What is the Impact of Cars on the Environment

New Mexico

Supercomputing Challenge

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Team 22

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Summary

We are modeling carbon dioxide (CO_2) emissions in the US given off by different sources including cars, houses, and factories. We are also modeling the sinks that take in CO_2 and convert it to oxygen. The Starlogo agents in our model consists of trees/plants, ocean, cars, houses, factories, and air bubbles. Over time the air bubbles will change into two different states: blue (oxygen), and red (CO_2). The rates that they change depend upon the number of collisions between the different agents. We made graphs that show how the CO_2 pollution levels change over time depending on the number of sources and sinks, and on the rates that the sources (like cars) give off CO_2.

Background

The earth maintains an average temperature of 15° C (59° F) because there is a balance of heat coming from the sun and heat leaving the earth into space. The gases in the earth's atmosphere help keep some of the heat from leaving. Carbon dioxide is one of the most important gases that traps heat. Figure 1 shows how the temperature increases

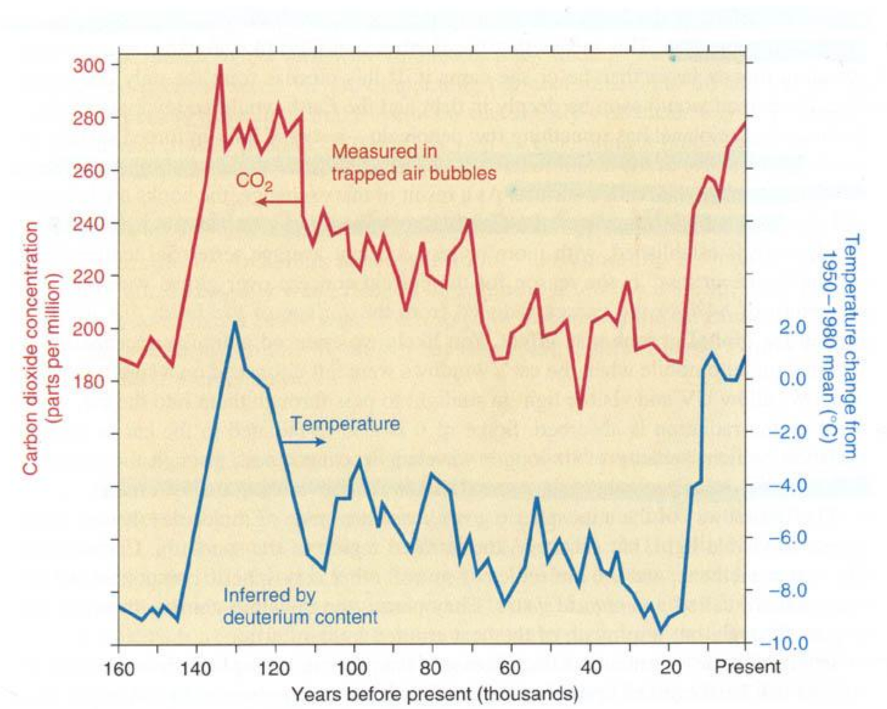

Figure 1: Correlation between temperature and CO_2 concentration. From http://www.chemistryland.com/CHM107/GlobalWarmin g/GlobalWarming.html

(decreases) when the CO_2 concentration increases (decreases). In the last 40 years we have seen a jump in CO_2 concentration of almost 50 parts per million. In the past these large increases occurred over a time span of 10,000 years! The recent increase in CO_2 concentration is primarily due to human technology such as cars, houses, and factories. If the concentration of CO_2 continues to increase, the earth's average temperature will also increase which could lead to the extinction of plant and animal species (including humans!).

The CO2 sources are: Cars, Factories, Houses, Deforestation, Decomposition and Animals. All of those sources add up to 224 billion metric tons of CO_2 per year world wide. Now if we add up all of the sinks: Trees, Plants, and the Ocean. Those add up to 204 billion metric tons. If we subtract those we get an excess of 20 billion metric tons per year. That is the excess amount of CO_2 that is getting put into the atmosphere (see Figure 2).

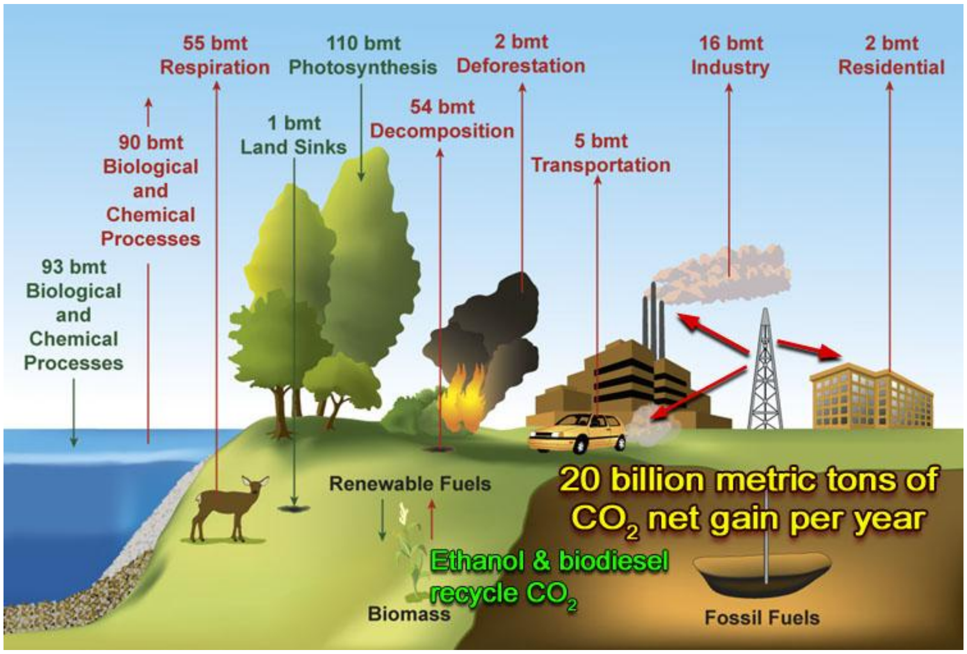

Figure 2: Sources and Sinks of CO_2. From:
http://www.chemistryland.com/CHM107/GlobalWarming/GlobalWarming.html

The total annual CO_2 emissions from the US is 5.9 billion metric tons which is 5.9/25 = 24 % of the worldwide emissions. From Figure 2 we can estimate the US contribution to the worldwide excess of 20 billion metric tons of CO_2. US power plants and other industries give off 3.8 billion metric tons, US cars give off (221 million cars times 5.2 metric tons per car) = 1.2 billion metric tons, and US households give off 0.5 billion metric tons. From these numbers we can calculate the percentages for each: power plants = 3.8/5.9 = 64%, cars = 1.2/5.9 = 20% and households = 0.5/5.9 = 8.5%. The forests and plants absorb about 8% of the CO_2 and the ocean absorbs about 12%. We will use these percentages to set the number of agents in our model. We ignored the 8% CO_2 from deforestation since it is mostly due to Brazil.

Starlogo Program

The Setup column in our Starlogo program creates the agents and sets a color to that specific agent: trees are green, the ocean is magenta, cars are brown, factories are black and houses are orange. The number of agents is chosen to correspond to the actual percentages of the US annual CO_2 emissions: 16 factories (16/ 23 = 69%), 2 houses (2/23 = 8 %), and 5 cars (5/23 = 22%). The number of forests/plants is 16 and the number of oceans is 24. These numbers were chosen to give a total of about 20% absorption. Once it is done creating the agents it then scatters all of the agents on Spaceland. We also have monitors and line graphs for the blue (oxygen) and red (CO_2) agents (see Figure 3). The Runtime column in our Starlogo program controls the agents movement. At each time step the agents move one unit and the direction (degrees) is random. The cars direction is a random degree between 1 and 3 and the pollution balls direction is a random degree between 1 and 6. The other agents do not move (see Figure 4). The Collision column in our Starlogo program determines how the air balls turn from blue (oxygen) to red (CO_2) (see Figure 5). When a red CO_2 ball collides with a tree or an ocean agent it turns to blue (oxygen) 4 times out of 1200 collisions. When a blue oxygen ball collides with a factory, car, or house it turns to red (CO_2) 4 times out of 1200 collisions. The rate of conversion (4/1200=0.33%) was chosen to be the same for all of the collisions initially. The 4/1200 was chosen to slow down the simulation so that each time step corresponds to one day. The number of source and sink agents and the conversion rate 4/1200 were chosen to match present day US annual CO_2 emissions. Our goal was to vary the number of source and sink agents and the conversion rate 4/1200 for some of the source agents (like cars for example) to model the effects of reduced emissions (by the use of electric cars for example).

Results

We first ran the model with just the sources (cars, houses and factories) for one year to determine the conversion rate which produced the 24% US emissions. Figure 6 plots the US CO_2 emissions for one year. The conversion rate 4/1200 produces about 99 red balls (out of 400 blue balls initially) in one year. We repeated this simulation ten times to verify that an average of 99.3 red balls are produced (24.8%). The number of red balls produced ranged from 87 to 114. We then ran the model with just the sinks (forests/plants and ocean). Figure 7 plots the absorption of CO_2 (red balls converted to blue balls) by the forests/plants and oceans. We changed the number of forests and oceans until we got an average of 73.9 blue balls (out of 400 red balls initially) in one year. We repeated this simulation ten times to verify that we got about 74 red balls on average converted into blue balls per year (18% which is close to the 20% we were trying to get). We are now ready to run the combined model (see Figure 8) with all of the sources and sinks turned on. We set the number of blue balls to 300 and the number of red balls to 100 and repeated the simulation ten times and averaged the results. The average number of red balls produced was 55.5 which is 55.5/300 = 18.5% of the worldwide CO_2 emissions per year (or 18.5% of 25 billion metric tons = 4.6 bmt). The plants and oceans absorbed about 1.3 bmt of the US annual emissions. Figure 9 is a plot of our spaceland for this simulation.

After the basic model was set up and running, we started investigating how the results change with different numbers of cars, and more efficient (reduced emissions) cars and factories. We increased the number of cars from 221 million to 300 million. Figure 10 plots the results of this simulation where the number of cars 5 (which represents 221 million) is increased to 7 (which represents 300 million). We ran the simulation 10 times and calculated an average number of 64 red balls produced. This gives 64/300 = 21.3%

of the worldwide CO_2 emissions per year (or 21.3% times 25 bmt = 5.3 bmt). Our simulation shows that the increase in the number of cars from 221 to 300 million increases the net US CO_2 emissions from 4.6 to 5.3 bmt. Next, we investigated the effects of changing the CO_2 emissions of cars. If half of the cars become electric, the emissions will be reduced by about half. So we changed the 4/1200 to 2/1200 in our conversion rate for cars. Figure 11 plots the results of this simulation. Again we ran the simulation ten times and averaged the results. The average number of red CO_2 balls was 43.4. This gives 43.4/300 = 14.5 % of the worldwide CO_2 emissions per year (or 3.6 bmt). Our simulation shows that the total US emissions can be reduced from 4.6 bmt to 3.6 bmt by reducing the emissions from cars in half. Figure 12 plots the results of the simulation where the factory emissions are reduced in half. After running the simulation ten times, we found that the average number of red CO_2 balls was 27.7 which corresponds to 27.7/300 = 9.2% of the worldwide CO_2 emissions per year (or 2.3 bmt). Since the emissions from factories are the largest, reducing these emissions has a large effect on the total US CO_2 emission (it decreases from 4.6 to 2.3 bmt).

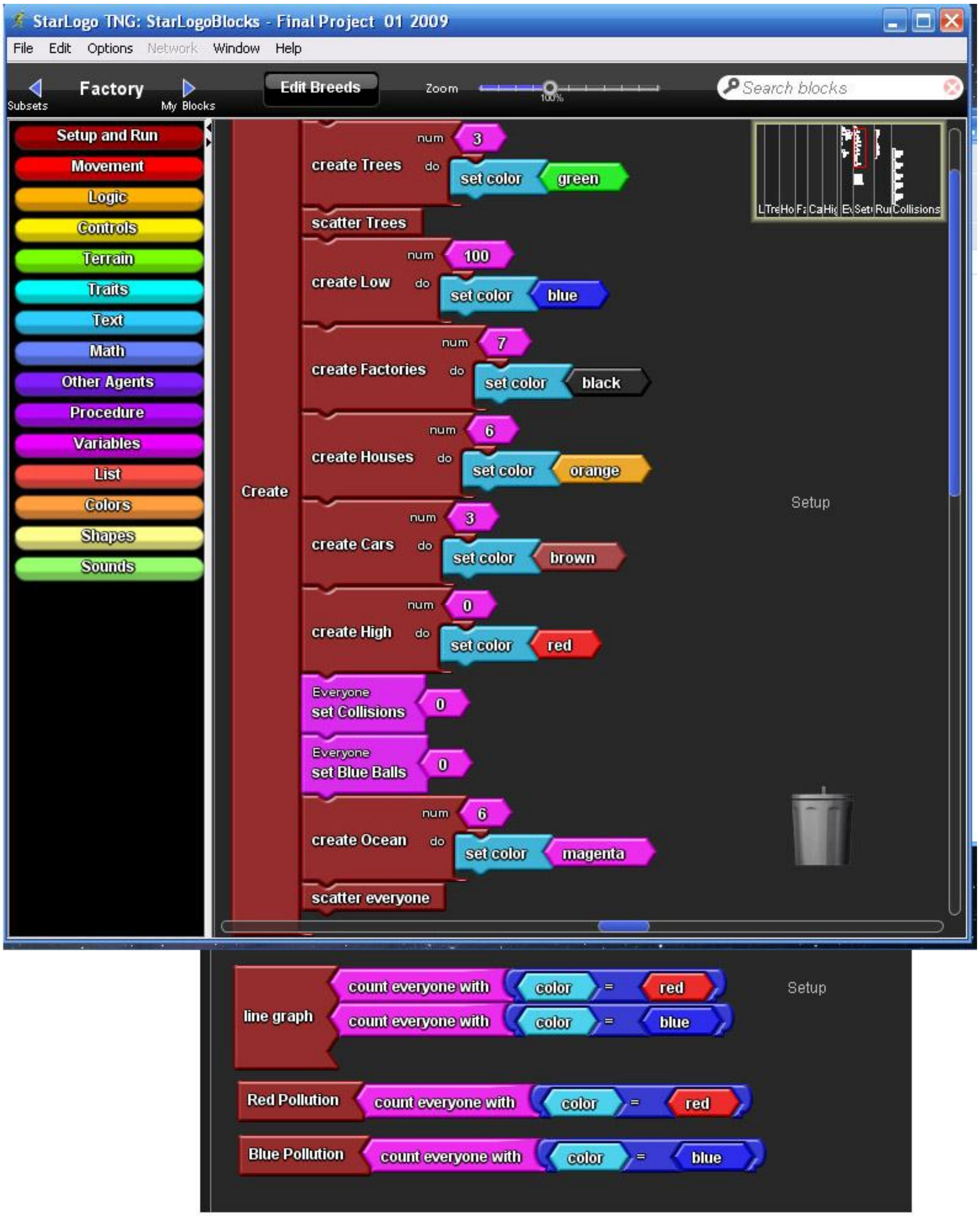

Figure 3: Starlogo Setup program for CO_2 emissions modeling

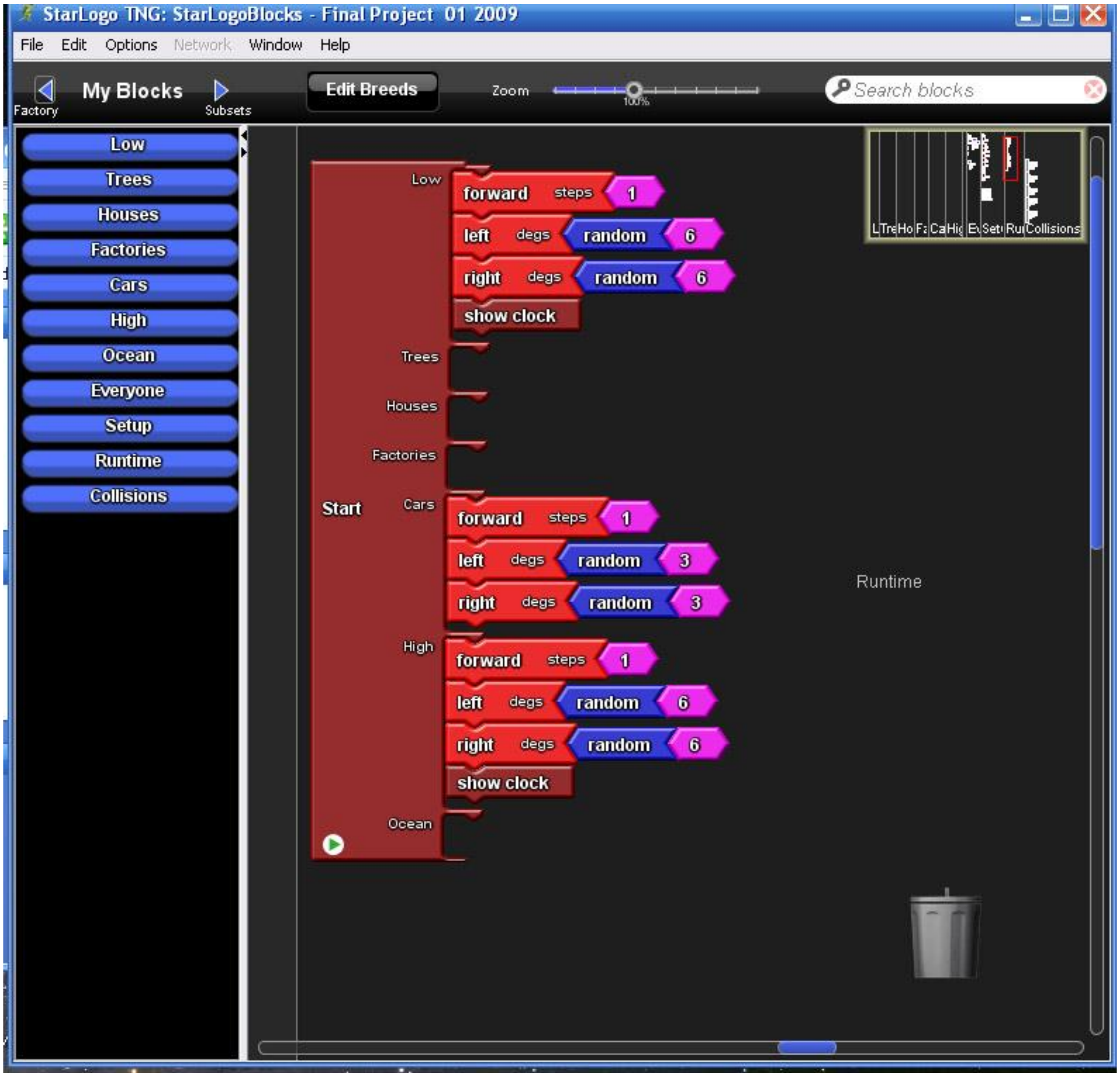

Figure 4: The Runtime column of our Starlogo program determines how the agents move for each time step.

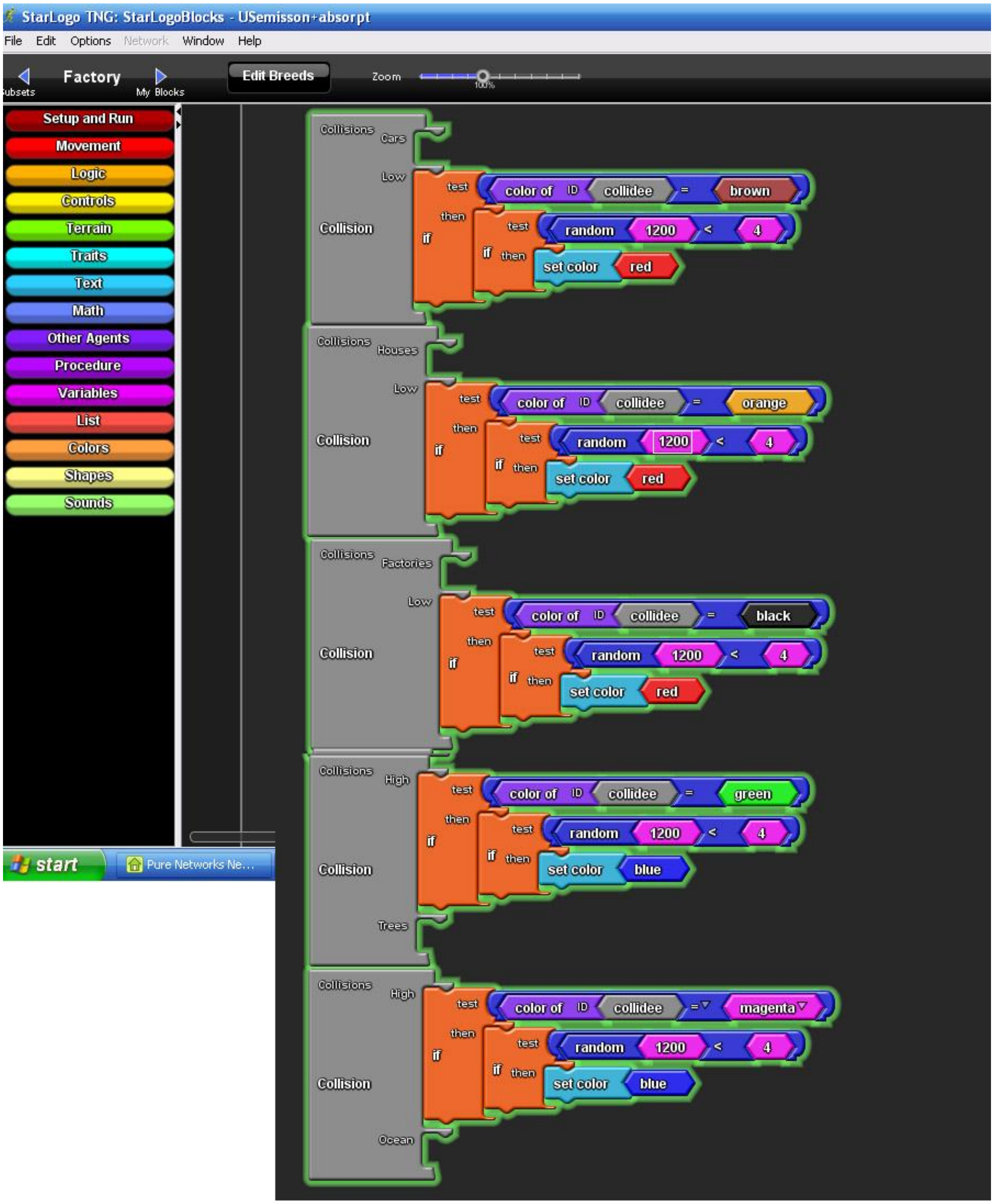

Figure 5: Collision part of our Starlogo program determines how the air balls change color from blue (oxygen) to red (CO_2).

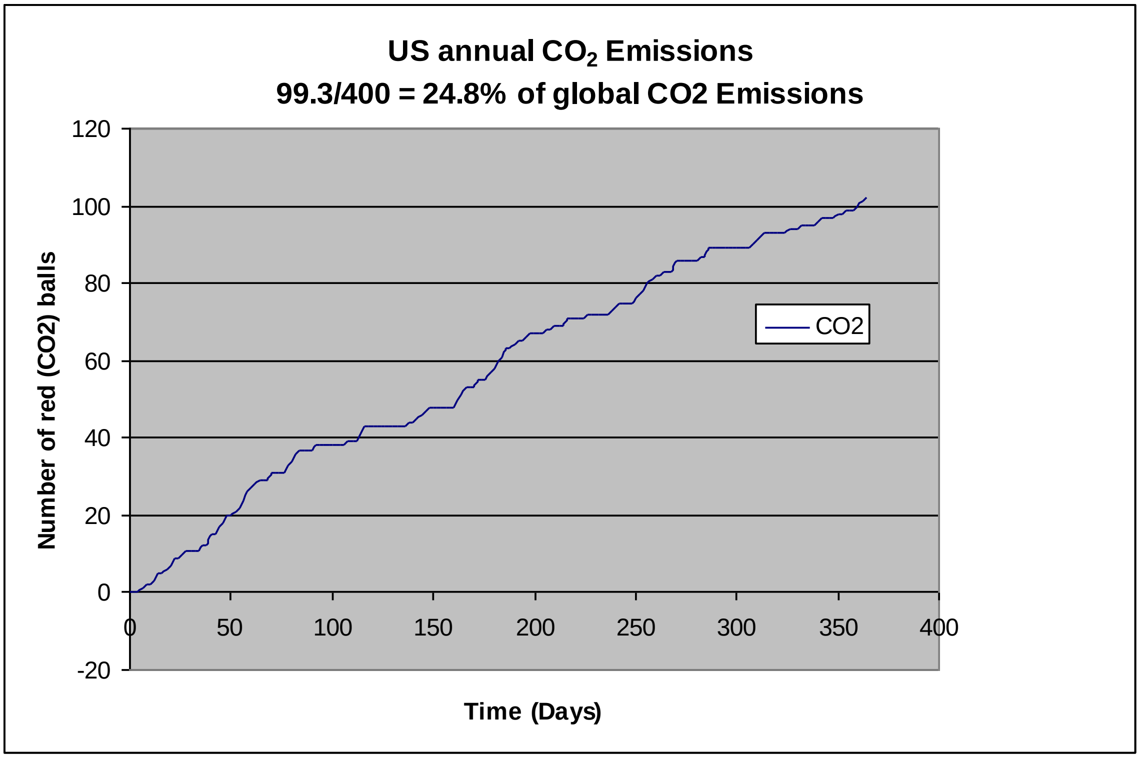

Figure 6: Annual US CO_2 emissions (24.8% of global amount = 6 bmt).

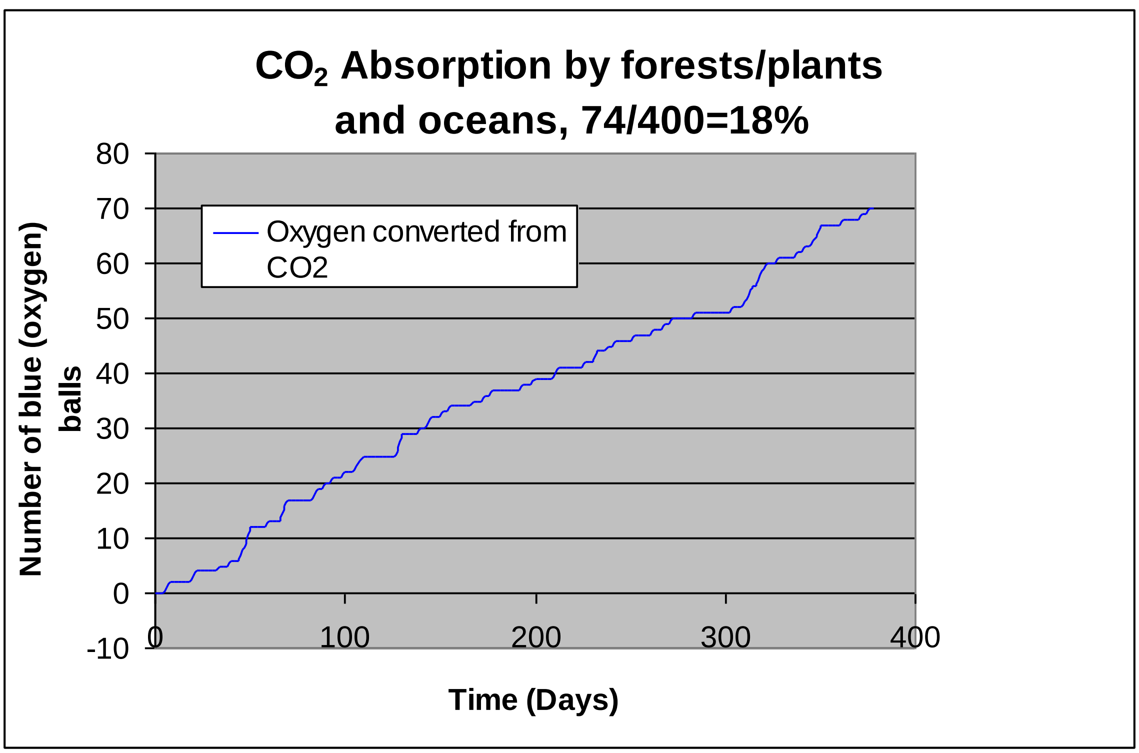

Figure 7: Annual US CO_2 absorption by forests, plants, and oceans (about 18% of 6 bmt = 1.2 bmt).

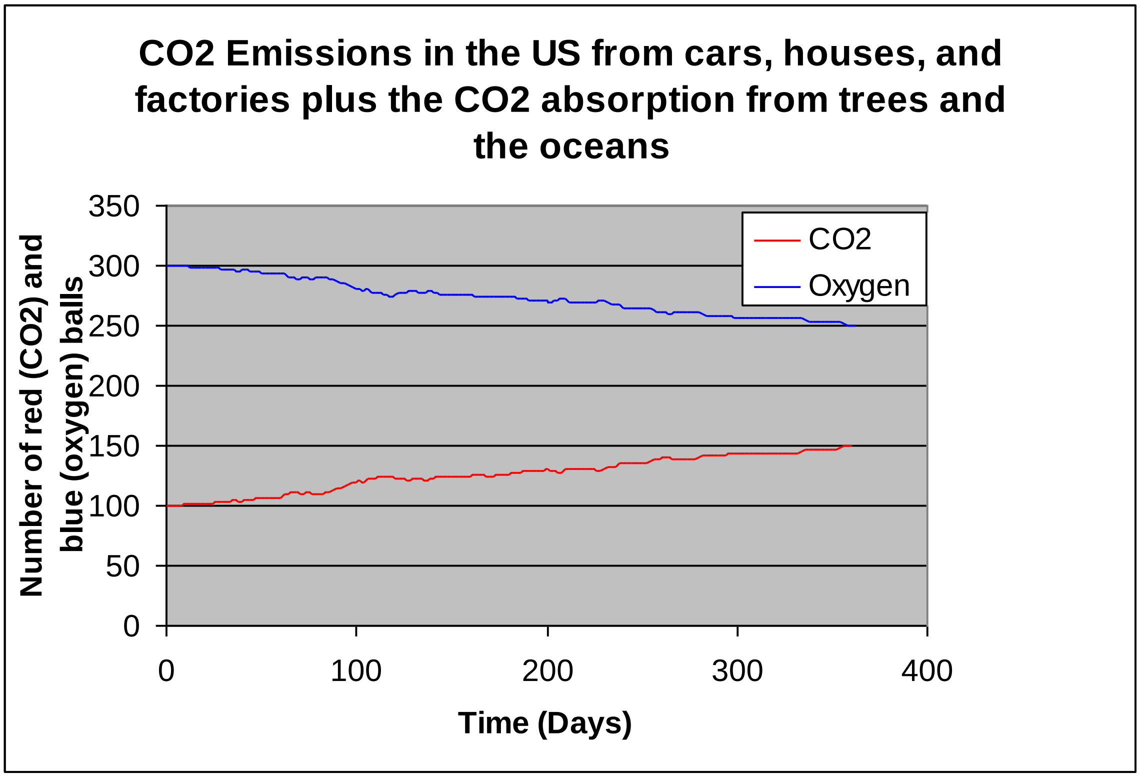

Figure 8: Combined model for the annual US CO_2 emissions by cars, houses and factories plus absorption by forests, plants, and oceans: 18.5% of 25 bmt= 4.6 bmt net gain.

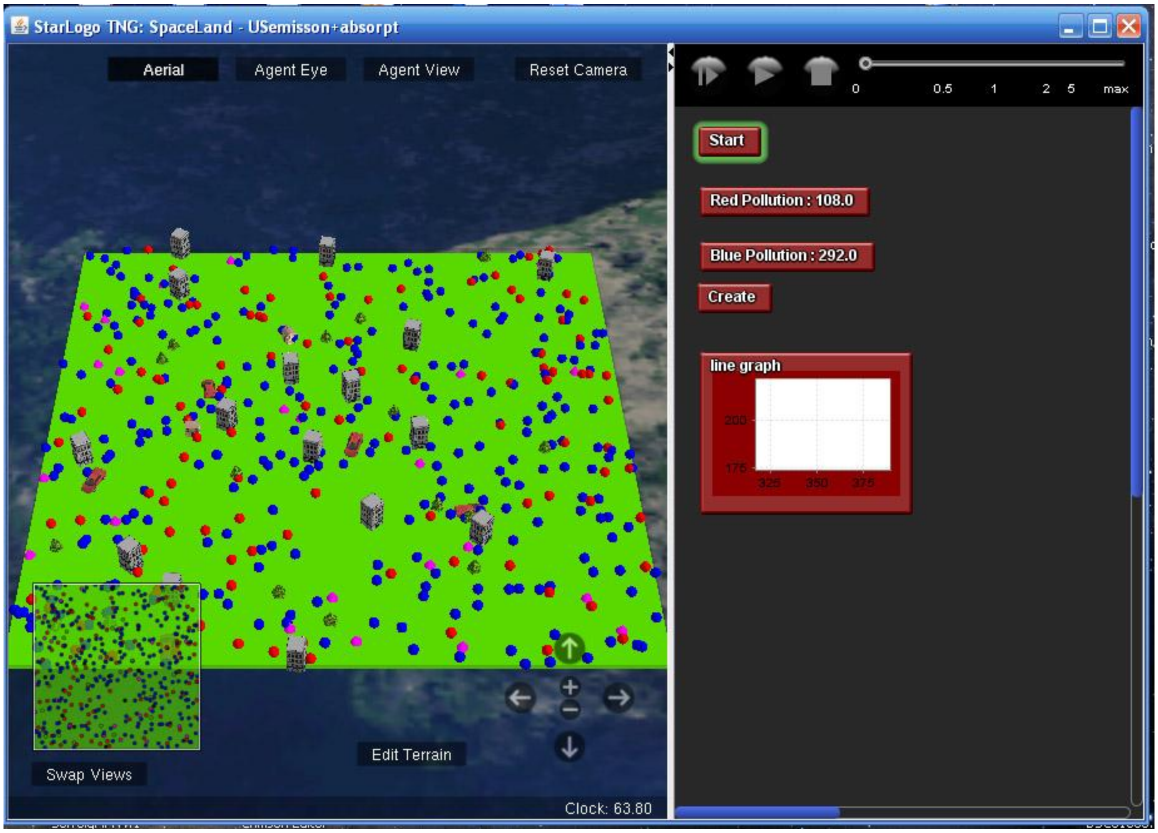

Figure 9: Spaceland for the simulation in Figure 8.

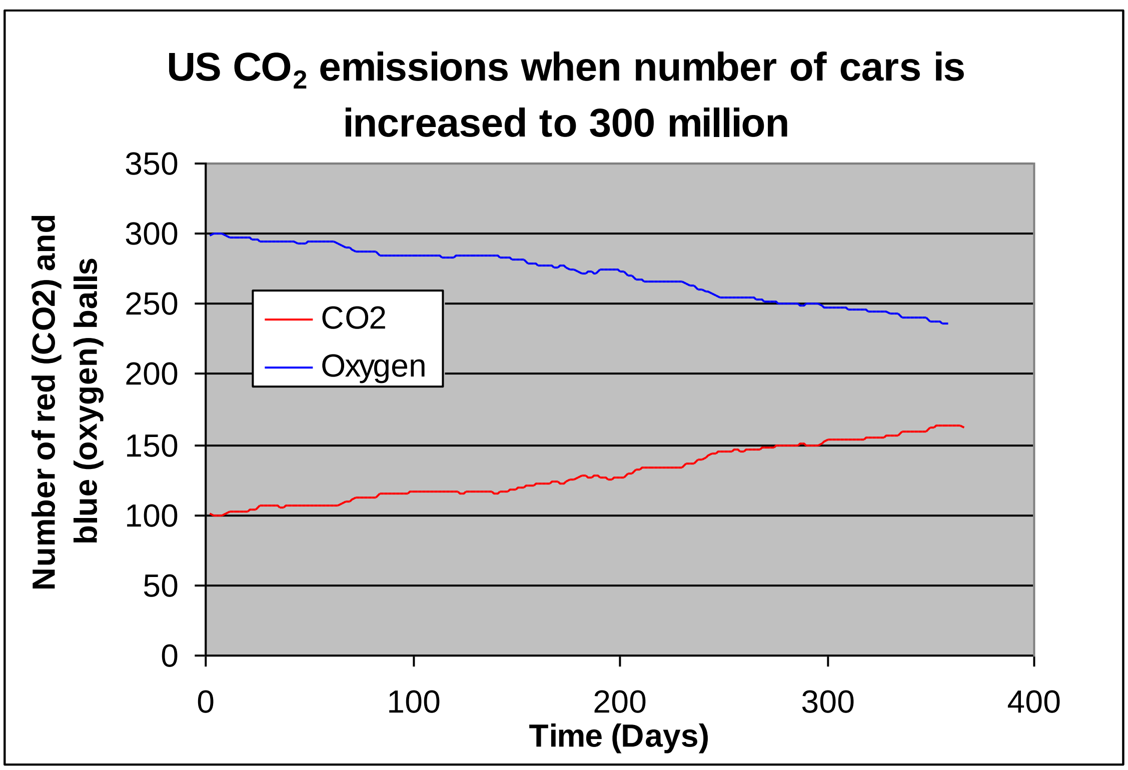

Figure 10: Combined model for the annual US CO_2 emissions by cars, houses and factories plus absorption by forests, plants, and oceans but with the number of cars increased to 300 million: 64/300 = 21.3% of 25 bmt= 5.3 bmt net gain.

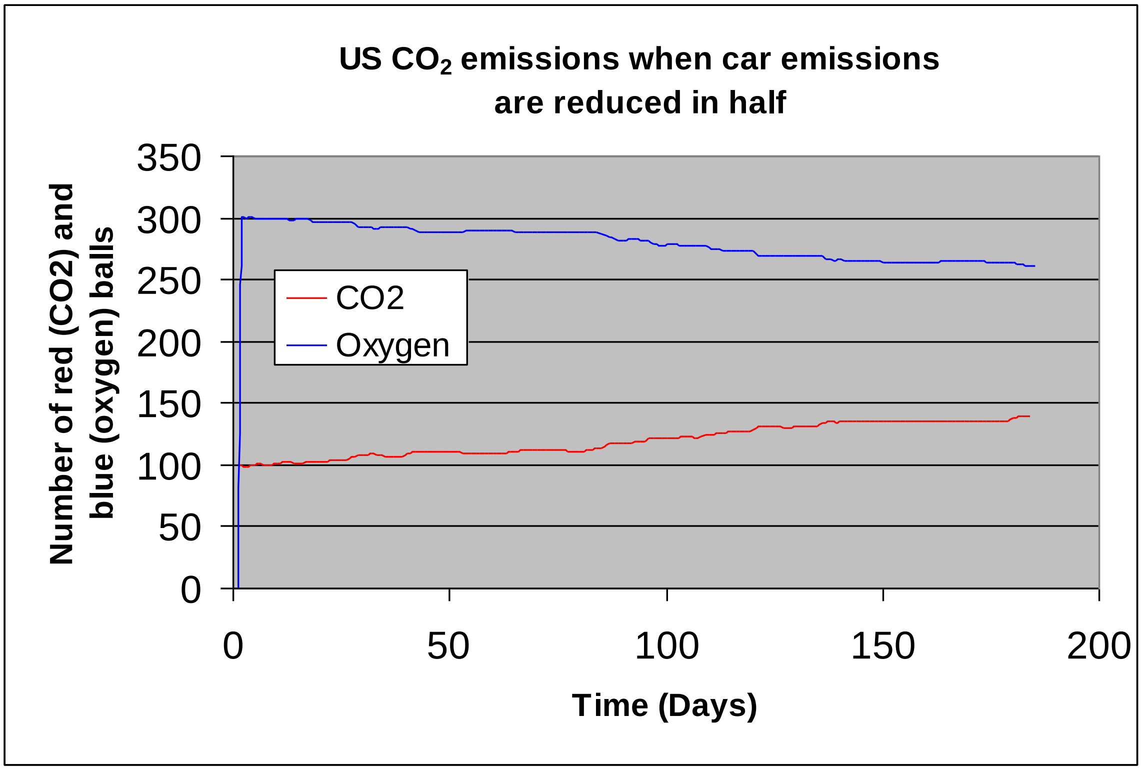

Figure 11: Combined model for the annual US CO_2 emissions by cars, houses and factories plus absorption by forests, plants, and oceans but with the car emissions cut in half: 43.4/300 = 14.5% of 25 bmt= 3.6 bmt net gain.

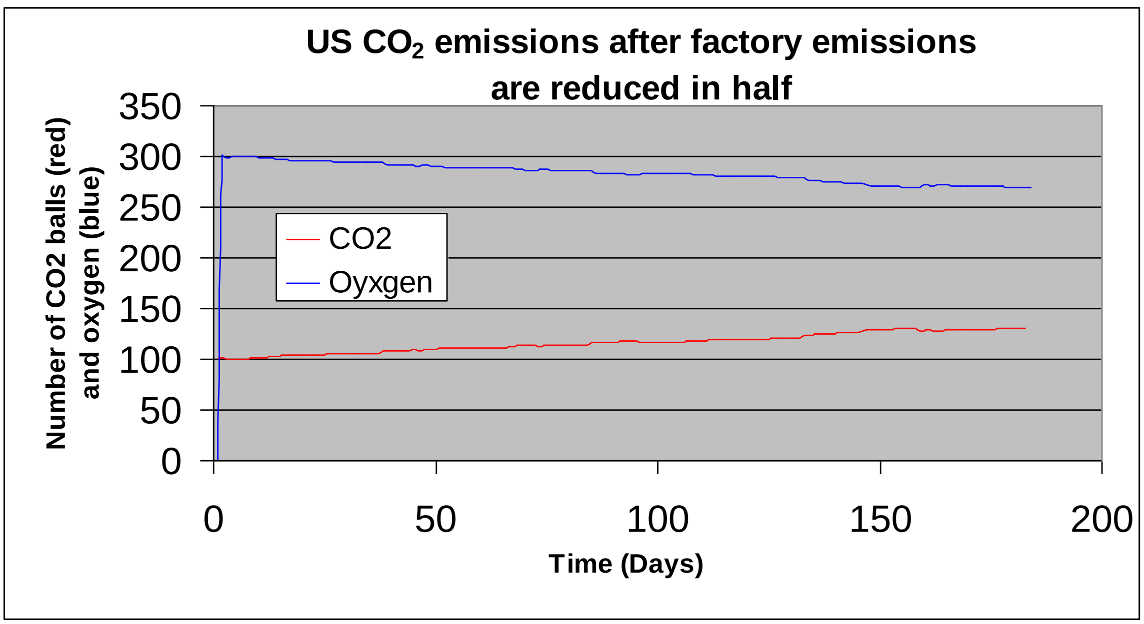

Figure 12: Combined model for the annual US CO_2 emissions by cars, houses and factories plus absorption by forests, plants, and oceans but with the factory emissions cut in half: 27.7/300 = 9.2% of 25 bmt = 2.3 bmt net gain.

Conclusions

We developed a Starlogo program which simulates the CO_2 emissions of the US relative to the worldwide emission rate of 25 bmt per year. The model includes the emissions from factories, houses, and cars plus the absorption of CO_2 by trees/plants and the ocean. The number of factories, houses and cars and the collision conversion rate were adjusted to give realistic annual CO_2 emissions. We also set the number of trees/plants and the ocean agents to give realistic annual CO_2 absorption rates. We then ran three simulations which changed the number of cars, the emission rate of the cars, and the emission rate of the factories. We found that when the number of cars is increased from 221 to 300 million the total US CO_2 emissions increased from 4.6 to 5.3 bmt. Our next simulation decreased the car emissions in half. We found that this decreased the total US CO_2 emissions from 4.6 to 3.6 bmt. In our final simulation, we decreased the factory emissions in half. From this simulation we found that the total US CO_2 emissions decreased from 4.6 to 2.3 bmt. We conclude that reducing emissions especially for factories will significantly decrease the total US CO_2 emissions.

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