Computational Analysis of Potential Rainforest Monoculture Due to Slash-and-Burn Techniques

New Mexico

Supercomputing Challenge

Final Report

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Team 146

School of Dreams Academy

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Executive Summary

"Slash-and-burn" is an agricultural method currently being used by farmers and manufacturers to clear out large areas of forest ecosystems, such as the Amazon rainforest. This process involves the falling and burning of large areas of trees for the purpose of planting crops and using the ash to give nutrients to the soil. Slash-and-burn has many environmentally negative aspects, but our project focuses on whether it has the ability to create a monoculture. A monoculture is a single species of plant inhabiting an area of land, where no other species are present. We believe that it can be created when areas of land are sectioned off with "slashes" (see Object 7) created by clear cutting strips of land using the slash-and-burn method.

There are over 16,000 different species of trees within the Amazon, but half the total number of trees consists of only 227 species. US ecologist and author Professor Miles Silman from Wake Forest University said, "Just like physicists' models tell them that dark matter accounts for much of the universe, our models tell us that species too rare to find account for much of the planet's biodiversity. That's a real problem for conservation, because the species at the greatest risk of extinction may disappear before we ever find them."

We have developed a computer program to determine whether slash-and-burn will cause a single species to completely dominate an area in NetLogo, an agent based modeling software. In our current model, we have five variables: Rock, Paper, Scissors, Lizard, and Spock (RPSLS). We have applied our present model to the competition of trees in the Amazon rainforest. Our model includes the life cycle of a tree: Seedling → Sprout competing for nutrients → RPSLS → Winner → Mature Tree → Produces Seedling, the entire process being equal to 1 "tick."

Through research of specific tress present in the Amazon, we have figured out the one tick is equal to about 50 years.

Our program in NetLogo works by following a number of steps in which all selections are made at random. The first step is to generate different colored dots on a field, each representing a specific species of tree. One dot will randomly select another dot that is either directly up, down, left, or right of the original dot. If this new dot is a different color than the original the game will continue, but if the two dots are the same another dot will be selected. Each colored dot or species will have one item from the following list assigned to it: Rock, Paper, Scissors, Lizard, or Spock. They will play against each other and whoever wins this game will "take over" the other space on the field which is indicated by a change in color. This process will continue until only one color is left. This determines a monoculture.

Problem

Our project is to develop a computer model that simulates a species' competition for dominance, ultimately creating a monoculture. This will show whether or not monocultures will develop due to slash and burn, furthering the damage done to the ecosystem.

Hypotheses

Our NetLogo model will simulate the effect of slash-and-burning in the Amazon rainforest in one of the following three ways:

1. The slash-and-burn method will increase the biodiversity of the affected areas of the rainforest.

2. The slash-and-burn method will decrease the biodiversity of the affected area of the rainforest.

3. The slash-and-burn method will not affect the biodiversity of the affected area of the rainforest.

Materials and Methods

All data acquired was gathered from the Behavior Space in NetLogo. While running our model in the Behavior Space, all results were analyzed in Microsoft Excel.

Materials:

3 multi-core Computers (to run tests in parallel)

NetLogo 5.0.4 Software

Microsoft Excel

Methods:

1. Open the NetLogo Program.
2. Open “Behavior Space” in the “Tools” tab of net logo.
3. Set the world sizes, measure ticks, and set the repetitions.
4. Run the program in “Behavior Space” until it is complete.
5. Open the data file in Microsoft Excel.
6. Analyze the number of ticks in which one game of Rock, Paper, Scissors, Lizard, and Spock (RPSLS) is played.

Results

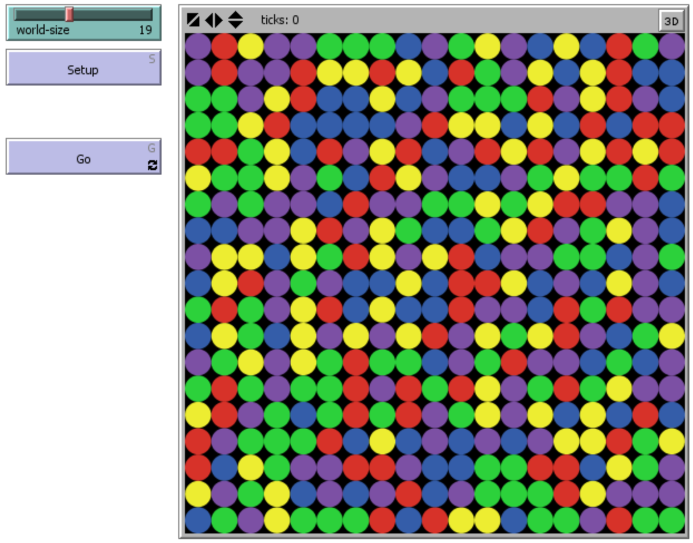


Figure 1. Display of the visual representation of an area of land in our NetLogo model.

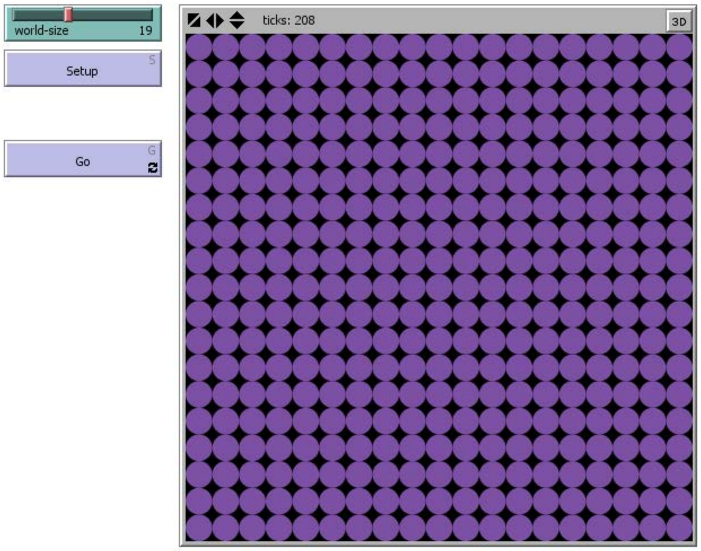
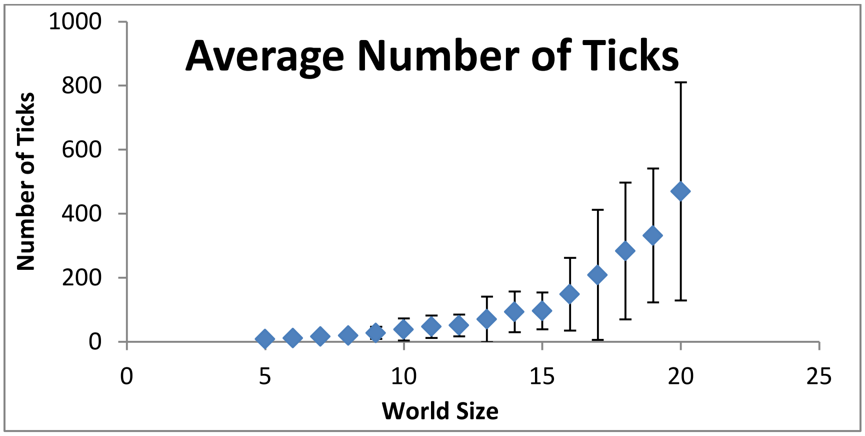
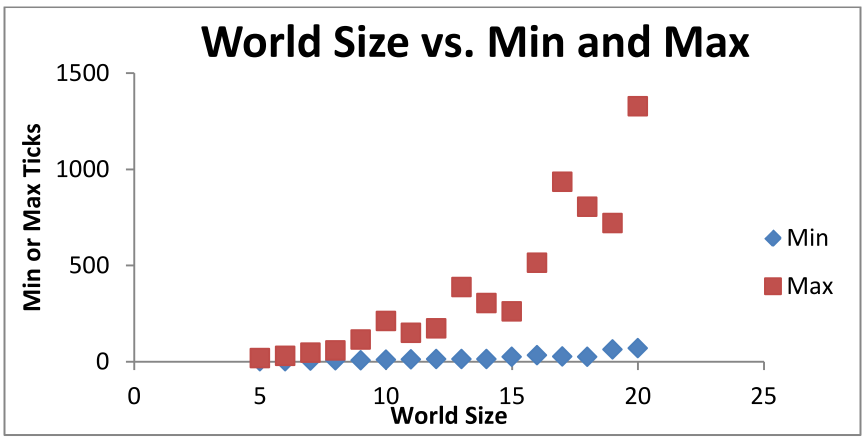


Figure 2. Display of the visual representation of a monoculture that has formed in our NetLogo model.

Figures 1 and 2 display the analyze results from world-sizes 5-20. Figure 1 shows the average number of ticks with standard deviation it took to develop a monoculture on our NetLogo model. Figure 2 shows the maximum and minimum number of ticks it took to develop a monoculture.



Graph 1. Average number of ticks per world size with standard deviation.



Graph 2. World size versus minimum and maximum number of ticks

Tables 1-3 show the data represented as a pivot table. A pivot table is commonly used to display large amounts of data with many variables in a condensed form. The tables summarize the average number of ticks, standard deviation, and minimum and maximum number of ticks.

Row Labels	Sum of ticks	StdDev of [step]
20	20316	436.9768403
21	29104	685.0329507
22	37045	1123.212544
23	67625	1784.45143
24	124590	2793.215019
25	157902	3632.403668
26	272942	5942.722578
27	389318	8414.55358
28	594409	12871.03173
29	1447922	31003.82362
30	2061258	52826.52455
Grand Total	**5202431**	**24833.68917**

Table 1. Pivot Table for world sizes 20-30

Row Labels	Sum of [run number]	Sum of ticks	StdDev of [step]
31	820	3423151	70049.16289
32	2420	7036802	147095.5346
33	4020	16467472	304353.6802
34	5620	28780977	754122.9837
Grand Total	**12880**	**55708402**	**478793.6604**

Table 2. Pivot Table for world sizes 31-34

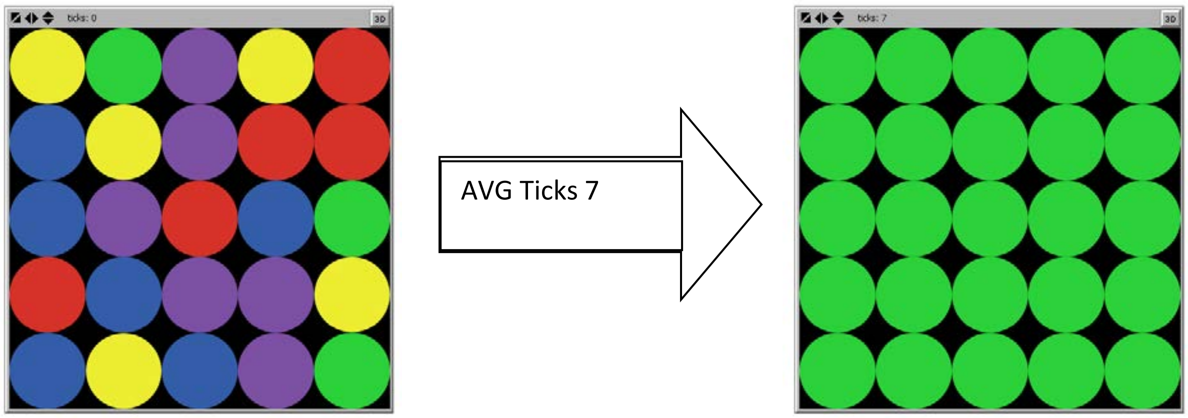


Figure 3. World size 5

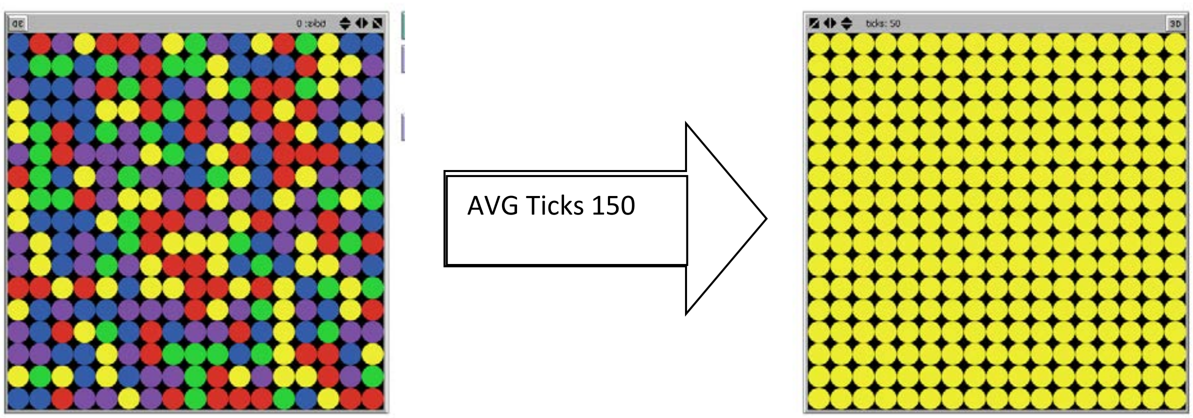


Figure 4. World Size 17

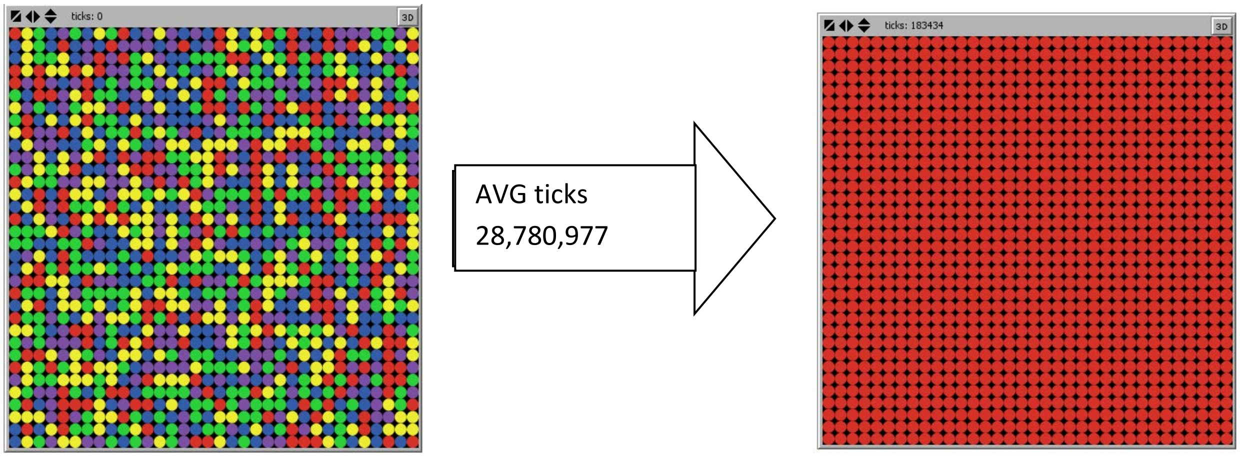


Figure 5. World size 24

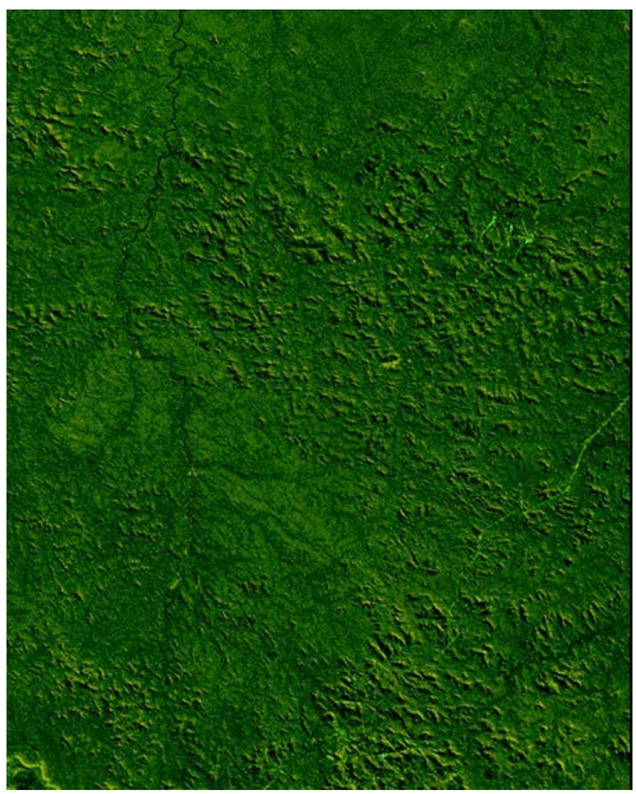


Figure 6. A monoculture in the Amazon rainforest

"'Green Desert' Monoculture Forests Spreading in Africa and South America."*Theguardian.com*.

Guardian News and Media, 26 Sept. 2011. Web. 02 Apr. 2014.

Figure 7. Slash-and-burn in the Amazon rainforest satellite overview from Brazil. (Google Maps)

"Landsat 8 to the Rescue." *Nature.com*. Nature Publishing Group, n.d. Web. 01 Apr. 2014.

Object 8. RPSLS patches added between the slashes and burns shown in the previous picture.

Discussion

Our program was run using different world-sizes, simulating the amount of slash-and-burn patches in the world being played, which included sizes 5-30. In analyzing our statistics, we noticed a pattern in the number of ticks it took for a single species to dominate. The smaller the world-size, the shorter the number of ticks, the larger world size the longer the number of ticks; in turn has a longer run time because of the large world size.

We applied our program to the Amazon rainforest which shows how quickly a monoculture will among different world sizes. In analyzing the results we found a neutral correlation in which each species would dominate, similar to what Nick Berry found in his experiment.

Future plans for the project include determining exactly how long one tick is on NetLogo compared to real time in the Amazon rainforest. In doing so, we can get an exact time frame for a monoculture to arise within a certain world size or environment. We also will figure out the real world size of one patch or dot, so we can predict when a monoculture will form based on an area's size. Next year we plan on determining that largest world size where a monoculture will form within a certain time period. This will help us predict whether a monoculture will form at all by using an area's size. Lastly we plan on adding the regrowth of forest, which would more accurately predict whether a monoculture will form.

Issues

During the midst of running our model to get our data, we encountered several issues. Our mentor, Nick Bennet, helped us to realize and fix some logical errors in our code. After doing so, the previous data collected was determined to be invalid, resulting in the team rerunning the program.

While running the model with the larger world sizes, the elapsed time was 467+ hours. There was not enough memory to complete the run due to the large amount of data being used by the Behavior Space. We also encountered runtime errors caused by problems with our code, which caused all the data recorded within that run to be unable to open in an Excel spread sheet.

Conclusion

The results of our experiment proved Hypothesis 2 to be correct, pending increased world-sizes and the parameters of the Amazon rainforest being set. The slash-and-burn method will decrease the biodiversity of the affected area of the rainforest. This is shown in the average number of ticks it takes for the model to reach a monoculture. An increase in the world-size shows an increased number of average ticks, which is expected. The overall trends for a monoculture to arise compared to different world sizes include a neutral correlation amongst the graphs and tables.

We finished running the world-sizes 5-30 with the final results, looking at the different life spans of five different tree species and comparing the information with the results to the Amazon rainforest. Appling to reality, trying finding out that there is an equal chance (randomness was priority) of ending up in a monoculture in the five variables we had. Coming to the conclusion that if and when a monoculture occurs, the regeneration of the trees will be +fighting for dominance (playing the RPSLS game) with their neighbor seeing which tree will take over residency of a particular location in the Amazon rainforest.

The RPSLS model is applicable to many areas, including political/social influence, contagious diseases, and other biological/ecological systems. First we started with three variables (Rock, Paper, and Scissors) and it seemed almost impossible to come up with a single color as the victor. But, with the three variables in a smaller scale a single color prevailed rather quickly. Then we added two more variables (Lizard and Spock) and within a large scale it is almost impossible for a single-species to dominate, in a small scale it will dominate in less than 200 ticks. The more variables we added the faster a single-species dominated.

Achievements

One of our biggest accomplishments is the development of our computer model that simulates a set of species of trees competing for dominance in a certain area, ultimately creating a monoculture. This computer model and data we gathered will form a strong foundation for a continuation of this project next year, where we will determine the probability of a monoculture forming based on the size of the area. Lastly, all members of our team have learned valuable skills in communication, collaboration and working as a team in general.

Acknowledgements

We would like to thank our teachers and mentors for all their help and support, because without them this project could not be possible. Thank you, Creighton Edington, for all the time and effort you put in assisting us with our project. Thank you, Talysa Ogas; you have been there through all the ups and downs, giving us nonstop support and confidence. Thank you, Nick Bennett, for your enhanced knowledge in NetLogo, because without you we wouldn't have discovered logical errors found within our coding.

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