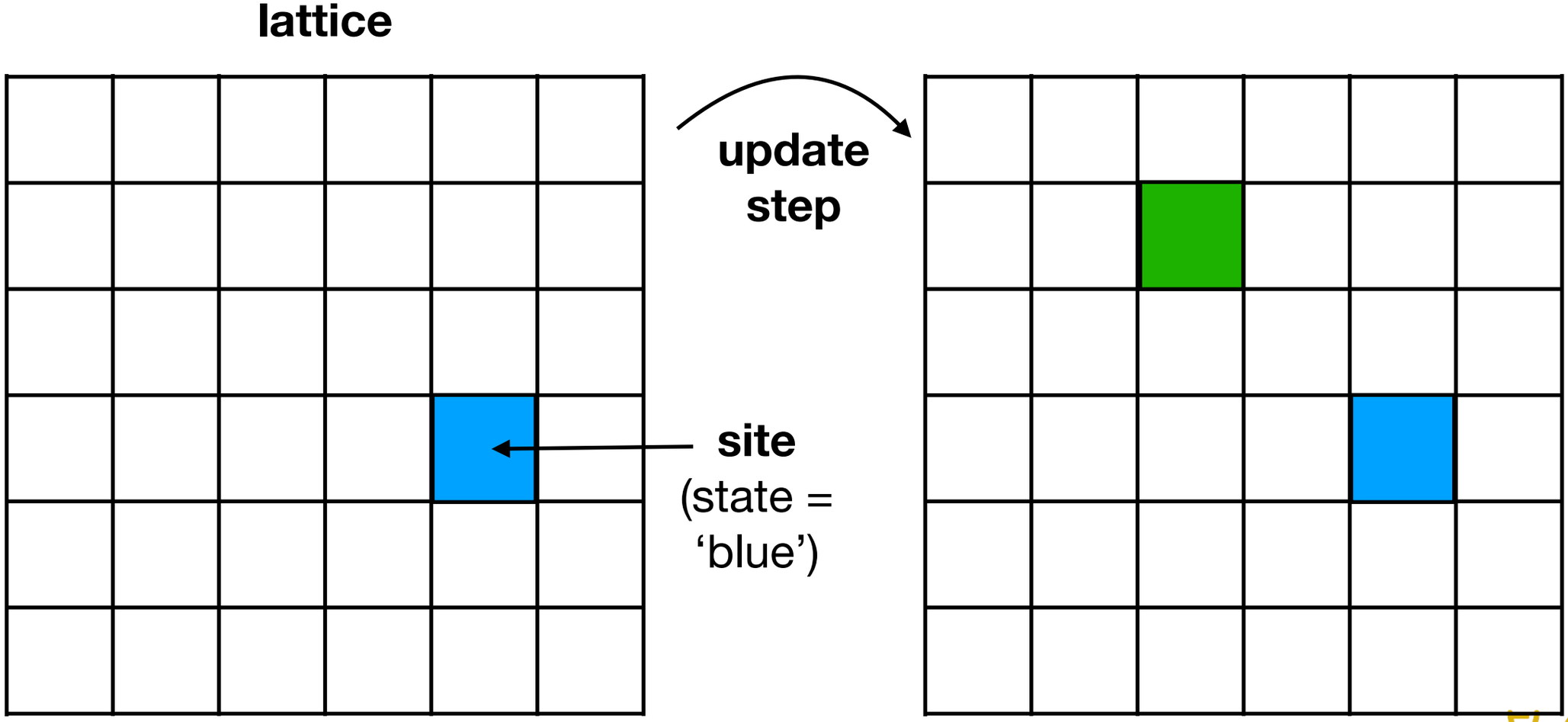
Simulations of Lattice Models

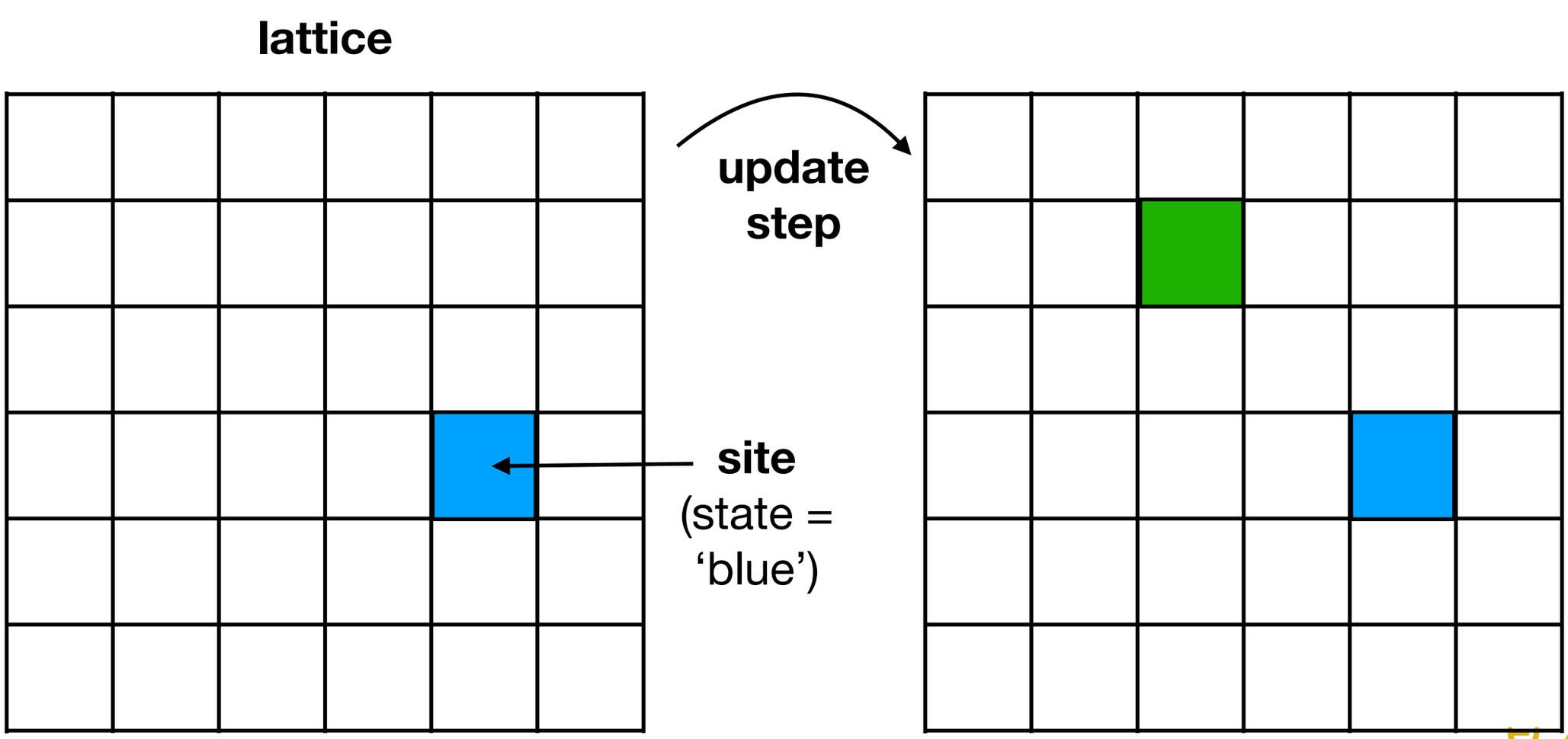
- In science, we want to understand how and why a change occurs in a ***system***.
- A ***model*** is a set of rules that describe how our system changes. If we study these rules, we can **predict** what will happen in similar systems in the future.
- A good model **simplifies** a complicated system to only the most important details.
- For example, we want to understand how a forest grows without counting every single tree.
- Or, we want to understand a chemical reaction without counting every single molecule.



Simulations of Lattice Models

Lattice models allow us to simulate complex systems with many interacting parts.

- We represent the system as a grid, called a ***lattice***.
- Each square on the grid is a ***site***.
- Each site has a **state**.
- The state may change when we do an **update step**, according to the rules of the ***model***.



Python

This week, we will explore lattice models using **Python** notebooks.

There are many computer programming languages.

The **Python** programming language is popular in science.

Python notebooks are a way to use Python in an Internet browser.

```
[1]  print('Hello world')
```

```
Hello world
```

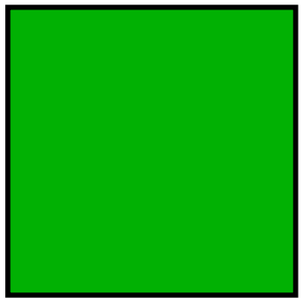
```
[2]  x = 5
     x + 2
```

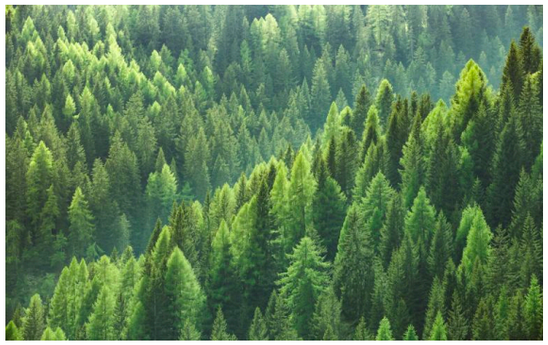
```
7
```

Forest Fire Model

A site is in one of three states:

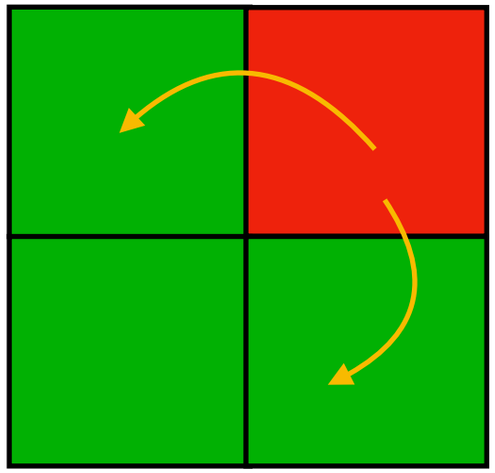
trees





burning

empty



trees next to burning site become burning

burning sites become empty

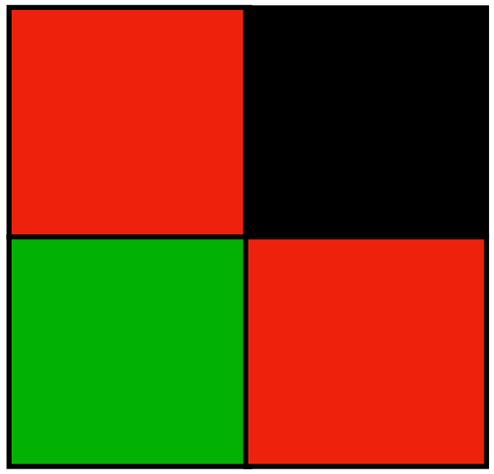
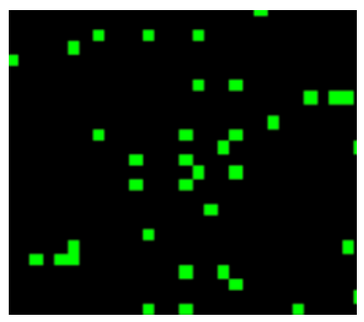


Image Sources
https://www.sierraclub.org/sierra/forest-conservation-part-climate-conversation-too
https://en.wikipedia.org/wiki/2019_Bandipur_forest_fires#/media/File:Bandipur_fires_2019.jpg
https://www.cbc.ca/news/technology/forests-wildfires-1.4444998

Forest fire model, Activity 1: Stopping the spread of a fire

dense forest

vs.



sparse forest

Which forest is better at stopping a fire from spreading?

- If a fire starts on the left side, does it burn all the way to the right side?

1. First, try a dense forest.

   - Set `start_tree_percent = 90` and run

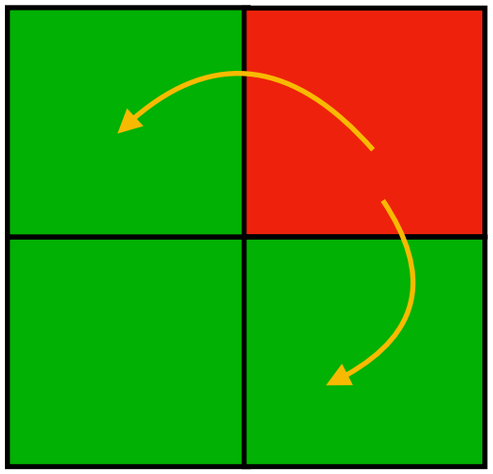
2. What changes if the forest is very sparse (not dense)?

   - Stop the simulation, set `start_tree_percent = 10` and run

3. The fire's outcome depends on whether `start_tree_percent` is above or below a special number. Physicists call this number the **critical value** ("critical" meaning important).

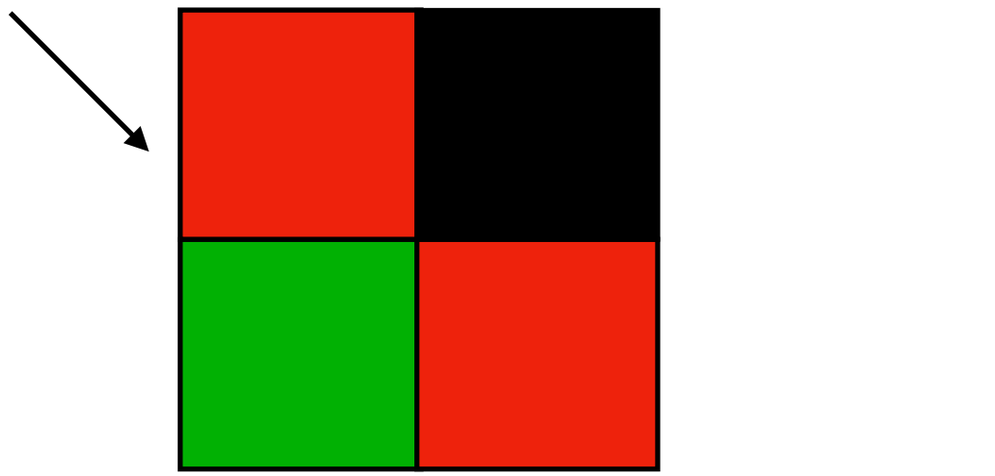
   - Raise or lower `start_tree_percent` and run again, repeating until you find the critical value of `start_tree_percent` to the nearest 5%.

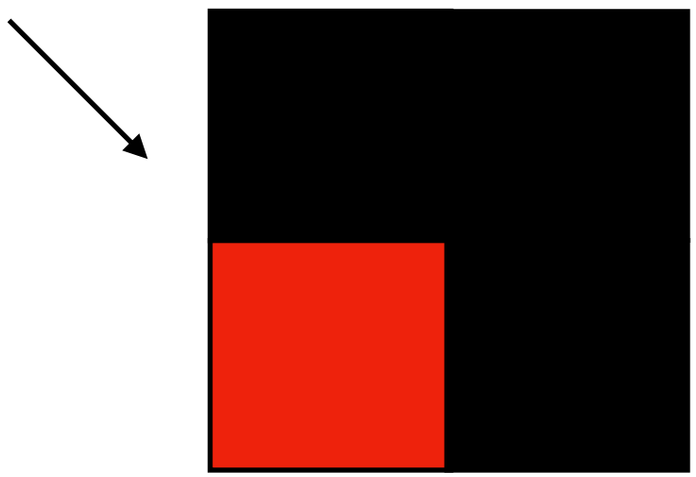
Forest Fire Model, version 2



trees next to burning site become burning

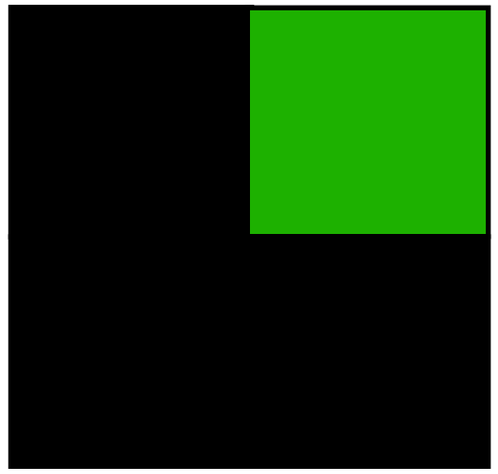
burning sites become empty

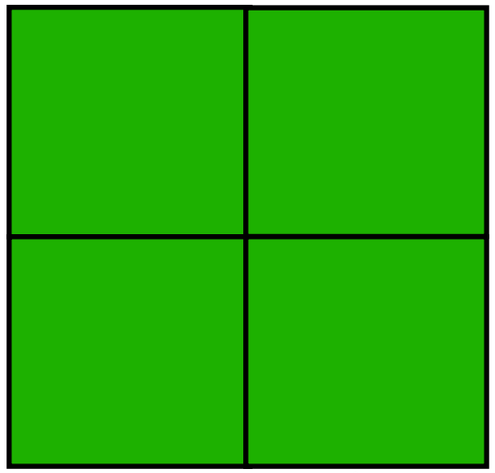




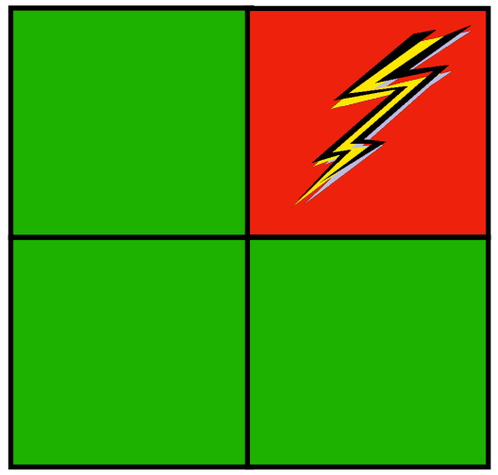
Same rules as before plus two new ones

trees grow on an empty site





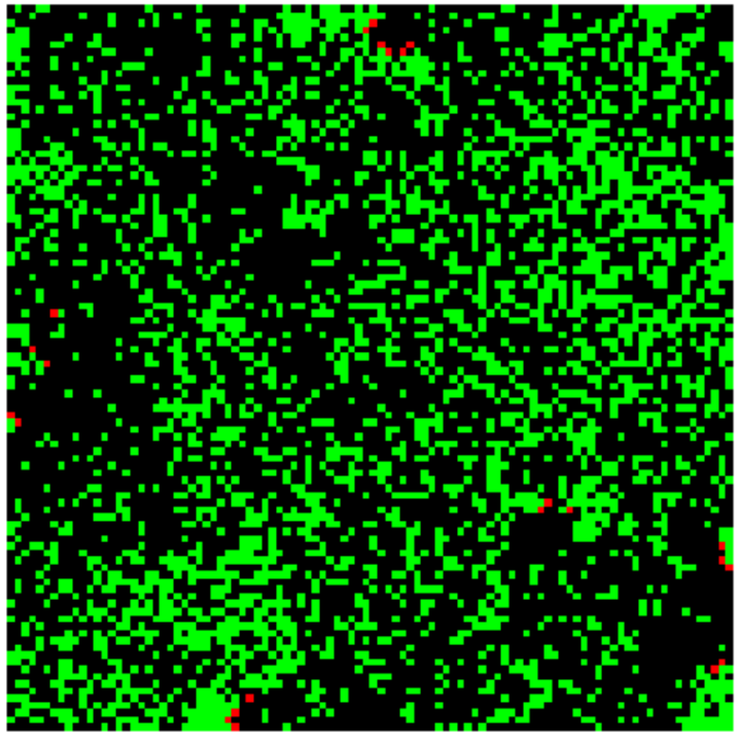
random lightning: trees catch fire!



Forest fire model, Activity 2: A sustainable forest

You will see in the simulation that eventually tree growth and lightning strikes will balance out:

The % of trees will go up and down, but after a while its *average* value will stay more or less the same.



1. Make the following changes:

```
run_simulation(
    start_tree_percent = 50,
    start_fire = False,
    tree_growth_rate = 100,
    lightning_strike_rate = 1,
    update_plot_wait = 5
)
```

2. Try some different values of `start_tree_percent`.
   How does this affect the average tree coverage?
   Make a scatter plot in a spreadsheet of average tree coverage vs. `start_tree_percent`*. What can you conclude?*
3. Try different values of the `lightning_strike_rate`.
   Make a scatter plot in a spreadsheet of average tree coverage vs. `lightning_strike_rate`*. What can you conclude?*