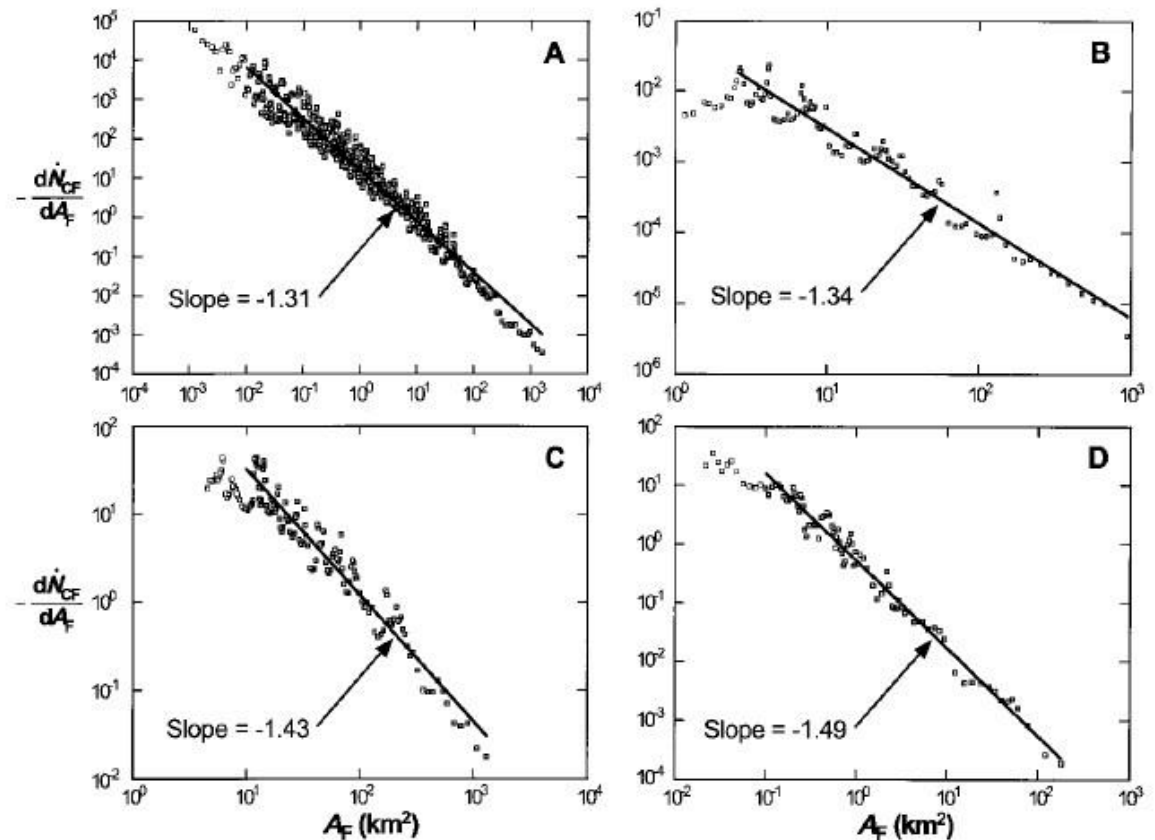
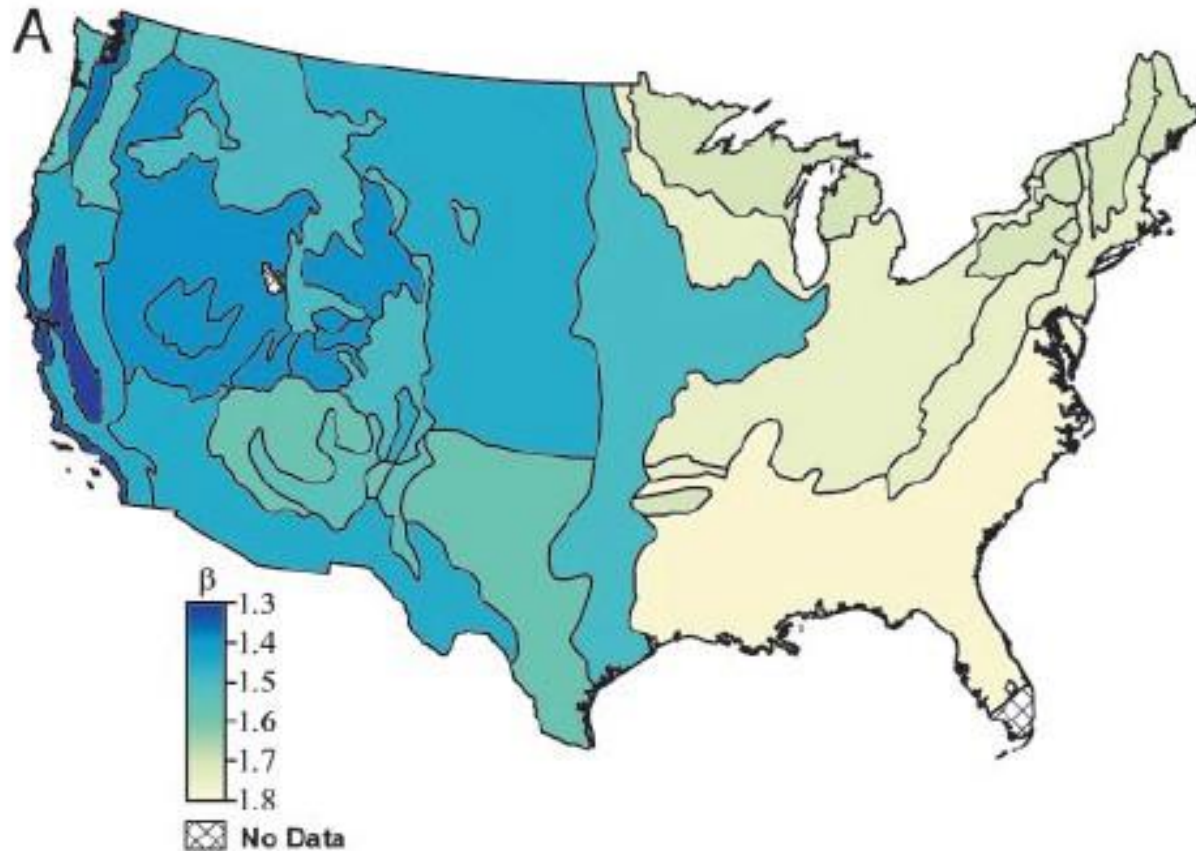


Fig. 2. Noncumulative frequency-area distributions for actual forest fires and wildfires in the United States and Australia: (A) 4284 fires on U.S. Fish and Wildlife Service lands (1986–1995) (9), (B) 120 fires in the western United States (1150–1960) (10), (C) 164 fires in Alaskan boreal forests (1990–1991) (11), and (D) 298 fires in the ACT (1926–1991) (12). For each data set, the noncumulative number of fires per year ($-dN_{CF}/dA_F$) with area (A_F) is given as a function of A_F (13). In each case, a reasonably good correlation over many decades of A_F is obtained by using the power-law relation (Eq. 1) with $\alpha = 1.31$ to 1.49 ; $-\alpha$ is the slope of the best-fit line in log-log space and is shown for each data set.

Spatial Patterns of Statistics

Variation in frequency-area distributions across USA



Malamud et al. (2005)

Walking Agents (Ungulates)

setup go step

go-length 10000

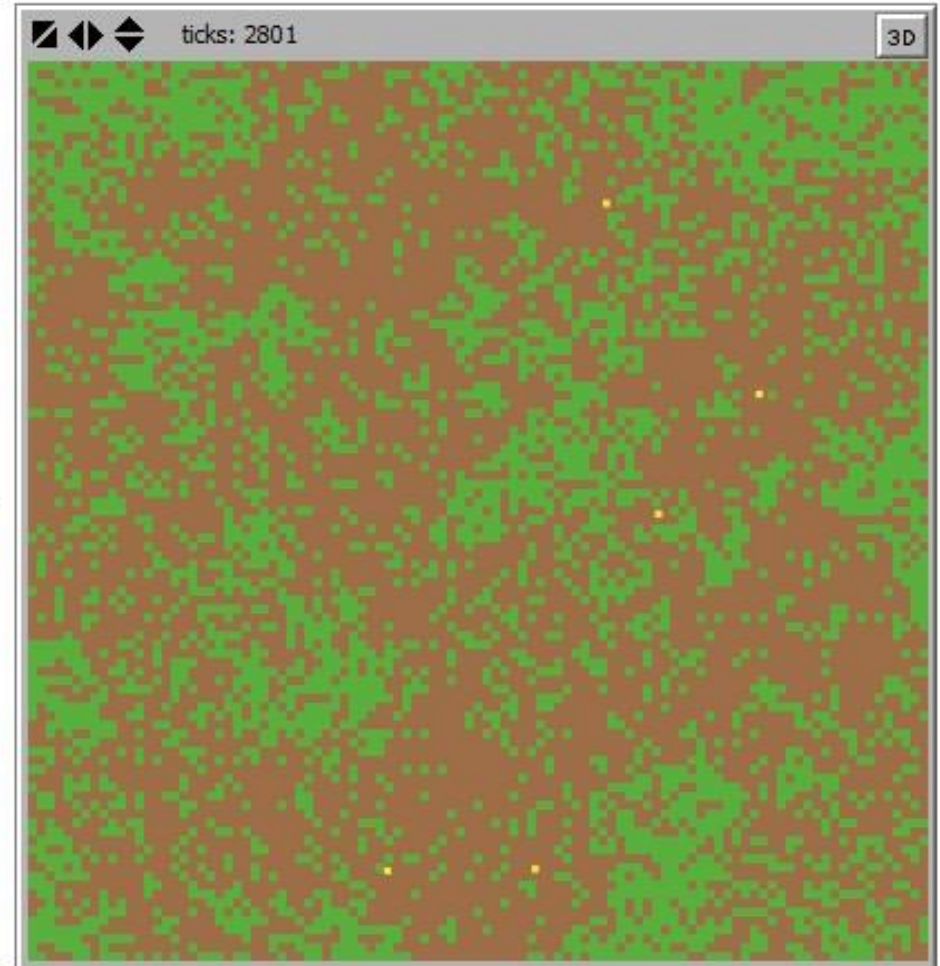
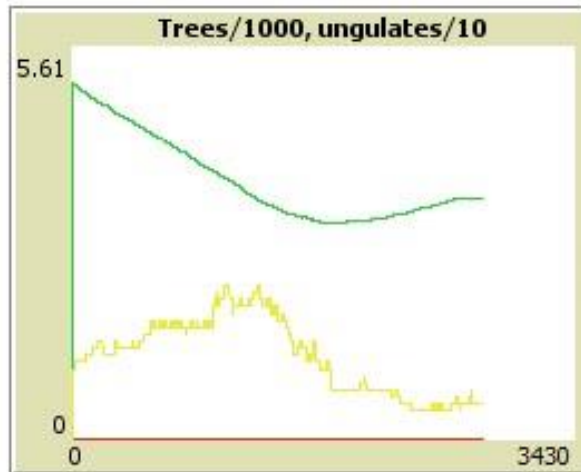
initial-ungulates 10 initial-trees 50 %

energy-from-food 10 reproduction-rate 0.2

walk
random

trees 3451 ungulates 5

Chooser



Ungulate Browsing Model

- *Random Walk*: A fundamental stochastic model used to investigate movements of individuals through space and time
- Can be truly random, correlated or directed.
- *Directed*: ungulates turn to face any vegetation in Moore neighbourhood, otherwise they turn to a random direction.
- In both cases, after turning ungulates move forward a distance of one patch.

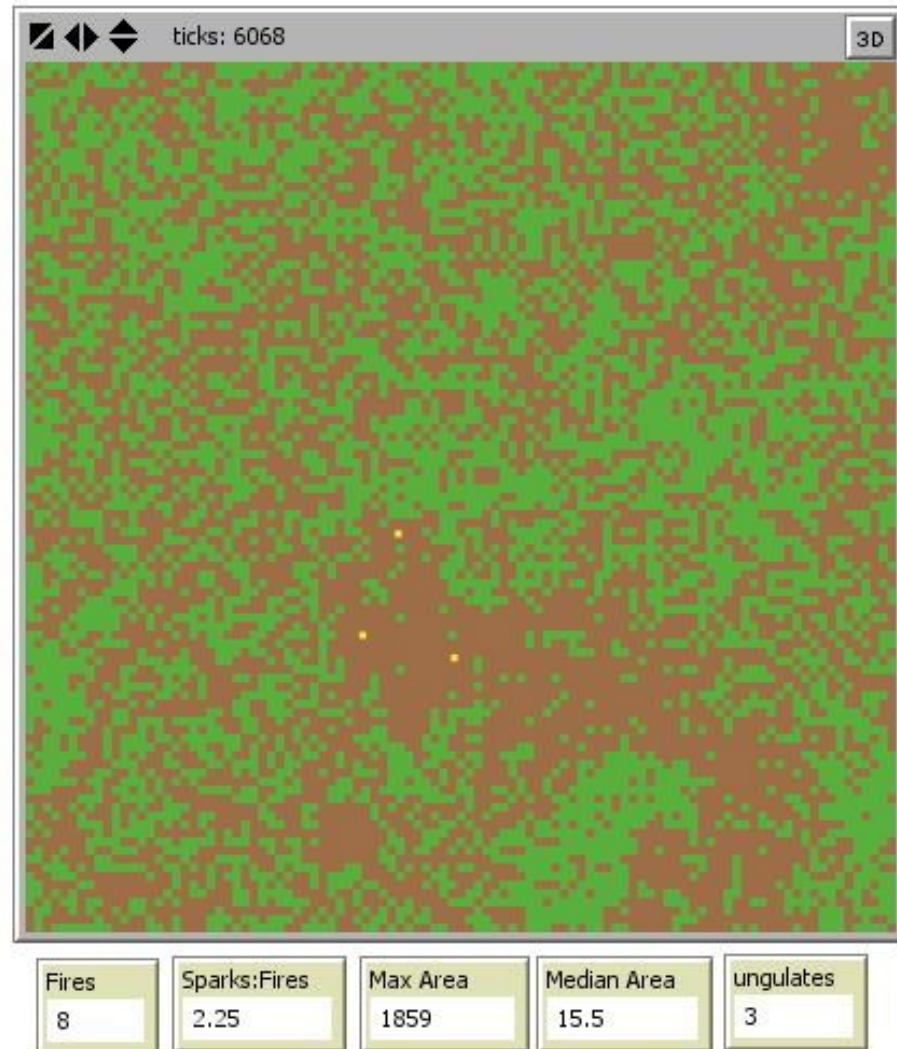
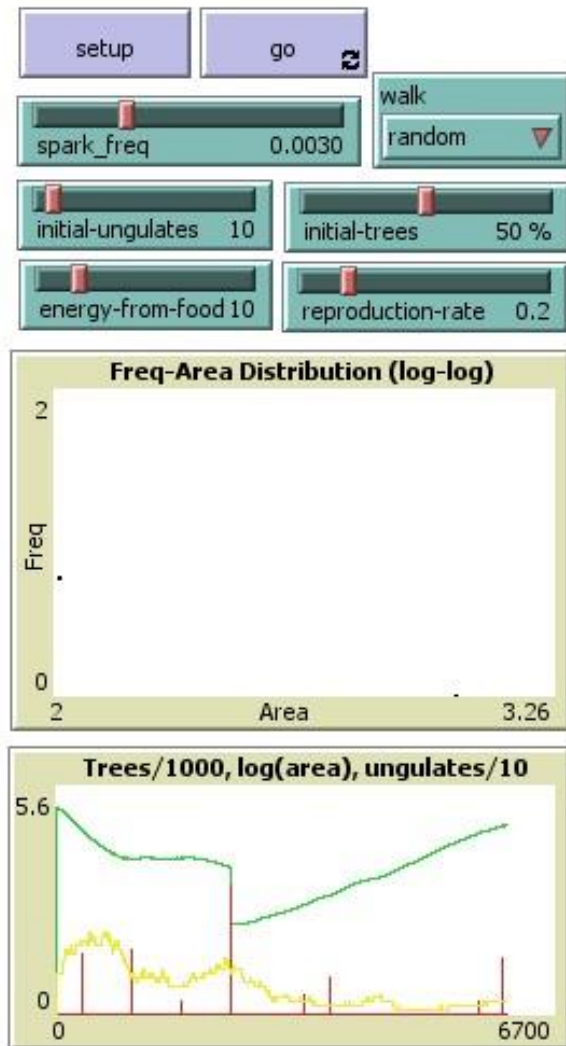
Ungulate Browsing Model

- Each time they move ungulates use up (subtract) one unit of energy.
- After moving, if vegetation is present in the patch the ungulate is at, the ungulate eats the vegetation, removing it from the landscape and gaining an amount of energy specified by energy-from-food.

Ungulate Browsing Model

- First, play with the model to understand properly how each type of walk operates:
 - How 'efficient' are the two different walking strategies?
- Second, examine system dynamics more systematically
 - Run for 'directed' and 'random' walking
 - Run each for 5, 10, 15 *energy-from-food*
 - Create a spreadsheet for results: mean trees, mean ungulates and others

Combining Models



Contagion and Memory

