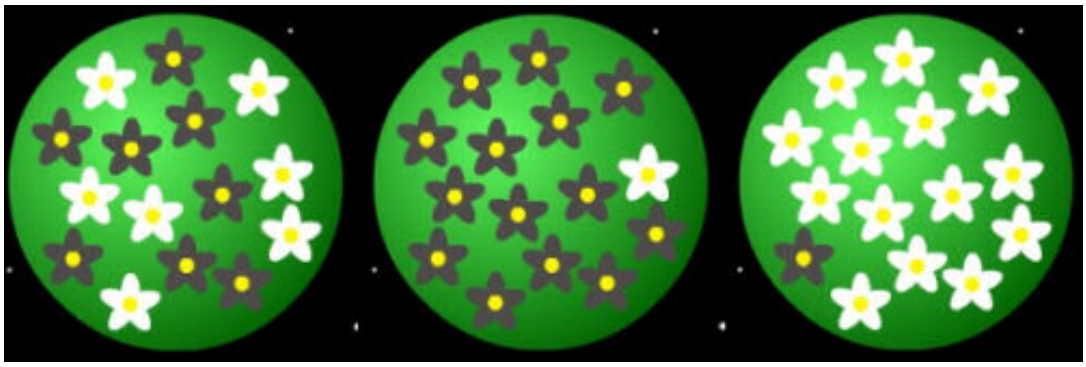
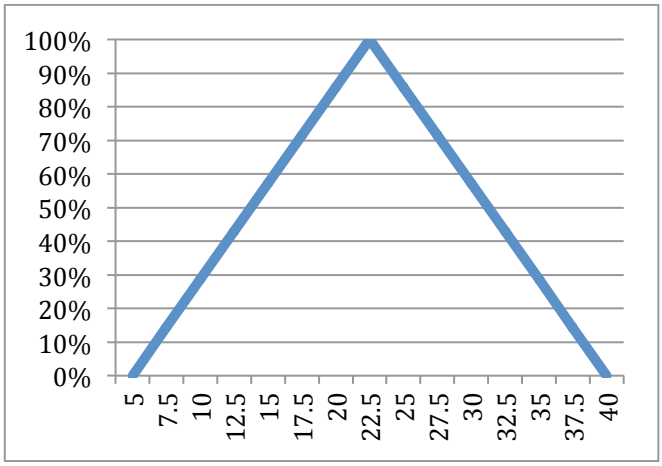
Environmental Modeling
Exercise II: Daisyworld



Daisyworld is a hypothetical planet proposed by James Lovelock and Andrew Watson to illustrate the Gaia hypothesis. This hypothesis states that living organisms interact with their inorganic surroundings, creating a self-regulating system that can maintain the conditions for life on the planet.

The planet surface is comprised of white daisies, black daisies, and bare ground. White daisies grow best in a warm climate but reflect light and make the planet colder. On the other side, black daisies prefer a cold climate but absorb light and consequently make the planet warmer. These feedbacks objective to keep the temperature constant even when the solar energy changes.

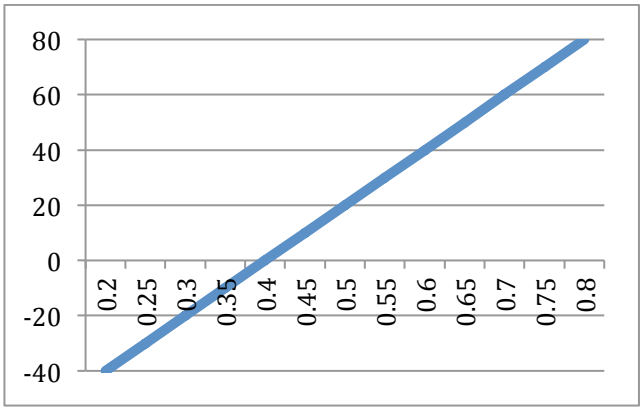
In the beginning of year 2000, Daisyworld has 400ha of white daisy area, 270ha of black daisy area, and 330ha of empty area. Flowers have a constant rate of decay of 30%/yr. Their growth rate is 100%/yr when the world temperature is 22.5°C. If the temperature is higher or lower, the growth rates decay linearly until zero when the temperature is 40°C or 5°C, as shown in the figure below[1]:



[1] The two figures presented in this document can be reproduced using the script available in the course webpage.

The growth rates are related to the bare ground area. For example, if 30% of the bare ground is available, flowers growth would be 30% of the values shown in the figure above.

The planet average temperature is calculated from the proportions of each type of daisy, according to the albedos for white daisies (0.75), black daisies (0.25), and bare ground (0.5). The planet albedo in 2000 is then 0.525 (0.75 * 0.4 + 0.5 * 0.33 + 0.25 * 0.27). Given a solar luminosity of 1.0, the planet will reflect 0.525 of the solar luminosity, absorbing 46.75% of its luminosity. The planet average temperature is a linear function of the absorbed luminosity, according to the figure below:



However, the average temperature of the planet does not define the growth rate of the daisies because there are *local* temperatures. The area covered by black daisies has temperature equals to the average temperature *plus* 20 times the difference between the world average albedo and black albedo (0.25). On the other hand, the area covered by white daisies has temperature equals to the average temperature *minus* 20 times the difference between white albedo (0.75) and the average albedo.

Implement the Daisyworld model and investigate the stable state of the system in four different scenarios.

1) If luminosity stays constant at 1.0.
2) If a heat shock occurs: Luminosity jumps to 1.10 in 2010.
3) If a cold shock occurs: Luminosity drops to 0.95 in 2010.
4) If several heat shocks occur: Luminosity grows 4% each ten years from 2010 until 2040.

The delivery should contain the source code to solve each of the above scenarios and a small report with the stable temperatures, the amount of each type of daisy, and a discussion about why the simulations reached such states.