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New Mexico
Supercomputing Challenge
Final Report
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Team #67
Melrose High School

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Executive Summary

This year, my goal was to model at least a portion of the world food supply. I hoped to be able to change such variables as drought, recession, and changes in farming techniques.

I felt that such a model could be used for targeting areas that might need the most support, whether it be developing agricultural techniques or changing their practices altogether. Our model might even able to be used to predict how agriculture would be affected by climate change. One possible usage of such a model might be suggesting different crops to grow in regions where they hadn't been tried before.

We used NetLogo to create our model because of its versatility and the ability to import patch colors, but mostly because it is relatively easy to use. Based on our research, we created a preliminary model using winter wheat and an estimated 2.5 bushels per acre for each inch of rain.

Problem Statement

Based on the current world population growth, the United Nations predicts that the world population will grow to 9 billion by 2050. That could be a major problem, considering how in 1989 with a population of only 5.19 billion, there was an estimated 450 million people on the verge of starvation, and another billion undernourished.

The ability to maximize production would be an incredible advancement towards ending world hunger. There has been much controversy recently about how crops should be produced. Advocates for organic production present the case for protection of the environment. Advocates for conventional farming say that producing more to feed more people is their goal. Genetically modified organisms have the potential to revolutionize the agricultural industry, but they could potentially upset much of the natural ecosystem if they cross pollinate with unmodified plants. We must weigh the possible benefits against the costs, and determine what is best for our society and our world.

We wanted to be able to model the agricultural inputs and outputs of specific areas under different scenarios. Such a model could be used to predict how to be able to maximize production output depending on conditions.

Research

Most of the year was spent researching various aspects of the production of crops. This included rainfall data for the United States, the costs of production for wheat, and the amount of rainfall needed to produce a crop. I found vast amounts of USDA records for past crops, dating back for over 100 years, which I used to help calibrate the model (Appendix A).

I decided that I should choose a single crop to focus on; this would result in narrowing the scope of the project to an attainable goal, and once I have a working model for one crop, it should be easy to alter the inputs for different crops. I determined that the crop I would pursue first would be hard red winter wheat. I chose it because it is a major crop, but primarily because I am familiar with the crop as I have grown up raising it and can compare results of the tests to personal experience.

Our research showed that it takes 11,000 gallons of water to produce one bushel of wheat. Under typical conditions, wheat taking 2.5 inches of rainfall to minimally grow a healthy enough plant to produce grain. That translates to, under average rainfall amounts, every inch of rain producing approximately 2.5 more bushels per acre. We used these numbers to create the preliminary model that could give us an estimate of how the program should work.

Our research also showed that the production of wheat can be graphed using a Cobb-Douglas Function, a function showing the relationship between inputs and outputs (Figure 1). The original Cobb-Douglas function is shown as $P(L,K)=bL^{\alpha}K^{\beta}$ where P is total production, L is labor input, K is capital input, b is total factor productivity, and α and β are output elasticities of labor and capital. For my purposes, the factors will include rainfall, health, and nutrients available.

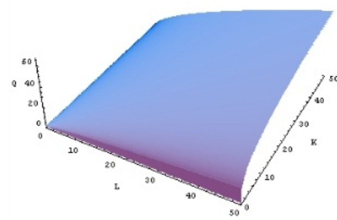

Figure 1

An example of a Cobb-Douglas Function

Model

I decided to use NetLogo to create the model; however, being unfamiliar with NetLogo, I spent much of my time familiarizing myself with the program and how it works rather than the actual programming.

Nevertheless, I was able to get it figured out enough to create a preliminary model. The model reads the patch colors from a rainfall data map that is imported into the modeling space (Figure 2)

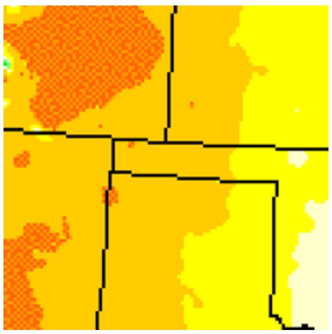

Figure 2

The map portion used in the preliminary model

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It then assigns a rainfall value for each patch color. The mean of the rainfall values is found, and then multiplied by a percentage representing a yearly rainfall higher or lower than normal. The new rainfall value is then multiplied by a factor of growth, determined by adding a value of health, ranging from 0.1 to 1, to 1.5. The value of health represents pestilence, severe weather, or any other damage that may occur to crops. The growth factor is based off of the afore mentioned 2.5 bushels per acre per inch of rainfall. When multiplied, we get estimated bushels per acre. With the current model, it creates almost linear results, which works for typical amounts of precipitation for the region which I modeled, but will skew results for higher amounts of rainfall, as there is a maximum that can be produced, and flooding can damage crops. I hope to fix this soon though, by changing the growth factor for different amounts of rainfall.

Results

Over the course of the year, I have done research on how different variable affect the production of hard red winter wheat. I have taken these variables and made a preliminary model that can estimate crop production based upon yearly rainfall and health of the crop.

Further Plans

In the next month, I plan to further elaborate upon the relationship between rainfall and production, as it is not a linear function (though it is nearly linear through typical rainfall amounts. I also would like to implement some more variables such as soil nutrients and the season in which the moisture comes.

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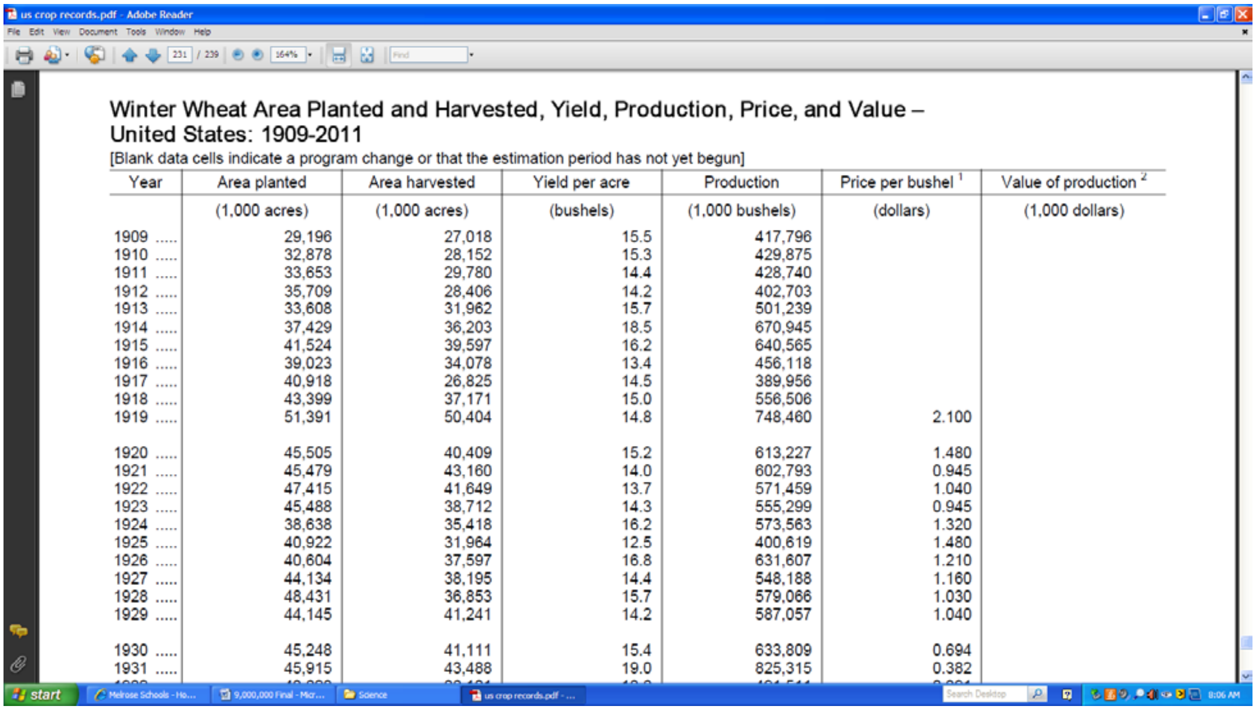
Appendices

A: Research



Winter Wheat Area Planted and Harvested, Yield, Production, Price, and Value – United States: 1909-2011

[Blank data cells indicate a program change or that the estimation period has not yet begun]

Year	Area planted	Area harvested	Yield per acre	Production	Price per bushel [1]	Value of production [2]
	(1,000 acres)	(1,000 acres)	(bushels)	(1,000 bushels)	(dollars)	(1,000 dollars)
1909	29,196	27,018	15.5	417,796		
1910	32,878	28,152	15.3	429,875		
1911	33,653	29,780	14.4	428,740		
1912	35,709	28,406	14.2	402,703		
1913	33,608	31,962	15.7	501,239		
1914	37,429	36,203	18.5	670,945		
1915	41,524	39,597	16.2	640,565		
1916	39,023	34,078	13.4	456,118		
1917	40,918	26,825	14.5	389,956		
1918	43,399	37,171	15.0	556,506		
1919	51,391	50,404	14.8	748,460	2.100	
1920	45,505	40,409	15.2	613,227	1.480	
1921	45,479	43,160	14.0	602,793	0.945	
1922	47,415	41,649	13.7	571,459	1.040	
1923	45,488	38,712	14.3	555,299	0.945	
1924	38,638	35,418	16.2	573,563	1.320	
1925	40,922	31,964	12.5	400,619	1.480	
1926	40,604	37,597	16.8	631,607	1.210	
1927	44,134	38,195	14.4	548,188	1.160	
1928	48,431	36,853	15.7	579,066	1.030	
1929	44,145	41,241	14.2	587,057	1.040	
1930	45,248	41,111	15.4	633,809	0.694	
1931	45,915	43,488	19.0	825,315	0.382	

An example of some of the data that was found

B: Code

```
patches-own [rainfall]


globals [wheat]


to setup
  ask patches [
    set rainfall 0
  ]
  ask patches [
    set wheat 0
    ]
end
```

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```
to-report average-rainfall
  report mean [rainfall] of patches
  report mean [wheat] of patches
end


to grow
  ask patches
  [if rainfall > 4 [
    set wheat ( ( random health + 1.5 ) * ( rainfall ) )
  ]]
end

to test
  ask patches
  [if pcolor < 25.6 [
    set rainfall (random 5 + 10)
  ]]
  ask patches
  [if pcolor > 44.6 [
      set rainfall (random 5 + 15)
  ]]
  ask patches
  [if pcolor > 44.7 [
      set rainfall (random 5 + 20)
  ]]
    ask patches
  [if pcolor > 48 [
      set rainfall (random 5 + 25)
  ]]
    ask patches
  [if pcolor > 66 [
      set rainfall (random 5 + 30)
  ]]
end

to drought
  ask patches [
    set rainfall (rainfall * rain)
  ]
end
```

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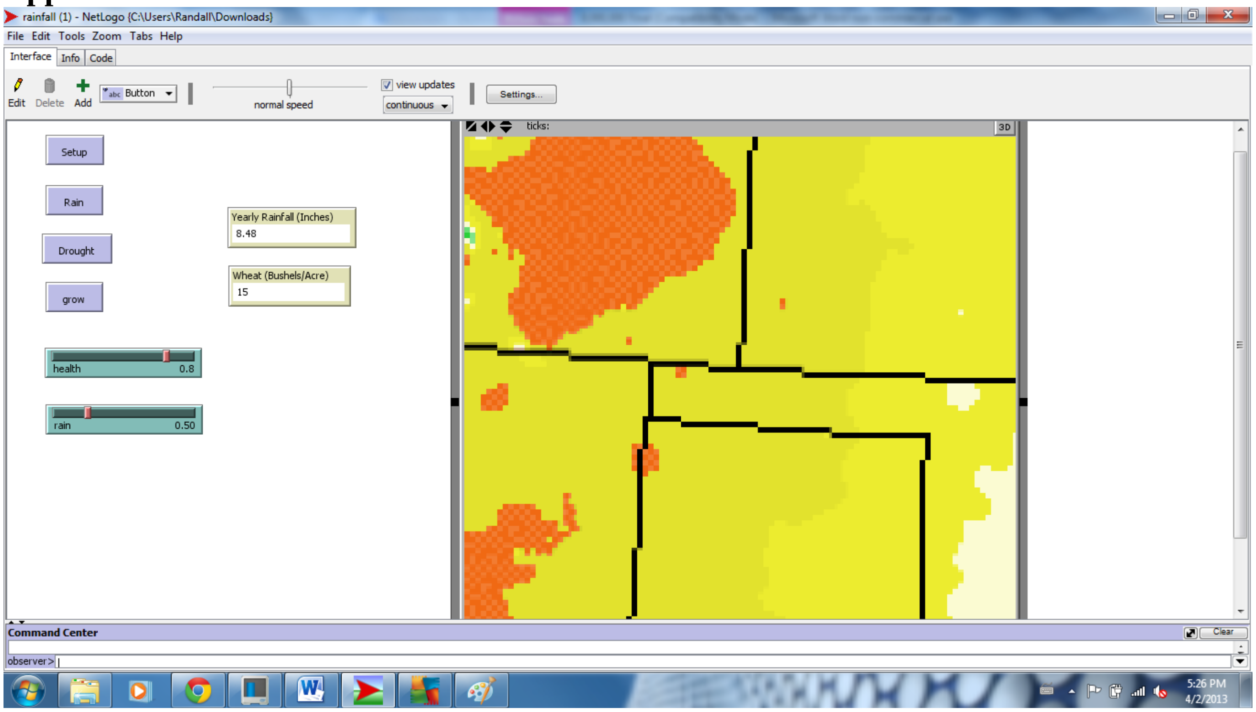
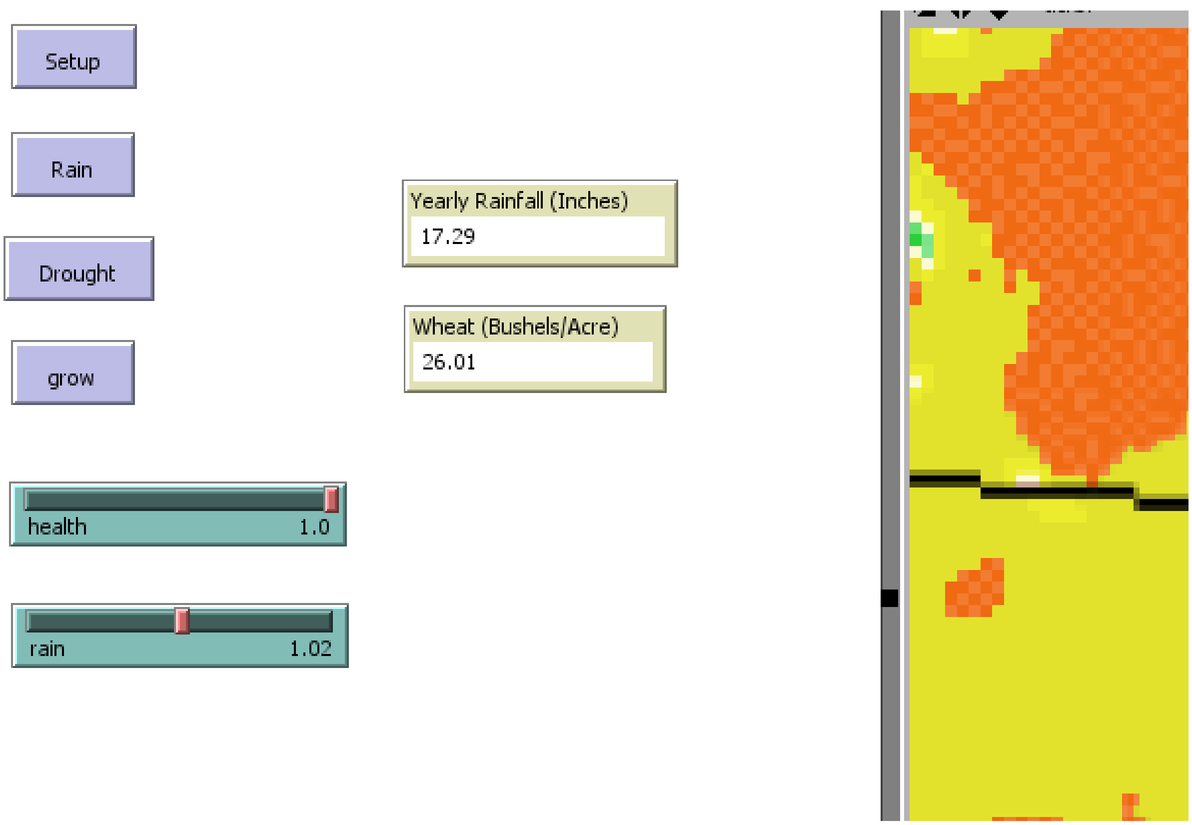
Appendix C: Screen Shots



Screen shot of the whole page



A wheat crop with good health and typical rainfall

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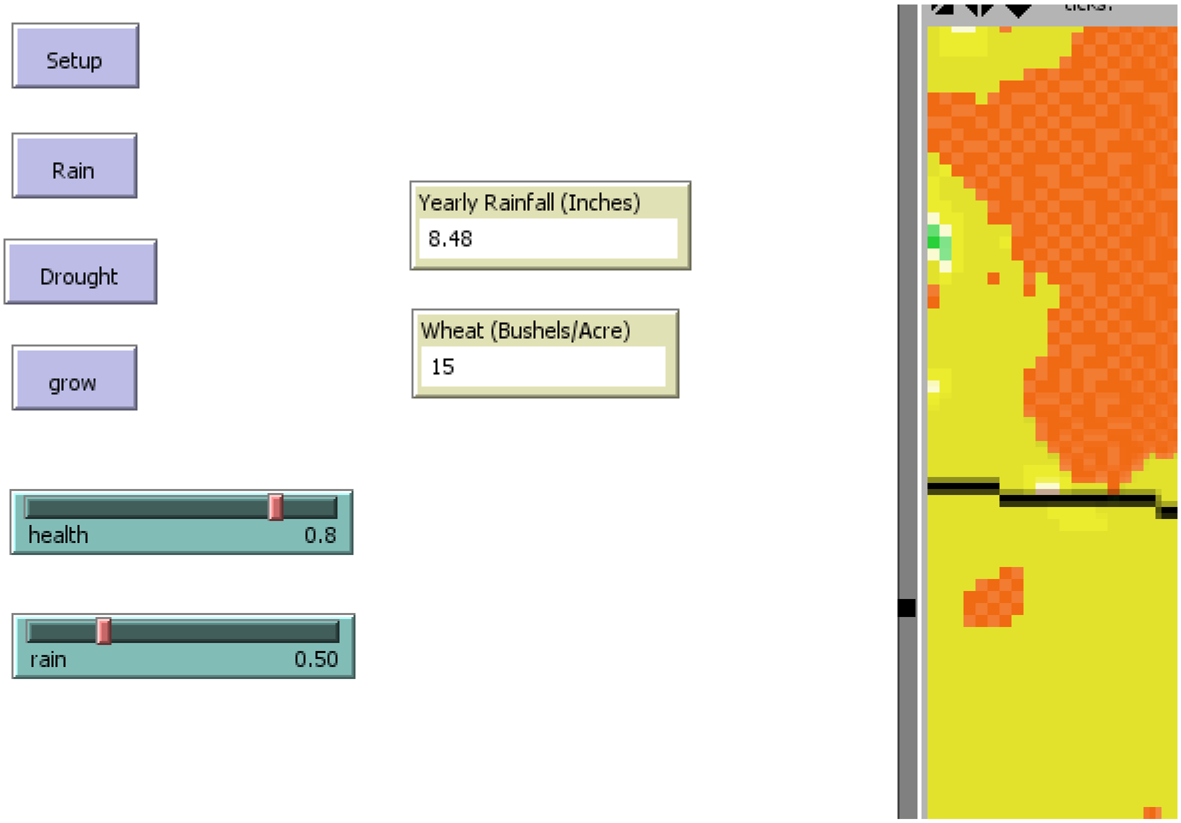

A wheat crop with slightly lower health during a moderate drought

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