SWEN90004 Assignment 2 Report

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Number of words: 1498

1. Background & Model

This project is to replicate a Netlogo model DaisyWorld in Java, perform experiments to verify the behaviour of the replicated model and to explore the relationship between living and nonliving parts in an ecosystem, and extend the model by adding soil quality as new attribute and find how different soil quality distribution can result in different system behaviour.

a. DaisyWorld

The chosen Netlogo model is the DaisyWorld [1]. The DaisyWorld is composed of daisies (living parts) and global temperature (nonliving parts). It explores how daisies and global temperature both alter each other in a single, self-regulating system, which simulates the Earth ecosystem in a simple fashion. Daisies has two types: black and white, which differs in albedo. Black daisies have a low albedo so they reflect less energy, thus heating the environment around them. White daisies have a high albedo so they reflect more energy, thus cooling the surrounding environment. The temperature of the neighbour environment also affects the probability of the daisy's reproduction success. All daisies can only reproduce within a range of temperature. A daisy dies when it reaches the maximum age. A patch diffuses part of its temperature to its 8 neighbour patches evenly.

Daisies and the environment interact with each other parallely by simple rules above with no controller. Each daisy only knows its local temperature and behaves accordingly. So no patch knows the global temperature. However, for a wide range of parameter setting, daisies can eventually stabilize the global temperature and the population of daisies, which shows a system property that the individual parts do not show. That is why this model being a complex system is of interest.

b. Java Implementation

A UML class diagram of the implementation in Figure 1 provides a static structure of the replicated model. Beside the concept classes mapped from the domain model, Util class is to provide some general methods such as diffuseTemperature and reproduce for logic separation and ease of testing, and Params class is used for the model parameter settings.

A summary of assumptions is listed below.

- The topology of the world is a torus which wraps in both x and y directions.
- Diffusion of patch value is synchronized across all patches in the grid.
- Reproduction of daisies is synchronized across all breeds in the grid.
- When two or more daisies choose the same patch as their seeding place, they go into a candidate list of that patch. After all daisies have chosen a place to reproduce, a daisy will be randomly chosen from the candidate list for each seeding place to reproduce in that place.

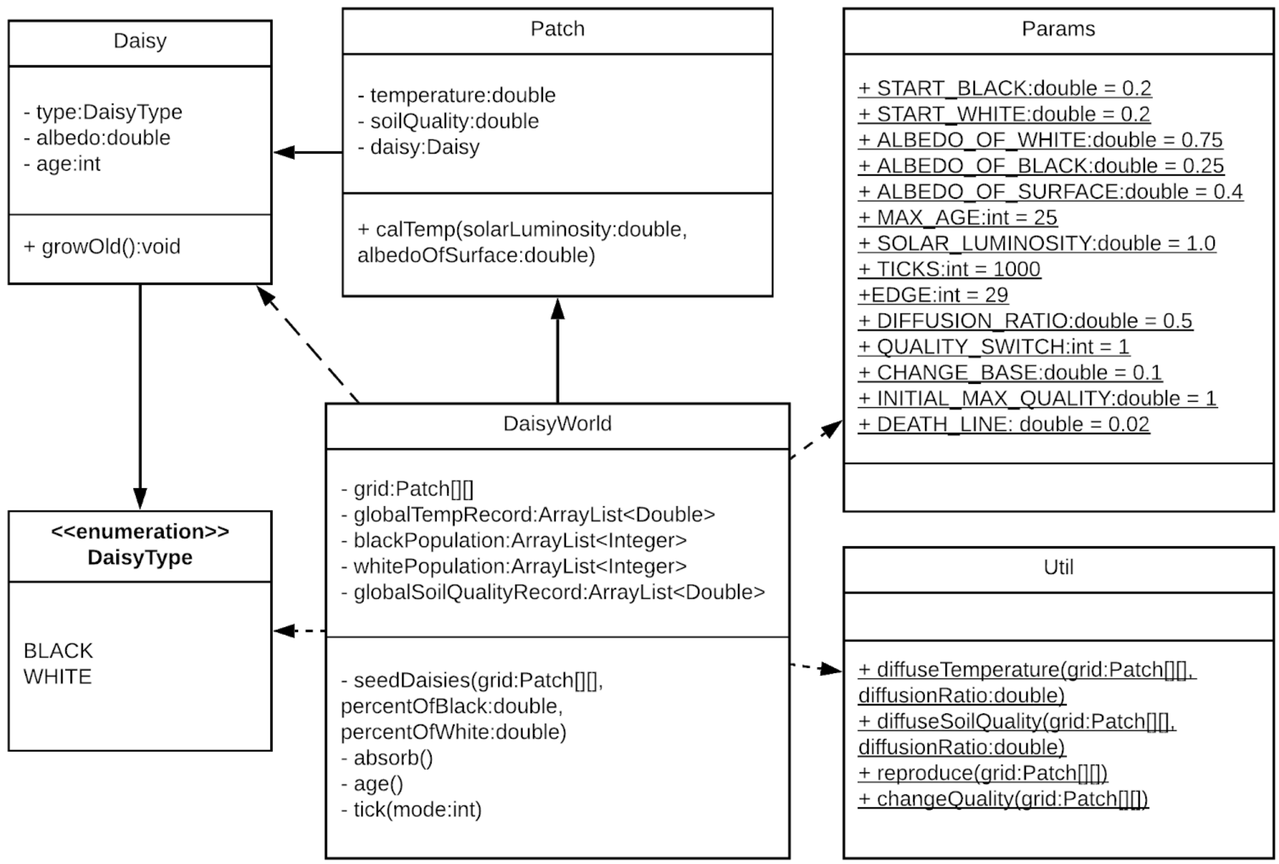

Figure 1: Class Diagram of Java Implementation

2. Replication & Extension

a. Replication

Experiment one:

By observing one of the rule functions used in this model, we found that solar luminosity is an important parameter to alter the global temperature. Thus, in this experiment, the solar luminosity was set to low, our, high respectively to investigate the effects of different solar luminosity on model behaviour by observing three measured output: global temperature, number of white daisies and black daisies.

Experiment two:

Another factor that would alter the temperature is daisies. In particular, each time step, every patch will calculate the temperature based on the energy absorbed by the daisy and the diffusion of 50% of the temperature value at that patch between its neighbors. We decided to tune the diffusion percent to zero to observe the effects on model. More specifically, three scenarios with 0% diffusion percent and low, our, high solar luminosity were implemented respectively with three measured output: global temperature, number of white daisies and black daisies.

b. Extension

A new attribute of patches called quality with range of 0 to 1 is introduced to the system with the switch to enable. Good soil quality will result in good fertility rate while bad quality will obviously decrease the chance of diffusion of daisies. In the worst case (i.e. quality is closed to 0) the land desertification will happen so that there will not be any plant on the land anymore and it cannot get recovered with help of this World, which is similar to the actual situation of the real World.

The quality of patch will change over time. Quality of patch with daisies will increase and quality of those bare ones will decrease. At the same time, the quality is also diffusible with the same rule as temperature. However, if land desertification happens in a patch it cannot get good quality diffuse from other patches to get better any more.

Linear model is applied to calculate the influence between daisies and patches. To calculate whether seeding is successful, an independent condition is added to the process, a random double type number should be smaller than quality to make the seeding successful. And for a healthy land, it has three key parameters, quality, non-perfect rate and calculate-base. Non-perfect rate is calculated as (1 – quality) and calculate-base can be set in Params class. When there is no plant on the land the quality will be decreased by product of non-perfect rate and calculate-base. In opposite, the quality will be increased by product of quality and calculate-base. The theory of design is the irreversibility of land desertification. The worse the land condition the easier it would become incurable.

3. Results & Discussion

a. Replication

For the figures of results, left figures are netLogo output and right figures are Java output. Due to the accurate implementation of each part in Netlogo, our Java model can recapture the same behaviours as original model.

Experiment one:

Three scenarios were implemented for this experiment. In the first scenario, the solar luminosity was set to low (0.6). The output plots are shown in the following:

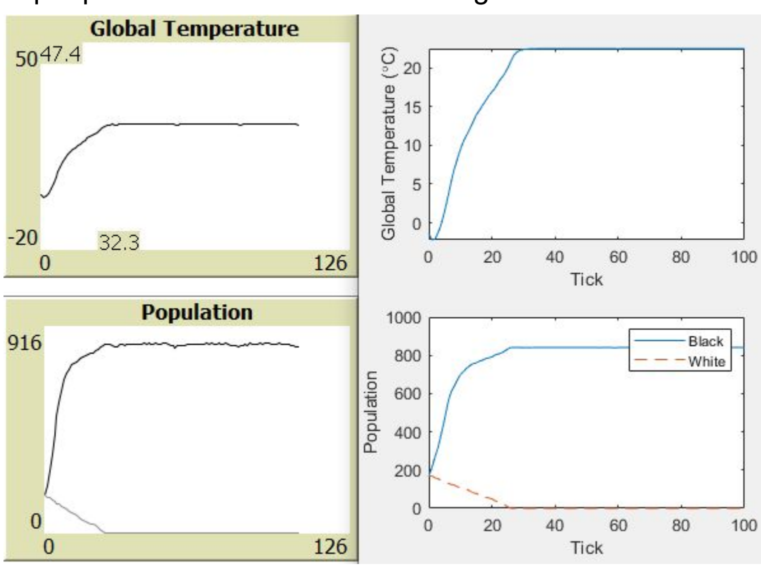

Figure 2: low luminosity output

In the second scenario, the solar luminosity was set to our (1.0). The output plots are shown in the following:

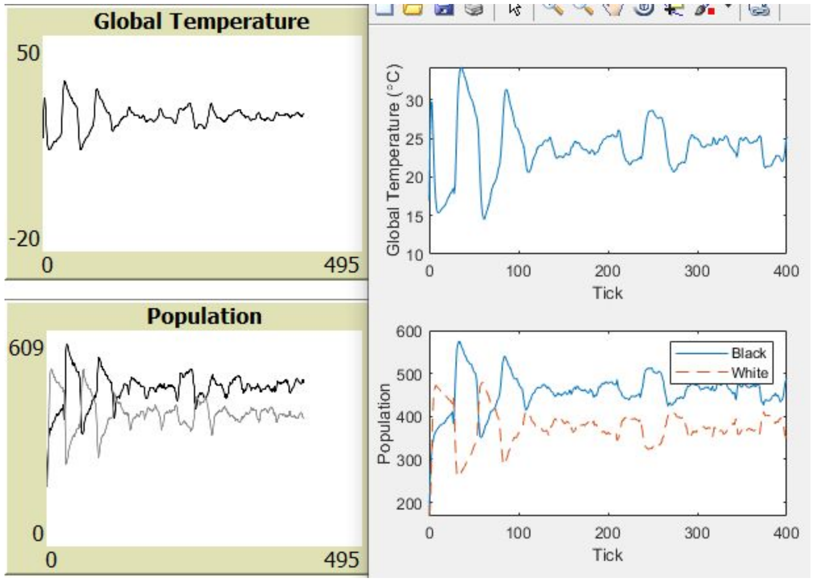

Figure 3: our luminosity output

In the third scenario, the solar luminosity was set to high (1.4). The output plots are shown in the following:

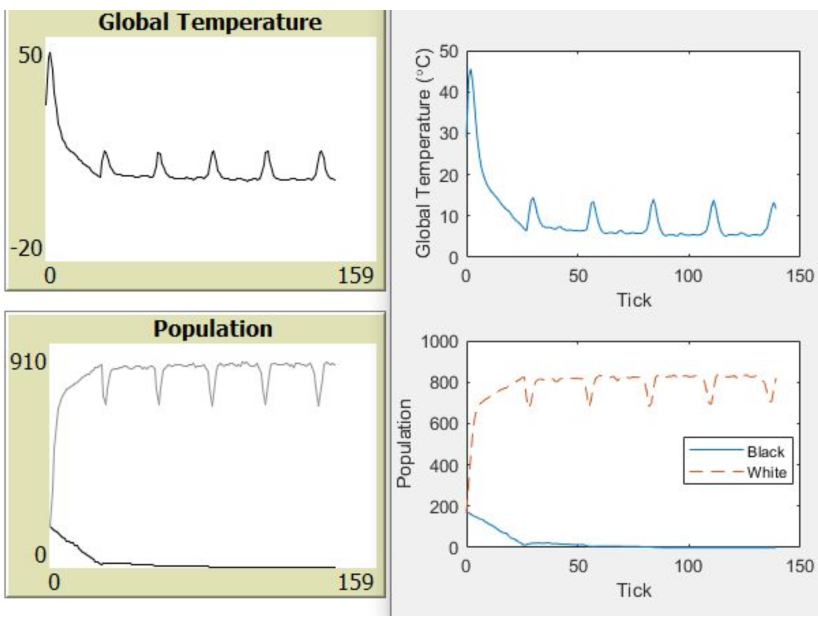

Figure 4: high luminosity output

To sum up, solar luminosity has great influence on the sprouting of different daisies. For example, from figure 2, we found that global temperature finally maintains about 22 and the black daisies fill almost every patch. The main reason is that low luminosity would cause low temperature. For survival, daisies with low albedo that could increase the temperature are significant. So finally, white daisies with high albedo gone die and black daisies lived to the end.

Experiment two:

The results of the three scenario with diffusion rate 0% are shown in the following:

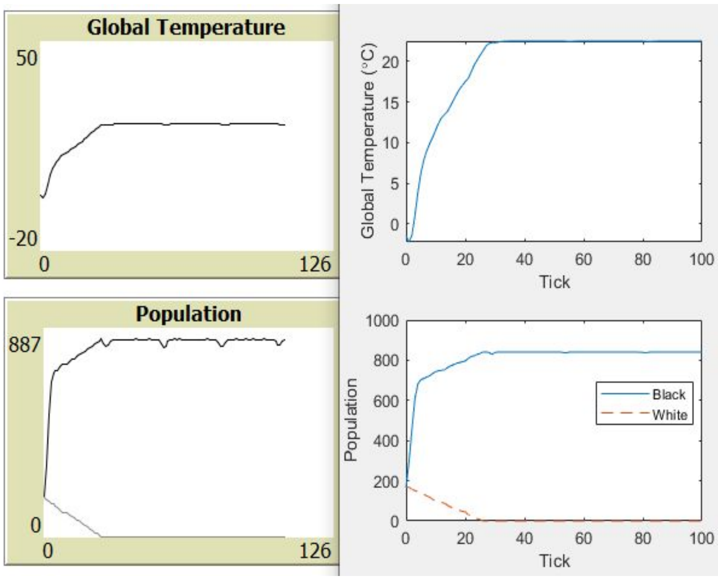

Figure 5: low luminosity output

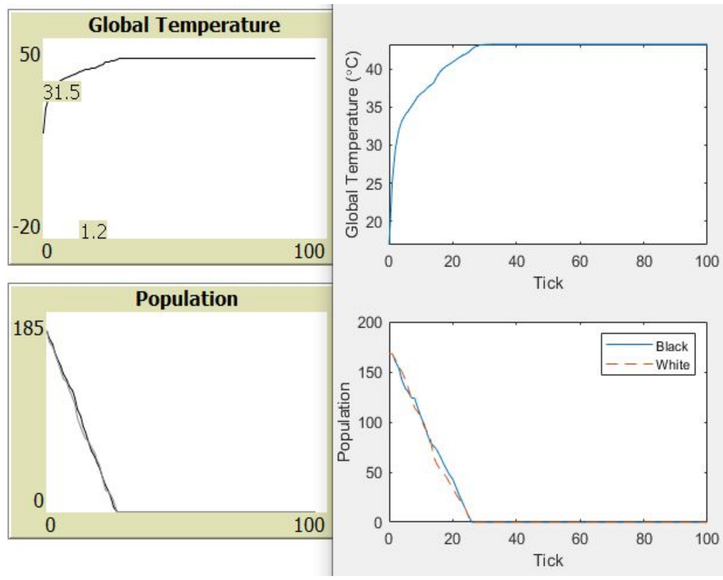

Figure 6: our luminosity output

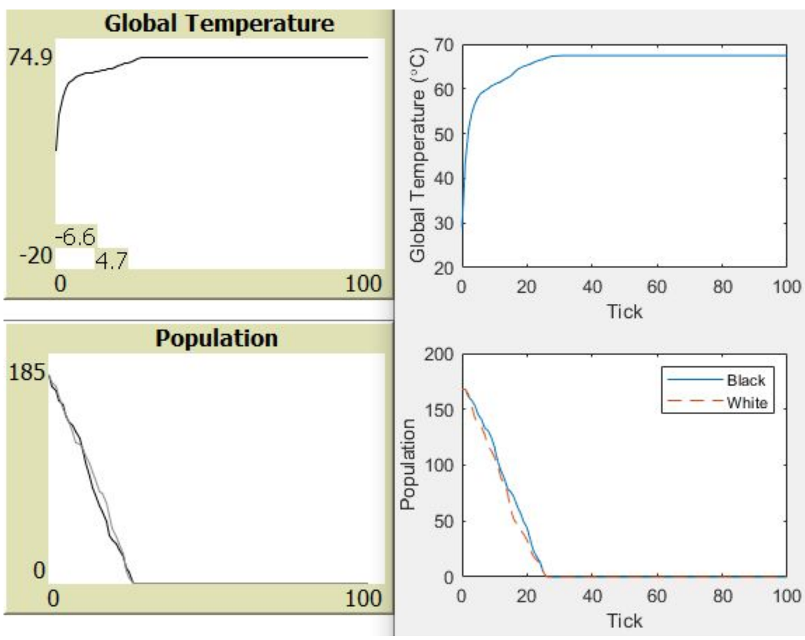

Figure 7: high luminosity output

From the results, it can be seen that all the daisies die in the our and high luminosity. The first reason is that, according to table 1, the default temperature in our and high luminosity are 43 and 76 respectively [1], both will cause a 0% sprouting rate. Secondly, diffusion rate can help patches to average their temperature and achieve a better environment for daisies to sprout. Set the diffusion rate to zero would decrease the ability of tune hostile temperature. In addition, due to the default temperature is 7, which would not cause a 0% sprouting rate, black daisies survives to tune the temperature.

b. Extension

The question should be answered is how many plants could save the environment. To solve the question, two series of experiments was taken with control variable method. Only three parameters have been changed to do the experiment: initial number of different daisies and ticks. The ticks number is set to be 1000 to achieve a stable result and the initial number of each daisy is set to be .1 and .2, which means plant coverage is 20% or 40%.

For the first series of experiment with plant coverage of 20%, the typical final map as Figure 8 indicates severe desertification of the World. The good news is that for half of the 10 experiments, there would be oasis in the desert gives people hope. The final average quality varies in 10 experiments as shown in Figure 8.

```
  43|  43|  43|  43|  43|  43|  43|  43|● 45|● 37|o  3|o  2|o 10|  41|  45|  44|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  42|  43|  44|● 47|● 34|o  7|● 34|● 48|● 51|  45|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  42|  38|  35|● 42|● 43|● 39|o 12|● 35|● 45|● 44|  41|  39|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  38|  30|o 10|o 12|● 35|o  8|● 25|o  4|o 10|● 30|o 14|  34|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  39|o 15|o 12|● 31|o  6|o -0|o -2|o  3|o  3|● -1|o  4|  30|  41|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  41|● 43|● 45|● 36|o  9|o  1|o  3|● 29|● 29|o  7|o  5|  29|  37|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  45|● 52|● 54|● 41|o 13|● 27|● 30|o 12|● 39|● 38|● 28|o  8|  34|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  41|● 48|● 45|● 37|o 14|● 36|o 17|o 17|● 39|● 42|o  7|o  9|  30|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  40|o 19|● 34|o  9|o 14|● 41|● 40|● 39|● 38|o 15|● 29|o  9|  34|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  39|  34|o  5|o  2|● 30|● 39|● 39|o 15|● 32|● 32|o  2|● 31|  34|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  42|  37|  29|o  4|o  6|● 30|o  3|o  2|● 27|●  4|o  5|o  8|  38|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  42|  37|  25|o  5|o  3|o  3|o -1|o -2|● 24|o  4|  29|  38|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  42|  34|o 12|● 32|● 28|o  2|  15|o  9|  33|  37|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  39|  39|  39|  35|o 14|  27|  35|  38|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
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  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
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  43|  43|  43|  43|  43|  43|  43|  43|  43|  42|  42|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  39|  34|  30|  34|  38|  42|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  40|o 14|o  5|o  4|  30|  38|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|
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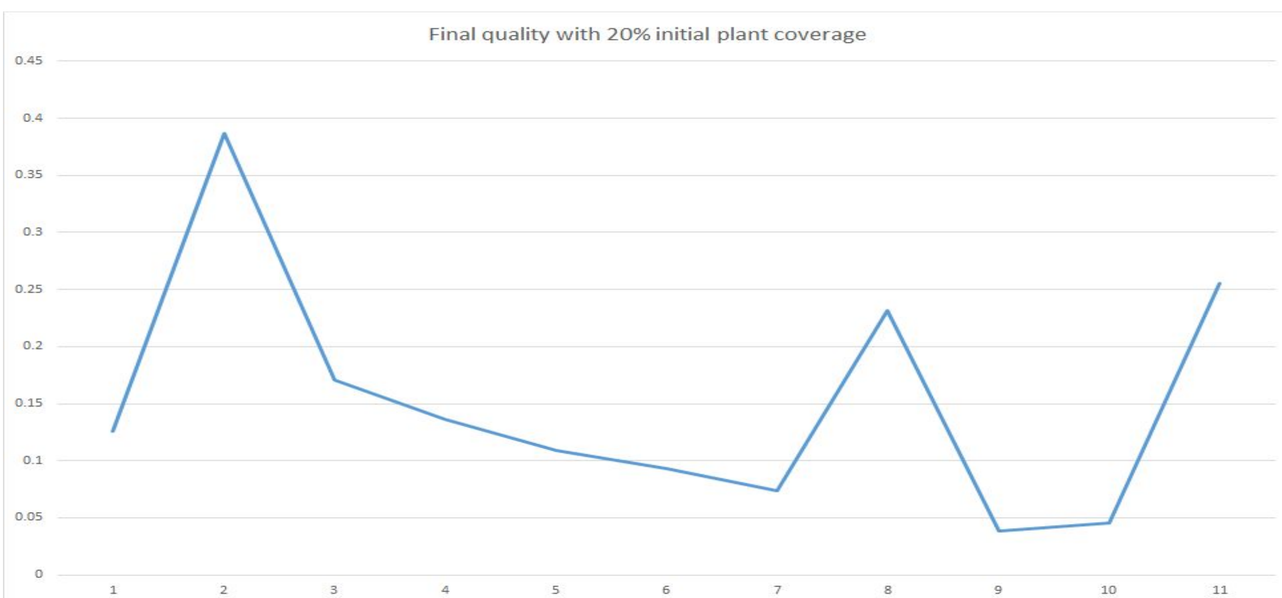

Figure 8 Final distribution and average quality with 20% coverage

For the second series of experiment with plant coverage of 40%, the typical final map is attached as Figure 9. As is shown in the map, most of the land is occupied and limited area has been destroyed, which indicates with help of other ecosystem livers the system would be fine. After 10 experiments, the final quality concussion is smaller than previous series of experiment and the quality is much higher as is shown in Figure 9.

```
  42|  43|  43|  43|  43|  43|  43|  35|o  9|o  5|  26|  30|  29|  29|  27|o 11|o 12|● 38|● 28|o -4|o -4|● 32|● 38|o 14|● 35|● 38|  39|  38|  42|
  43|  43|  43|  43|  43|  43|  43|  38|  34|  34|  37|  40|  40|  37|● 35|o 13|● 40|● 43|o 33|o  1|o  6|● 38|● 37|o  8|o 17|  37|  42|  41|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  42|  42|  41|  37|  33|  27|o 11|● 41|● 50|● 49|o 12|o  4|● 30|● 35|o 10|o 15|o  6|● 37|  38|  42|  43|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  42|  41|  32|o 10|o  2|o 12|● 42|● 54|● 49|● 34|o  4|o  9|● 30|o  5|● -1|o  3|● 35|● 45|  43|  44|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  42|  37|  23|o -2|● 16|o  9|o 32|● 40|● 44|● 39|o 13|o  9|o  8|● 25|o  2|● 23|o 14|● 39|● 46|  40|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  43|  39|o  8|o -1|o -3|●  1|o  2|o  2|o 11|● 38|● 38|● 34|● 34|o 12|o 15|● 24|o 10|● 35|o 24|  41|
  43|  43|  43|  43|  43|  43|  43|  43|  43|  44|● 46|● 37|o  2|o -4|● 14|o -8|o -8|o  5|● 37|o 42|o 20|● 42|● 44|● 34|o  2|o  1|● 29|● 41|  40|
  43|  43|  43|  43|  42|  42|  42|  42|  43|  44|● 49|● 41|o 33|o  6|o  2|o  1|o  1|● 33|● 39|o 14|  32|o 41|● 44|● 34|o -3|o -4|o  9|  39|  43|
  43|  44|  44|  40|  35|  30|  30|  34|  38|● 46|● 42|● 40|o 16|● 35|● 30|o  8|● 34|● 41|o 20|● 38|o 19|o 18|● 39|o 16|o  6|o  4|  29|  38|  43|
  44|  44|● 45|● 41|o 13|o  8|o  8|o  9|● 35|● 29|● 34|● 32|o 16|● 40|● 40|o 14|● 39|● 38|o 25|● 35|● 32|o  7|● 28|● 35|● 33|  34|  38|  42|  43|
  40|● 42|● 34|o 11|● 28|● 27|o  1|● 28|o  9|o 14|o 14|o 11|● 34|● 35|o 15|● 36|o 18|● 39|o 20|o 33|o  8|o  0|o  9|o 16|  39|  42|  42|  42|  43|
● 37|o 11|o  7|o 10|● 33|o 11|● 25|o  2|● 30|● 35|● 35|● 34|o  7|o  8|● 31|o 14|● 42|● 40|o 21|● 36|o 11|o  4|o  4|● 30|  32|  39|  40|  35|  31|
o  6|● 29|o  8|● 38|● 39|● 33|o  3|o  6|o 13|● 47|● 42|o 15|● 25|o  3|o  0|● 32|● 40|o 28|● 43|● 38|● 37|● 33|● 34|o  7|o 11|● 37|● 41|o 15|o 10|
● 23|o  9|● 40|● 49|● 51|● 40|● 32|o 10|o 38|● 43|● 32|o  5|● 25|o  9|o  7|o 13|o 21|● 49|● 42|o 17|● 34|● 43|o 21|● 35|o 12|o 13|● 39|● 31|o  6|
o 12|o 15|● 41|● 51|● 55|● 48|o 40|● 36|● 45|● 42|o  5|o -5|o  2|● 36|● 39|o 23|● 44|o 46|● 35|o  8|● 25|● 35|● 39|● 40|● 40|● 36|o 17|● 36|o 16|
o 39|● 43|o 20|● 47|● 51|● 50|o 23|  41|● 49|● 38|o  0|o-10|o  5|● 43|● 51|  47|● 47|● 40|o  7|o  8|● 34|o 12|o 11|● 39|● 43|o 17|● 40|● 37|o 21|
o 46|● 51|● 47|o 20|● 46|● 41|● 38|  34|● 42|● 33|o -2|● -3|● 30|● 43|● 48|● 44|● 39|o  7|o  2|● 28|● 32|● 31|o  6|o  7|● 34|● 35|o 13|● 37|● 45|
● 50|● 56|● 52|● 47|o 22|● 38|o 10|o 11|● 38|o 11|o  3|● 23|● 37|● 37|o 12|● 30|o  7|o  5|● 27|o  5|o  7|● 34|● 29|o  2|o  7|● 34|o 12|o  9|● 40|
● 42|● 53|● 56|● 47|● 43|● 27|o  5|o  7|● 39|● 34|o  9|● 34|● 39|o 11|o  6|o  2|o  5|● 31|  26|o  5|o  1|o 14|● 26|o -0|o  5|● 33|● 31|o  0|o  5|
o 11|● 48|● 56|● 46|o 16|● 27|o  9|● 38|● 43|● 39|o 12|● 38|● 38|o 12|● 24|● 23|o  8|  33|  33|o 13|● 31|o 14|o  9|o  9|o 19|● 42|o 14|o -1|o -5|
o  8|● 47|● 56|● 46|● 16|o  7|● 37|● 43|● 44|o 17|● 35|o 16|● 38|● 33|o  5|o  4|  30|  37|  37|  35|● 33|● 34|● 35|● 37|● 38|● 38|● 31|o -2|o -6|
● 34|● 49|● 55|● 46|● 40|● 31|o 16|● 39|● 38|o 16|● 34|● 33|o  6|● 22|o -0|o  3|  33|  41|  41|  34|o  9|o  6|● 33|● 38|o 17|o 17|● 34|o  2|o  2|
● 35|● 49|● 46|o 45|o 22|● 40|o 17|● 28|o  6|● 33|● 33|o  5|o -5|o -6|o  2|  28|  37|  42|  42|o 34|o  4|o -3|o  2|o 11|● 35|● 35|o 13|● 30|o 11|
● 32|o 18|● 40|o 14|● 39|● 35|● 33|o -2|● -3|o  6|● 29|o  0|o-14|o -7|  23|  36|  41|  39|  38|  35|  31|o  6|o  2|● 29|● 34|o 17|● 44|● 37|o 14|
o 10|● 31|o 12|● 31|o 12|● 29|o  6|o  2|o  2|o 12|● 34|o  5|o -9|o -6|  24|  37|  42|  37|o 20|  39|● 47|  43|● 34|o  7|o  8|● 35|● 40|● 38|o 16|
o 14|● 30|o 15|● 33|o 13|o  1|o  6|● 30|● 40|● 45|● 45|● 38|o  6|o  3|o 10|  33|  39|● 39|  35|● 46|● 53|  49|● 38|o  2|o  5|● 34|o 22|o 20|o 37|
● 35|o 12|● 41|  36|  34|  27|● 15|● 44|● 49|● 50|● 49|● 44|● 33|● 23|  26|  31|o 18|● 40|● 43|● 45|● 44|● 40|o 11|  19|o  1|● 30|● 40|o 41|● 36|
o 15|● 41|  40|  43|  42|  39|● 46|● 44|● 40|o 14|● 36|● 35|o  6|o  0|o  8|● 36|● 38|o 11|● 33|● 32|o  7|o  7|● 32|o  6|o  5|o  7|● 42|● 43|o 19|
  36|  40|  43|  43|  43|  44|  45|● 42|o  8|o  3|o  8|o 10|o  4|o -1|o  5|● 33|● 34|o 11|o  6|o  0|o -4|o  6|● 33|● 34|o  7|  29|o 19|  37|  36|
```

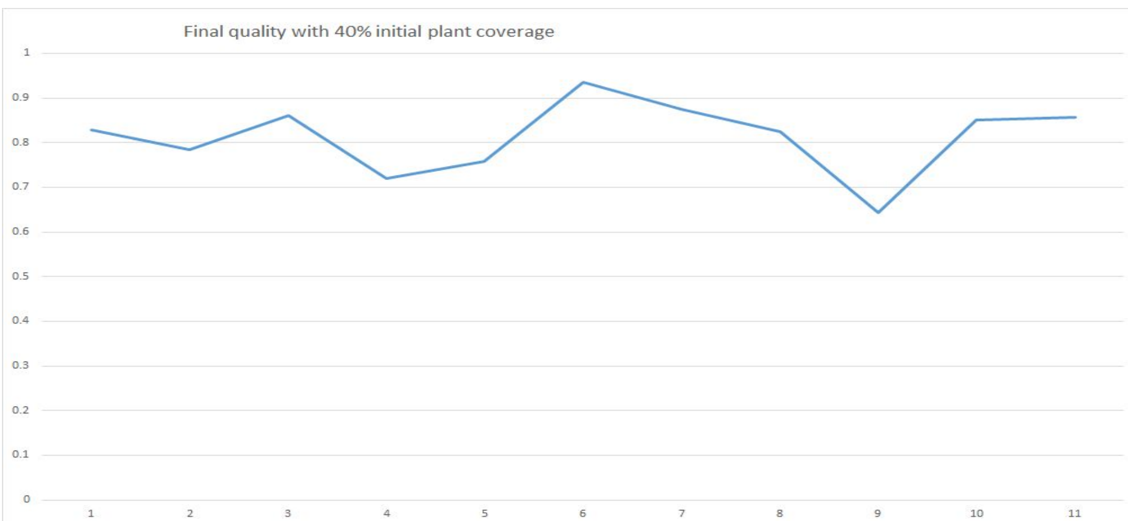

Figure 9 Final distribution and average quality with 40% coverage

The reason of concussion is the random initial distribution of daisies. And it is concluded that with proper percentage of plants and reasonable position distribution, the environment can be saved.

Reference:

[1] Novak, M. and Wilensky, U. (2006). NetLogo Daisyworld model. http://ccl.northwestern.edu/netlogo/models/Daisyworld. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Appendix

These are the challenges our group worked out (successes):

During the implementation, our group has two main challenges which have been already solved. The first one is that, growing tendency of our simulation graph was always slower than graph produced by NetLogo. We went through all documents and experiments and finally found that only first generation has random age and all other daisies has maximum life. The reason why we trapped is that we were not familiar with the characteristic of plants.

The second one is that how to deal with multiple seeding to one patch. At the initial implementation one group member used 'coverage method' which means the daisy seeds later it succeed. However, after discussion we found it not responsible because during traverse the left-up side is always earlier operated than right-down side. Finally we create d candidate list of each empty patch and if multiple patch want to seed just random choose one to be successful. After these two improvement our result is same as NetLogo model.