Oxysynthesis

New Mexico
Supercomputing Challenge
Final Report
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Team 143
Taos Middle School

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Executive Summary

In today's 21st century society, the majority of people are reliant on industry, enterprise, and technology and their constant advances; this dependence is causing great and very dangerous changes to the environment. That is why we need to take a stand now and fix what we've done wrong as a population; this is Delaney's goal. With previous successful experimentation of using various methods of using Vitamin E on plants, in particular Buck Forage Oats, Delaney has produced a functioning 'Oxygen Farm' that on a larger scale, in theory, could slow down the effects and output of pollution.

By using several terrariums made from 2 liter bottles and sealed, plastic tubs, Delaney was able to observe and complete data analysis on her Vitamin E treated plants. The terrariums provided a real world application of the plants and their co-existing variables; carbon dioxide, oxygen, growth rates, pH and moisture retention. Doing this, Delaney got an accurate outcome of the results, in which she then took to develop her model in NetLogo.

In her model, she has the following variables; carbon dioxide molecules, sunlight, clouds, that both rain and deflect sunlight, a layer of topsoil and dirt beneath and the model measuring the global temperature. As of right now, her model has an accurate real world scenario of what would be taking place if the plants were added.

Further applications of this model would be to finish developing it with more variables and scenarios to make it even more of a usable model. Delaney would also like to finish developing a formula that she could plug into the model that would measure how long her Vitamin E treated plants would take to decrease pollution amounts as well as how much of the plants would be needed to decrease those amounts.

Background Research

Photosynthesis

Photosynthesis is the synthesis of sugar from light and water, with oxygen as a waste product. Without photosynthesis we would not be here on this earth today. Photosynthesis is the production of oxygen that nearly all life depends on. It occurs in higher plants, algae, some bacteria, and some protists. Photosynthesis occurs in photoautotrophs which are plants that can synthesize food directly from inorganic compounds like the sun, water, and carbon dioxide. Photosynthesis is important because it helps maintain a balanced cycle called a carbon sink, where the carbon dioxide gets absorbed and used by the plants while also taking into account other realistic variables such as industries, rainfall, average temperature, etc.

Vitamin E

Vitamin E or scientifically known as alpha-Tocopherol is a vitamin that dissolves in fat. It is found in many foods including vegetable oils, meat, poultry, eggs, fruits, vegetables, and wheat germ oil. It is also available as a supplement that can be taken by mouth or as a lotion. Vitamin E can be a treatment for dry skin, Vitamin E deficiency, and it can even possibly help certain blood deficiencies and dementia patients.

Buck Forage Oats

Buck Forage Oats or commonly known as buckwheat is a widely cultivated plant throughout the United States that has many uses. Some of Buck Forage Oats' uses include using it as livestock feed, as a main ingredient in some vegan foods like milk and pancakes and using it for medicinal purposes. When growing Buck Forage Oats, they grow best in a moist and cool environment with a very acidic soil pH. Buck Forage Oats are beneficial because they are very healthy, have many uses, and are widely cultivated.

Carbon Dioxide

Carbon dioxide is a chemical compound composed of two oxygen atoms each covalently double bonded to a single carbon atom, that is also known as CO2. (Carbon being element number 6 and oxygen being element number 8.) As of 2011, carbon dioxide accounted for 84% of all greenhouse gas emissions from human activities. Those human activities that are increasing the levels of carbon dioxide in the atmosphere (which is changing earth's carbon cycle) is the combustion of coal, natural gas, and oil which is used for electricity, transportation, and industry. This carbon dioxide combustion is constantly being exchanged between the atmosphere, ocean, and land surface, and is being absorbed by many microorganisms, plants, and animals; these interactions take place in a carbon sink. Because of all of these emissions the CO2 levels are expected to grow about 1.5% every fifteen years.

Air Pollution

The most common and obvious form of air pollution is the smog floating over cities around the world, but generally any substance that people let into the atmosphere that has damaging effects to living things is considered air pollution. Air pollution is everything from CO2, to methane, to chlorofluorocarbons (CFC), to sulfur dioxide. All of these chemicals are also associated with climate change.

Chevron Mine

__In a small town in Questa, New Mexico, there is a Molybdenum mine that brought booming business and agriculture to the town all throughout the 1900's. Since then, the mine has been shut down, but still affects the town, just in a negative way. When it shut down, it laid off a huge amount of people that lived in Questa with no other forms of acquiring employment. It also now lingers contaminating the soil and land throughout Questa.

Sesame

Sesame (scientifically known as Sesamum indicum) plants grow seeds in their triangular-shaped pods that contain the famous seeds the plant is cultivated for.The sesame plant can grow up to about 3.5 feet in height and has many medicinal uses. Sesame plants also have a taproot system, this allows for the plants to grow in somewhat drought affected areas.

Alfalfa

Alfalfa is a plant that has numerous uses. Some of these uses include animal food, medicinal uses, grazing, and even used for diets, and lowering cholesterol. The reason why alfalfa is used for so many purposes is because it is rich in fiber, nutrients and vitamins. But there are some downsides. Alfalfa is toxic to itself so it won't reproduce itself if there is a crop that already exists. For this reason, it is necessary to plow a crop that has finished before planting the next season's crop. It is also harmful to your intestines if you consume too much, and is most likely unsafe if you take alfalfas seeds for too long.

The Oxygen Cycle

The beginning of the oxygen cycle all starts when the plants create the oxygen using photosynthesis. Next animals (and us) breathe in the oxygen which we use to break down carbohydrates down into energy (which is also called respiration) Finally, we let out carbon dioxide (CO_2) so that the photoautotrophs can start the process again. Although it seems simple it certainly isn't. The photoautotrophs have to break down the carbohydrates just like we do, but to accomplish that they have to keep some of that oxygen during the day so that they can use it to help them break down their carbohydrates. In order to maintain their metabolism and continue respiration at night they must absorb oxygen and let out carbon dioxide so that everything stays balanced.

Adenosine Triphosphate (ATP)

ATP is considered to be the energy currency of life. It is the high-energy molecule that stores the energy we need for just about everything in life. ATP is present in the cytoplasm and nucleoplasm of every cell. Essentially all of the physiological mechanisms that require energy use the stored ATP in the cell. As food in the cells is gradually oxidized (combined chemically with oxygen) the energy that is released is used to restore the ATP so that the cell always has a supply of this very important molecule. (In animal systems the ATP is formed in the mitochondria.) Living things can use ATP as a sort of “battery”. It can power needed reactions by losing one of its phosphorous groups to form ADP, but use the energy from food to then convert it back to ATP so that it can go back to its work as life’s battery.

Krebs Cycle

In plants sunlight energy can be used to convert the less active compound back to the highly energetic form. But for animals you use the energy from your high energy storage molecules to do what you need to stay alive, after that you “recharge” them to put them back in the high energy state. This process is called the TCA cycle or Krebs Cycle.

Krebs Cycle is the sequence of reactions by which most living cells generate energy during the process of respiration. Like ATP it takes place in the mitochondria. During that process there is consuming of oxygen, producing carbon dioxide and water as a waste product. This all leads up to the conversion of ADP to energy-rich ATP.

Cell Signalling

Cells use a large number of clearly defined signalling pathways to regulate their activity. These signalling pathways fall into two main groups depending on how they are activated. Most of them are activated by external stimuli and function to transfer information from the cell

surface to internal effector systems. However, some of the signalling systems respond to information generated from within the cell, usually in the form of metabolic messengers. For all of these signalling pathways, information is conveyed either through protein–protein interactions or it is transmitted by diffusible elements usually referred to as second messengers. Cells often employ a number of these signalling pathways, and cross-talk between them is an important feature.

Top Ten Polluted Cities in America

Rank	**Location**	**Population**	**Cardiovascular Cases**
1	Bakersfield, California	852,000	168,000
2	Merced, California	260,000	51,000
3	Fresno, California	1.1 Million	25,000
4	Los Angeles, California	18.1 Million	4 Million
5	Hanford, California	154,000	30,000
6	Modesto, California	519,000	110,000
7	Visalia, California	429,000	87,000
8	Pittsburgh, Pennsylvania	2.5 Million	705,000
9	El Centro, California	177,000	37,000
10	Cincinnati, Ohio	2.2 Million	164,000

Problem Definition

Carbon dioxide, needed for life, but in large amounts, can also destroy it. In high amounts carbon dioxide (CO2) can be toxic, and in some cases, cause respiratory diseases. Originally, I started experimenting on sesame and other plants like alfalfa and buckwheat in June of 2013 for my science fair project. This was before I thought about doing a model for a larger comparison of data. Since then, I have created a model which creates a real world scenario of my 'oxygen farm' in StarLogo TNG.

This year, I planned on going bigger and better to create a variable-based model. This model would allow scientists to enter in what city they would like to model (such as Los Angeles) with variables such as population density, average temperature, carbon dioxide per square mile, etc. This would allow data collection and comparison on my method of using and enhancing Vitamin E to encourage soil remediation, aquifer cleansing, air cleaning, oxygen production, carbon dioxide reduction and carbon sink in widely cultivated plants (which is my science fair project.)

Since then, I have created a model in NetLogo. This model has the following variables; carbon dioxide molecules, sunlight, clouds (that both rain water droplets and deflect sunlight), a layer of topsoil, dirt beneath the layer of topsoil, and a reading of global temperature. This model, although still in work and not fully developed yet, is fully functioning and quite accurate.

Problem Solution

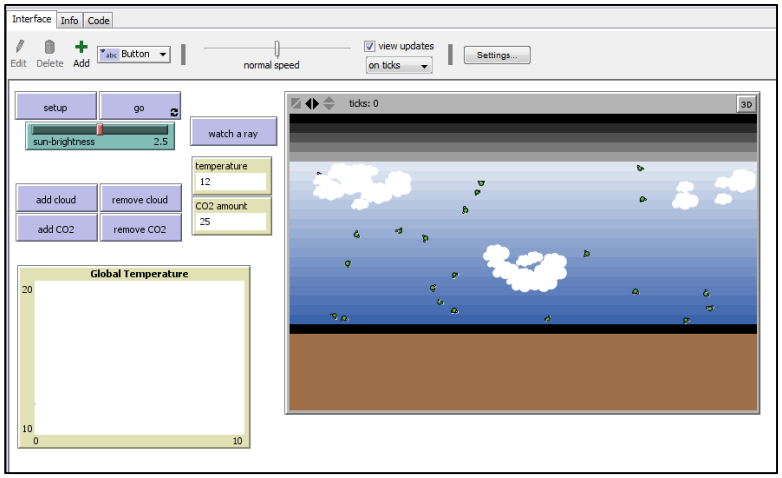
To my problem, there is a real world solution. The model is a supporting element to real world experimentation that takes carbon dioxide from the atmosphere and then converts it to oxygen in a solution called a carbon sink. This will also prove beneficial in multiple ways, including absorption of contaminants from the soil to regenerate drought and contaminated soil. The model can be used as an indicator of how much of the hyper-photosynthetically advanced seeds and the type of seeds can be planted for the best regeneration and remedial product for urban and rural contamination areas. As well as how long it will take to remediate these soils and decrease the amounts of pollution by using these Vitamin E treated plants.

Expected Results

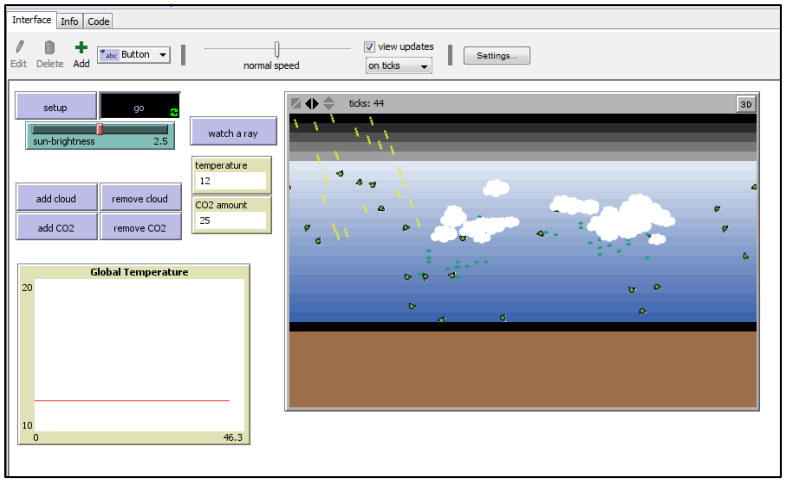
Earlier this year, I intended to complete my model, and be able to have enough time and data to produce a regularly comprehensive model to cover all variables and to debug the model so that it is a functional enhancement to the science fair project. I also hoped to have a working variable-based model, which hopefully in the future can be used by environmental scientists for research and experiments, as well as to expand the project to a fully encompassing environmental remediation solution that can be aimed at everything from drought to mine tailings remediation as a counteraction to climate change.

Software & Code

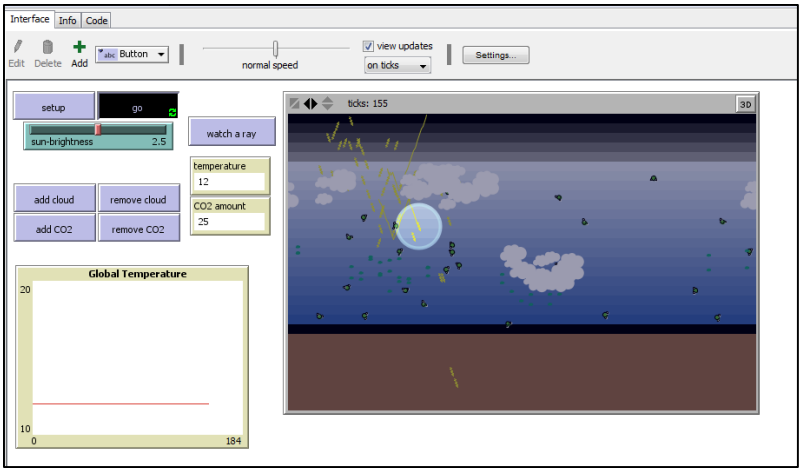
This year I decided to use NetLogo instead of when I used StarLogo TNG last year and the year before. This was due to the fact that actually typing out instead of building it block by block was easier for me. The following are pieces of the code I have written in NetLogo with comments and their own descriptions of what the code is meant to do as well as screenshots of the model in action:



This is a screenshot of when you first click the 'setup' button.



This is a screenshot of when you first click the 'go' button.



This is a screenshot of when you first click the 'watch a rav' button.

Interface | Info | Code

Find... | Check | Procedures | Indent automatically

```
globals [
  sky-top       ;; y coordinate of top row of sky
  earth-top     ;; y coordinate of top row of earth
  temperature   ;; overall temperature
]

breed [rays ray]      ;; packets of sunlight
breed [heats heat]    ;; packets of heat energy
breed [CO2s CO2]      ;; packets of carbon dioxide
breed [drops drop]    ;; packets of water/rain
breed [clouds cloud] ;; packets of clouds
breed [plants plant] ;; packets of sprouts
clouds-own [cloud-speed cloud-id]

;;
;; Setup Procedures
;;

to setup
  clear-all
  set-default-shape rays "ray"
  set-default-shape clouds "cloud"
  set-default-shape heats "dot"
  set-default-shape CO2s "CO2-molecule"
  set-default-shape drops "drop"
  set-default-shape plants "plant"
  setup-world
  set temperature 12
  reset-ticks
  plot temperature
end

to setup-world
  set sky-top max-pycor - 5
  set earth-top 0
  ask patches [  ;; set colors for the different sections of the world
    if pycor > sky-top [  ;; space
      set pcolor scale-color white pycor 22 15
    ]
    if pycor <= sky-top and pycor > earth-top [ ;; sky
      set pcolor scale-color blue pycor -20 20
    ]
    if pycor < earth-top
      [ set pcolor brown] ;; earth
    ;;if pycor = earth-top ;; earth surface

  ]
end

;;
;; Runtime Procedures
;;
```

This piece of code setups the main design of the model with the different colors in the sky and on the soils, it also sets the default shape for each agent.

This piece of code basically just has to do with the clouds. It has the ‘add cloud’ procedure, and the ‘create cloud’ procedure and the ‘go’ procedure.

Interface | Info | Code

Find... | Check | Procedures | Indent automatically

```
;;

to go
  ask clouds [ fd cloud-speed ]  ; move clouds along
  run-sunshine   ;; step sunshine
  run-heat  ;; step heat
  run-drops   ;; step water molecules
  run-CO2   ;; moves CO2 molecules
  tick
  plot temperature
end

to add-cloud            ;; erase clouds and then create new ones, plus one
  let sky-height sky-top - earth-top
  ;; find a random altitude for the clouds but
  ;; make sure to keep it in the sky area
  let y earth-top + (random-float (sky-height - 4)) + 2
  ;; no clouds should have speed 0
  let speed (random-float 0.1) + 0.01
  let x random-xcor
  let id 0
  ;; we don't care what the cloud-id is as long as
  ;; all the turtles in this cluster have the same
  ;; id and it is unique among cloud clusters
  if any? clouds
  [ set id max [cloud-id] of clouds + 1 ]

  create-clouds 3 + random 20
  [
    set cloud-speed speed
    set cloud-id id
    ;; all the cloud turtles in each larger cloud should
    ;; be nearby but not directly on top of the others so
    ;; add a little wiggle room in the x and ycors
    setxy x + random 9 - 4
          ;; the clouds should generally be clustered around the
          ;; center with occasional larger variations
          y + random-normal 2.5 1
    set color white
    ;; varying size is also purely for visualization
    ;; since we're only doing patch-based collisions
    set size 2 + random 2
    set heading 90
    let z drops hatch 1 ;;creates mini clouds they are copies meaning that 1 cloud equals 1 drop of rain
    ;;need to set code so it drops its load more than once make it repeat
    set heading 160
    set color turquoise
    set size .5
    if not can-move? 0.3 [ die ]  ;; kill them off at the edge
    fd 0.3
  ]
end
```

Interface | Info | Code

Find... | Check | Procedures | Indent automatically

```
end


to remove-cloud       ;; erase clouds and then create new ones, minus one
  if any? clouds [
    let doomed-id one-of remove-duplicates [cloud-id] of clouds
    ask clouds with [cloud-id = doomed-id]
      [ die ]
  ]
end


to run-sunshine
  ask rays [
    if not can-move? 0.3 [ die ]  ;; kill them off at the edge
    fd 0.3                        ;; otherwise keep moving
  ]
  create-sunshine  ;; start new sun rays from top
  reflect-rays-from-clouds  ;; check for reflection off clouds
end

to run-drops
  ask drops [
    if not can-move? 0.3 [ die ]  ;; kill them off at the edge
    fd 0.3                        ;; otherwise keep moving
  ]

end

to create-sunshine
  ;; don't necessarily create a ray each tick
  ;; as brightness gets higher make more
  if 10 * sun-brightness > random 50 [
    create-rays 1 [
      set heading 160
      set color yellow
      ;; rays only come from a small area
      ;; near the top of the world
      setxy (random 10) + min-pxcor max-pycor
    ]
  ]
end

to reflect-rays-from-clouds
 ask rays with [any? clouds-here] [   ;; if ray shares patch with a cloud
   set heading 180 - heading   ;; turn the ray around
 ]
end
```

This piece of code includes the ‘remove cloud’, ‘run sunshine’, ‘run drops’, ‘create sunshine’, and ‘reflect rays from clouds’ procedures.

This is the final piece of code. It includes the ‘run heat’, ‘add CO2’, ‘remove CO2’, and the ‘run CO2’ procedures.

```
to run-heat    ;; advances the heat energy turtles
  ;; the temperature is related to the number of heat turtles
  set temperature 0.99 * temperature + 0.01 * (12 + 0.1 * count heats)
  ask heats
  [
    let dist 0.5 * random-float 1
    ifelse can-move? dist
      [ fd dist ]
      [ set heading 180 - heading ] ;; if we're hitting the edge of the world, turn around
    if ycor >= earth-top [  ;; if heading back into sky
          set heading 20
          set color magenta ]
         set heading 100 + random 160 ] ;; return them to earth

end

to add-CO2  ;; randomly adds 25 CO2 molecules to atmosphere
  let sky-height sky-top - earth-top
  create-CO2s 25 [
    set color green
    ;; pick a random position in the sky area
    setxy random-xcor
          earth-top + random-float sky-height
  ]
end

to remove-CO2 ;; randomly remove 25 CO2 molecules
  repeat 25 [
    if any? CO2s [
      ask one-of CO2s [ die ]
    ]
  ]
end

to run-CO2
  ask CO2s [
    rt random 51 - 25 ;; turn a bit
    let dist 0.05 + random-float 0.1
    ;; keep the CO2 in the sky area
    if [not shade-of? blue pcolor] of patch-ahead dist
      [ set heading 180 - heading ]
    fd dist ;; move forward a bit
  ]
end


; Copyright 2007 Uri Wilensky.
; See Info tab for full copyright and license.
```

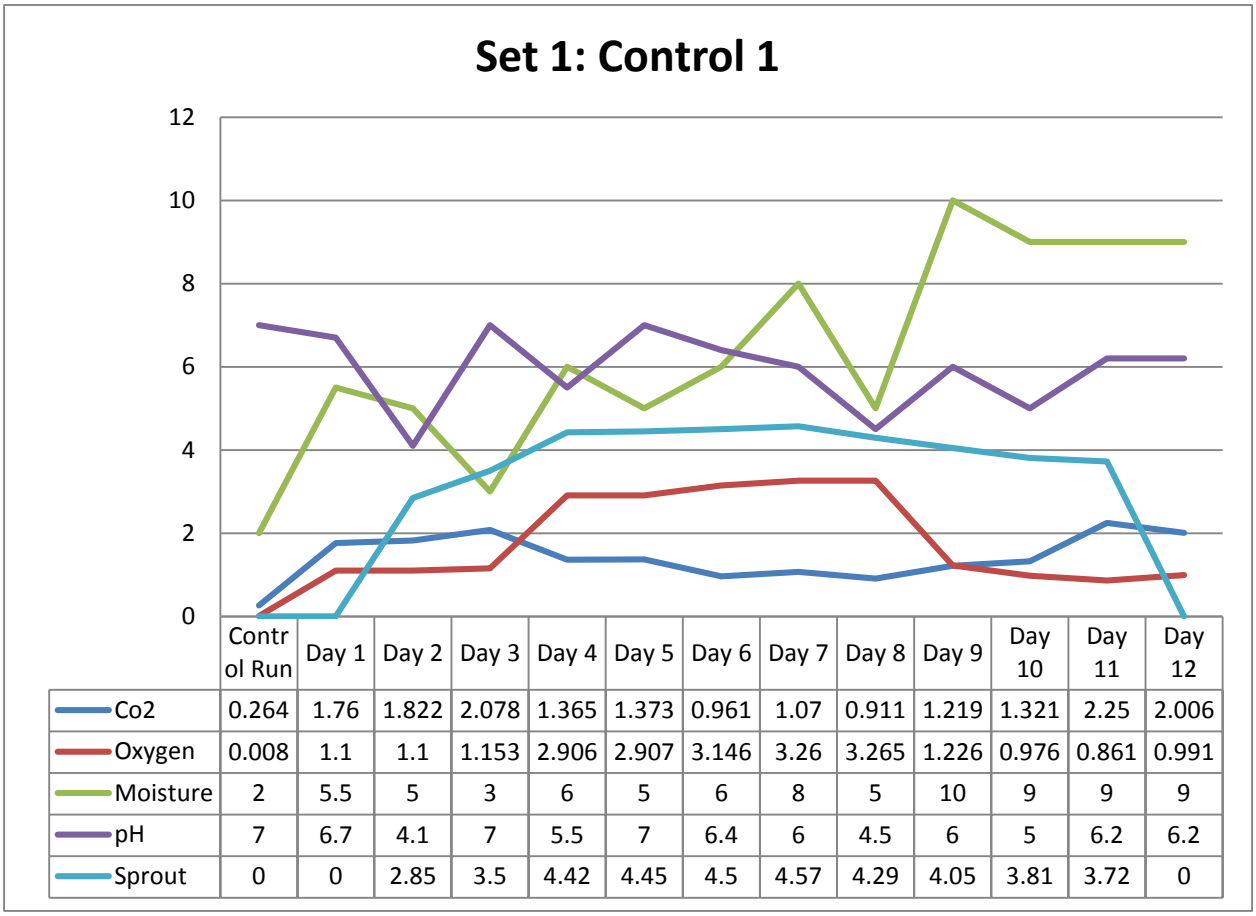
Data & End Results

Upon completing this year's challenge the data I have gathered is:

Starting Data:

Variable/Agent	Starting Amount
Sunlight	Uses Slider: Anywhere from 1 to 5
Carbon Dioxide Molecules	Can be added in increments of 25
Clouds	Can be added in increments of 1
Water Molecules	Rain from the clouds in increments of 25

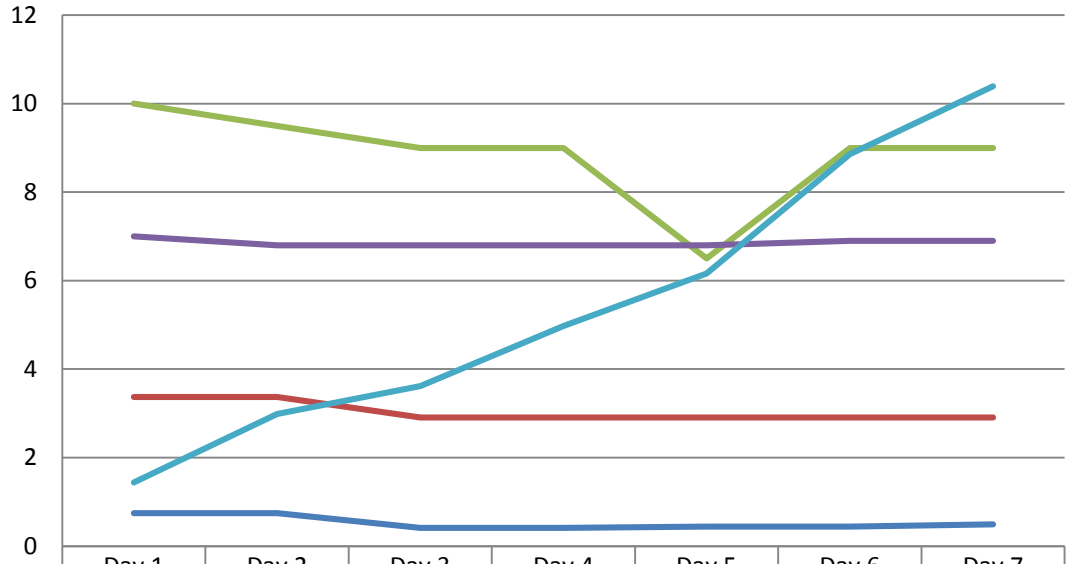
Graphs:



	Control Run	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
Co2	0.264	1.76	1.822	2.078	1.365	1.373	0.961	1.07	0.911	1.219	1.321	2.25	2.006
Oxygen	0.008	1.1	1.1	1.153	2.906	2.907	3.146	3.26	3.265	1.226	0.976	0.861	0.991
Moisture	2	5.5	5	3	6	5	6	8	5	10	9	9	9
pH	7	6.7	4.1	7	5.5	7	6.4	6	4.5	6	5	6.2	6.2
Sprout	0	0	2.85	3.5	4.42	4.45	4.5	4.57	4.29	4.05	3.81	3.72	0

This is a control graph from actual experimentation. As you can see, every data set is very unstabalized.

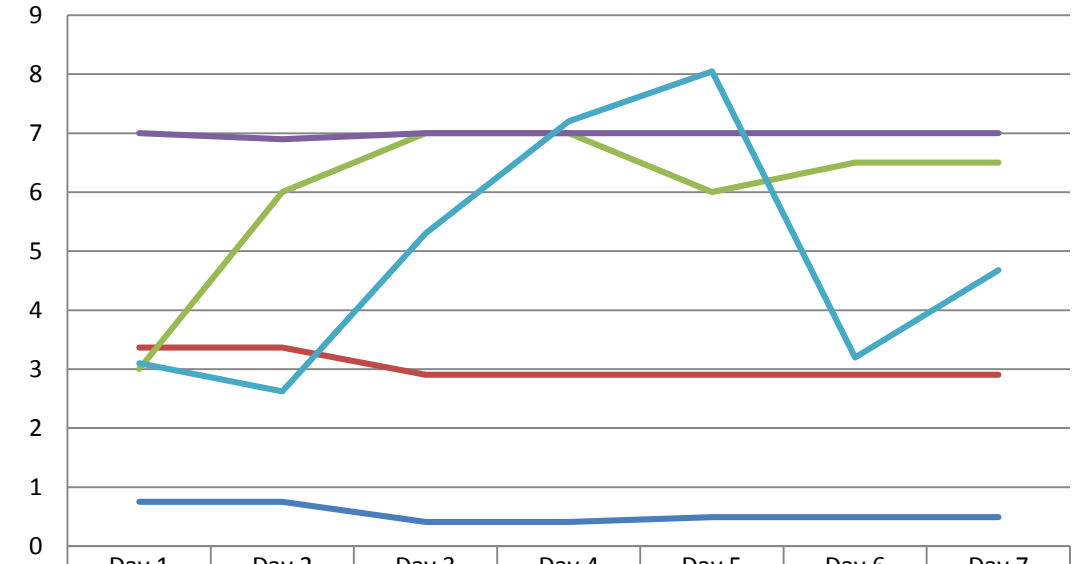
Set 7: Caliche, Buck Forage Oats-Presoak



	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Co2	0.748	0.748	0.411	0.411	0.439	0.439	0.493
Oxygen	3.367	3.367	2.905	2.905	2.905	2.905	2.905
Moisture	10	9.5	9	9	6.5	9	9
pH	7	6.8	6.8	6.8	6.8	6.9	6.9
Sprout	1.44	2.984	3.62	4.976	6.164	8.86	10.396

These are graphs from actual experimentation. Compared to the control, these data sets are very controlled, and stabilized. In these graphs, the plants were pretreated with a Vitamin E presoak method that I developed.

Set 7: Mine, Buck Forage Oats- Presoak



	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Co2	0.751	0.751	0.411	0.412	0.493	0.493	0.493
Oxygen	3.367	3.367	2.906	2.905	2.905	2.905	2.905
Moisture	3	6	7	7	6	6.5	6.5
pH	7	6.9	7	7	7	7	7
Sprout	3.1	2.625	5.3	7.2	8.05	3.2	4.68

Conclusions

Upon finalizing this year's data it has been concluded that more variables need to be isolated. In this year's model I have added in five variables (the carbon dioxide, water, sunlight, clouds and global temperature), but I still have many I want to add in (plants, growing season, altitude, climate, soil PH, population density, moisture retention, etc.) You may be asking why I didn't add in the plants yet, as that is arguably the most important part of the model; but there is an explanation. I didn't want to add in plants until I had completely developed my formula for the plants. This formula, which I would be able to use to find out how many plants I would need to decrease the amounts of pollution in parts per million with the coinciding amount of time it would take, is still in the works. This is because I want to make this model as real as possible so that it could be used for real scientific research. That is why I am still working on it and will continue to work on it so that I can develop it for scientific use and research.

As of present, the model shows a general correlation with the sun and the clouds, where the clouds reflect the sun from hitting the layer of top soil. The clouds also give out water molecules like they do when it is raining, and although the carbon dioxide molecules have no correlation to other variables except for the global temperature, they will have an effect in the model once the pretreated, vitamin E plants come into play with their accurate formula.

Achievements

This year, the biggest achievement I have accomplished is once again being able to say that I have completed the challenge. I am also able to say that I've been able to learn and comprehend another coding language, NetLogo. Finally, I am able to say that I've achieved pride in what i've produced this year with my model, web presentation, and presentation board. I hope to do very well at the Supercomputing Expo in April and maybe even become a finalist!

Acknowledgements

After completing yet another New Mexico Supercomputing Challenge I would like to thank the following people, without them I couldn't have accomplished what I have:

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- Mr. Alfred Cordova
- Mr. Robert Trujillo

Bibliography

McGuigan, Brendan, and Niki Foster. "What Is Alfalfa?" *WiseGeek*. Conjecture, 14 Jan. 2014. Web. 12 Sept. 2013 < http://www.wisegeek.com/what-is-alfalfa.htm>.

Oplinger, E. S., E. A. Oelke, M. A. Brinkman, and K. A. Kelling. "Buckwheat." *Buckwheat*. Alternative Field Crops Manual, Nov. 1989. Web. 1 Mar. 2015. <https://www.hort.purdue.edu/newcrop/afcm/buckwheat.html>.

Unknown, Author. "Vitamin E: Uses, Side Effects, Interactions and Warnings - WebMD." *WebMD*. WebMD, 2014. Web. 01 Apr. 2015. <http://www.webmd.com/vitamins-supplements/ingredientmono-954-vitamin%20e.aspx?activeingredientid=954&activeingredientname=vitamin+e>.

Unknown Author. "Carbon Dioxide (CO2)." *Chemical Fact Sheets*. Wisconsin Department of Health Services, n.d. Web. 18 Nov. 20143. <http://www.dhs.wisconsin.gov/eh/chemfs/fs/carbondioxide.htm.>.

Unknown Author. "Types and Sources of Air Pollutants." -*European Lung Foundation[uk]*. European Lung Foundation, n.d. Web. 18 Nov. 2013. <http://www.european-lung-foundation.org/16538-types-and-sources-of-air-pollutants.htm>.

Unknown Author. "10 Most Polluted Cities." *CNNMoney*. Cable News Network, n.d. Web. 13 Aug. 2013. <http://money.cnn.com/gallery/real_estate/2013/04/24/polluted-cities/>.

Unknown Author. "The Oxygen Cycle." *The Oxygen Cycle*. N.p., n.d. Web. 11 Sep. 2013. <http://water.me.vccs.edu/concepts/oxycycle.html>.

Unknown Author. "Adenosine Triphosphate." *Adenosine Triphosphate*. N.p., n.d. Web. 11 Sep. 2013. <http://hyperphysics.phy-astr.gsu.edu/hbase/biology/atp.html>.

Unknown Author. "Glycolysis, Krebs Cycle, And Other Energy-Releasing Pathways." *Glycolysis, Krebs Cycle, And other Energy-Releasing Pathways*. N.p., n.d. Web. 11 Sep. 2013. <http://www.uic.edu/classes/bios/bios100/summer2002/lect10.htm>.

Unknown Author. "Cell Signalling." *Nature.com*. Nature Publishing Group, n.d. Web. 26 Oct. 2013. <http://www.nature.com/scitable/topicpage/cell-signaling-14047077>.

Unknown, Author. "Chevron Questa Mine Site (formerly Molycorp, Inc. Site)." *EPA*. Environmental Protection Agency, 9 June 2012. Web. 01 Apr. 2015. <http://www.epa.gov/region6/region-6/nm/nm_molycorp.html>.