Examining the Effects on Wildfire Spread

New Mexico

Supercomputing Challenge

Final Report

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Team 1016

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Executive Summary

Introduction - Have you ever wondered how firefighters prepare and fight wildfires? Many prepare for trouble before trouble comes knocking on their door, and one way they can be better prepared is by seeing the fire through a model, and predicting what could happen. Modeling the possible outcomes of a wildfire not only better prepares firefighters, but also helps officers evacuate citizens out of potential areas where fires can cause great destruction.

Methods - We used NetLogo to model potential wildfires, and we tested four variables to see which one has the greatest impact on the fire. We talked to our friend and mentor firefighter, Iman Chudnoff, and she told us that elevation, vegetation, wind, and humidity have the greatest impacts on the outcome of a wildfire.

Takeaways - From our background information and analysis of data that we collected from this model, we conclude that humidity has the greatest effect on wildfires, reducing the size of the fire and how long it lasted. Slope followed behind humidity, with wind and vegetation having the least impacts. It makes sense why humidity would have such a great effect on a wildfire, verifying what our background information suggested.

Problem Investigated

Due to the increasing frequency and severity of wildfires over the past few years, our team felt that a wildfire model would be an important area of research. Last year, in Australia alone, there were more than 46 million acres burned in wildfires (CDP). California wildfires attract national headlines each year, and New Mexico is no stranger to devastating forest fires. We examined the Las Conchas and Whitewater-Baldy Complex fires, and we decided to focus on how factors like slope, wind, vegetation, and humidity affect the spread of wildfires.

Background

Slope: There are three characteristics to altitude that affect wildfires: aspect, slope, and terrain. Aspect is the direction the slope faces, which can determine the amount of fuel the fire receives from solar rays, the condition of the slope, and what fuels are present. Slopes that face south are more directly exposed to sunlight, which result in higher temperatures and lower humidity, while north slopes generally receive less direct sunlight, and have an opposite effect to what southern slopes receive. Slope is how much incline there is on a hillside. The more incline there is, the faster and hotter the fire burns, uphill than downhill. Since fire has an upward motion, fuels that are above a fire on a hillside catch on faster because they come into contact faster with the fire (Indiana). Terrain is the layout of the land and can have a great impact on the direction and spread of the fire. Fires in narrow ravines can easily spread onto the opposite slope by the heat of the fire and winds blowing through the ravines blowing sparks onto those slopes. These upslope fires will spread very quickly and can result in extreme conditions and be very dangerous.

Vegetation: Smaller vegetation such as grass will burn faster and hotter. Larger vegetation such as trees will burn much slower and at a cooler temperature (Chudnoff). They burn slower because they are more denser with the wood and have more moisture in there. With trees, there is more material for the fire to burn through. There are actual fuel gauges or values that firefighters give to various types of vegetation that suggest burn time in an actual wildfire.

Humidity: There are three forms of humidity present in an environment that affect wildfires: relative humidity, soil moisture, and the moisture in the vegetation itself or the fuel moisture. Areas of persistent high humidity decrease the spread of wildfires as the fuel moisture has to be evaporated before ignition can occur, often putting the wildfires out in their earliest stages. When the relative humidity is low, the air takes moisture out of the surrounding vegetation and when it is high, the vegetation absorbs available moisture from the air (Avarham). Light fuels, like grasses, vary rapidly in moisture content whereas heavy fuels, like trees, slowly build up their moisture content and thus maintain relatively stable levels of moisture.

Wind: The potential that wind contributes with wildfire spread is by increasing oxygen and decreasing humidity. Fire reduces humidity by drying up or taking the humidity around the fuel by evaporation (Auburn). Oxygen affects the fire by increasing combustion. That's what fire needs in order to burn, and the more there is the more heat and fire will create an increasing burn rate based on the article. Besides affecting the fire size, wind can constantly change making the fire change direction to surprising firefighters and people inside the fire. The wind is an unpredictable variable being that the fire "generates winds of its own… that [can be] as much as 10 times faster than the ambient wind," according to the article "Wildfires and Wind."

Methods Used

We used the Netlogo 6.1 agent-based modeling program to simulate our wildfire model. We used turtles as our agents for fire, wind, and trees. The patches represented slope, or varying degrees of elevation. Our fire had a variable of temperature, which affected the rate of spread. We spread the fire by "sprouting" new fire turtles. When a fire turtle reaches a certain temperature, it will sprout a new fire turtle, which causes the spreading effect that we captured in our model.

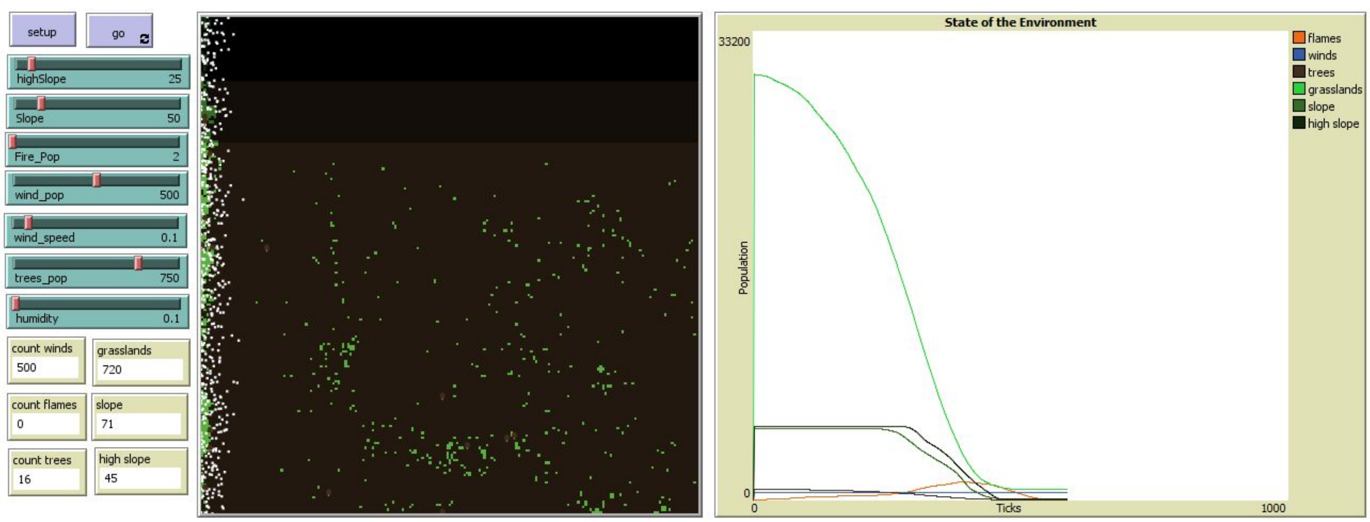
Model Verification & Validation

After running our model, we compared our results to our research. Our model suggested that humidity had the greatest increase of fire in our model. As the humidity value increased the number of fire turtles decreased. That makes sense because when the fuel has high moisture the more evaporation it needs before igniting. Our model did not show an increase of fire when an increase of wind appeared, which is something that contradicted our research. This is an area in our model and research that we would like to revisit.There are values we could add for vegetation but we needed more time to incorporate.

Results

To test our model, we ran three trials, each with five runs, where we changed a different variable regarding slope, wind, vegetation, and humidity. For slope, we tested it at values of 50, 140, and 175. We noticed that the fires burned longer at values with a higher slope. At 50, the fires ran around 400 ticks or iterations. At 140, they ran for about 595 ticks, and at 175, they ran closer toward 860 ticks.

Figure 1: Slope Value = 50. With a small slope incorporated into the model, we see that the grasslands burn down really quickly, but the bump in the orange line represents the increase in the flames as they encounter the higher slope.



This is data from a trial of slope = 50:

The max amount of flames when the model ran = 1494 flames
The average amount of flames present when the model ran = 399
How long the model ran, in ticks = 711 steps

For wind, we tested values equal to 0.1, 0.4, and 0.7. The average number of fire turtles actually decreased throughout the five trials from values of 0.1 to 0.7. The average number of steps with wind values at 0.7 did run a little bit longer than the wind at 0.1 and 0.4.

Figure 2: Wind Value at 0.7. We see that the orange fire value increases as it encounters the increased slope and higher slope, indicating that these variables have a greater effect on the fire than wind.

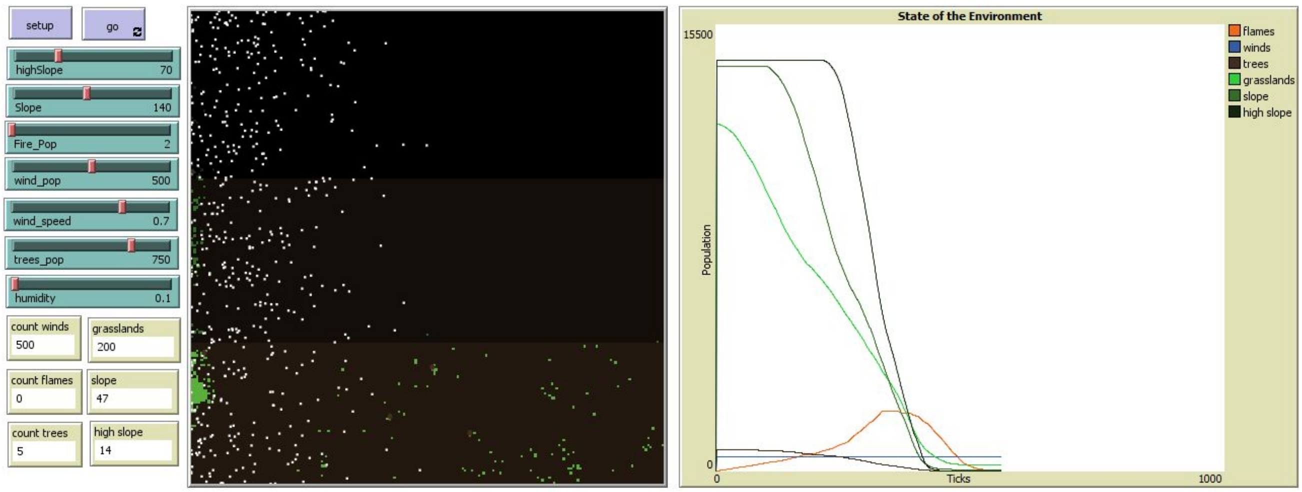


Table 1: Wind Data at 0.7

BehaviorSpace results (NetLogo 6.1.0)						
TheOne.1						
wind speed at 0.7						
04/07/2020 16:11:35:703 -0600						
min-pxcor	max-pxcor	min-pycor	max-pycor			
-100	100	-100	100			
[run number]	1	2	3	4	5	
wind_speed	0.1	0.1	0.1	0.1	0.1	
wind_pop	500	500	500	500	500	
Fire_Pop	2	2	2	2	2	
humidity	0.7	0.7	0.7	0.7	0.7	
highSlope	70	70	70	70	70	
Slope	140	140	140	140	140	
trees_pop	750	750	750	750	750	
[reporter]	count flames	count flames	count flames	count flames	count flames	
[final]	1	1	1	1	1	
[min]	1	1	1	1	1	
[max]	1825	1840	1697	1996	1867	1845
[mean]	615.2459547	635.8360656	486.9203297	598.1704545	544.6820896	576.1709788
[steps]	617	609	727	615	669	647.4

This is the average fire values with the wind at 0.7:

[max] 1845

[mean] 576

[steps] 647

We tested vegetation in the model by changing the amount of trees. We ran three trials, each with 5 iterations, with 300, 500, and 1000 trees. This model indicated that the greater number of trees, the greater the maximum number of flames.

Figure 3: Vegetation at 300.

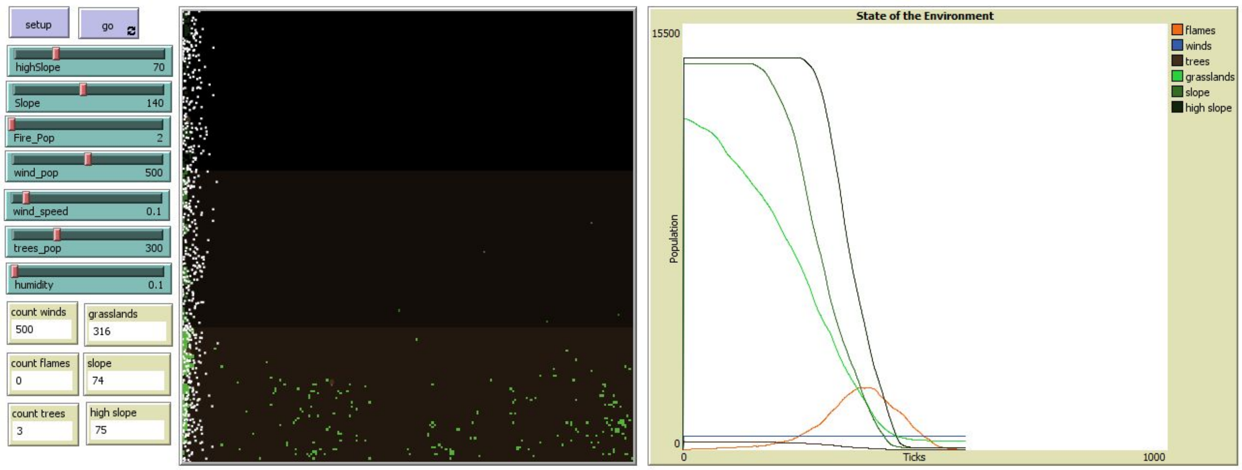


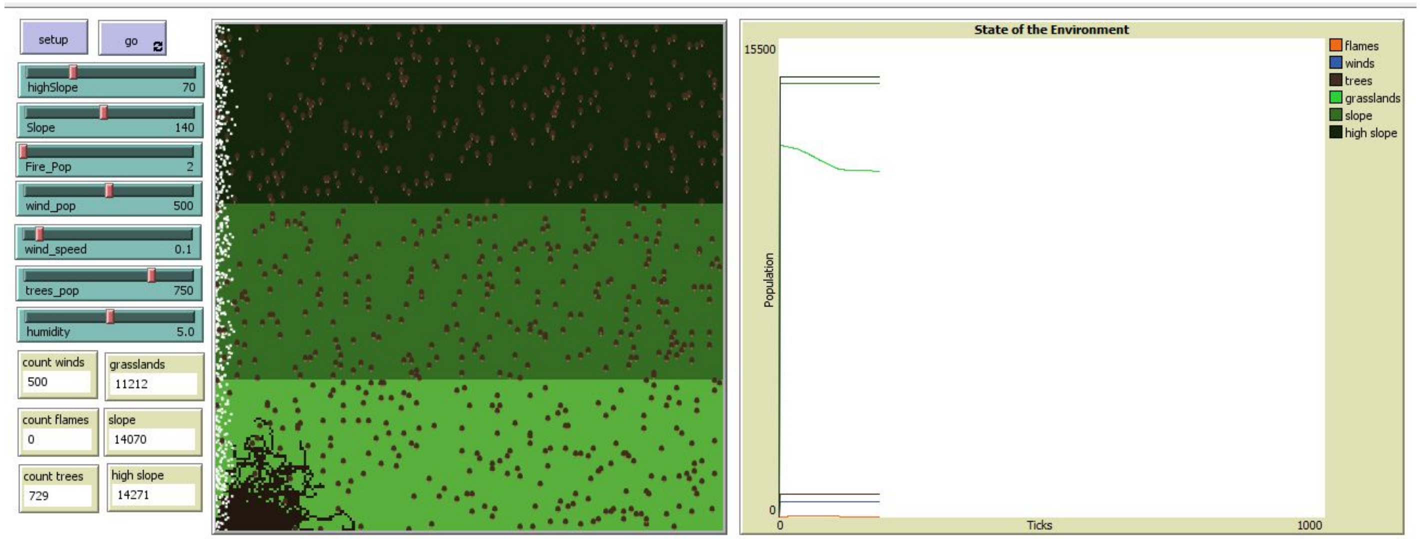
Table 2: Vegetation Data with 1000 Trees

BehaviorSpace results (NetLogo 6.1.0)						
TheOne.1						
vegetation at 1000						
04/07/2020 15:46:09:457 -0600						
min-pxcor	max-pxcor	min-pycor	max-pycor			
-100	100	-100	100			
[run number]	1	2	3	4	5	
wind_speed	0.1	0.1	0.1	0.1	0.1	
wind_pop	500	500	500	500	500	
Fire_Pop	2	2	2	2	2	
humidity	0.1	0.1	0.1	0.1	0.1	
highSlope	70	70	70	70	70	
Slope	140	140	140	140	140	
trees_pop	1000	1000	1000	1000	1000	
[reporter]	count flames	count flames	count flames	count flames	count flames	
[final]	1	1	1	2	1	
[min]	1	1	1	2	1	Average after 5 trials
[max]	2389	2144	1821	2073	2280	2141
[mean]	790.8805704	682.9598716	695.7289256	722.4139693	724.2771285	723
[steps]	560	622	604	586	598	594

We tested humidity at values of 0 (our control), 2.5 and 5, while holding all of the other variables constant. After five trials with a humidity value = 5, we received average values of:

Maximum number of fires: 65
Mean number of fires: 20
Total number of steps: 590

Figure 4: Effects of Humidity on Fire Spread. Notice that a humidity value = 5.0 shows how great its impact is on containing the spread of the fire.



Conclusion

This model simulated the spread of a wildfire by examining the variables: wind, vegetation, humidity, and slope. Some of our model verified what our research suggested. For example, as the slope increased, the number of fires increased. As the humidity increased, the number of fires decreased. As the vegetation increased, the number of fires increased. The big surprise was our wind variable, as it did not have the devastating effects that our research suggested. We had limited time to examine the effects of any of these variables on the speed of the fire. This leaves with us with so many avenues of exploration to make this model a valuable resource for examining wildfire spread.

Acknowledgments

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