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Replication Report

Summary of Methodology

Daisyworld is an artificial life dynamical system simulation created by Watson and Lovelock (1983) intended to understand climate feedbacks and stabilization. The researchers simulate a simple artificial ecology. *Daisyworld* is populated by two kinds of daisies, black ones and white ones. Each has a growth function that is maximum at a temperate temperature. Black daisies raise the global temperature by absorbing more sunlight, and white daisies, conversely, lower it. The researchers simulated the response of the daisies to changing solar luminosities to investigate how the daisies would stabilize the temperature of the planet.

Summary of Results (Original Paper)

The original Daisyworld paper presents the relationship between luminosity, temperature, and the proportion of flowers within Daisyworld. The original paper presents these results for four different experiments: only neutral daisies, only black daisies, only white daisies, and a mixture of white and black daisies. Given the varied albedos of each daisy, their proportions within Daisyworld follow predictable patterns.

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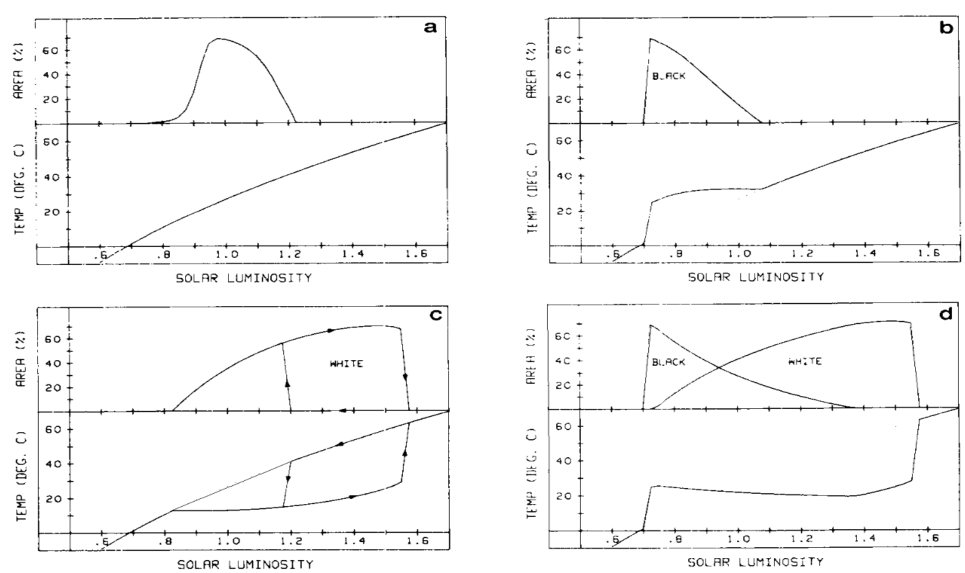


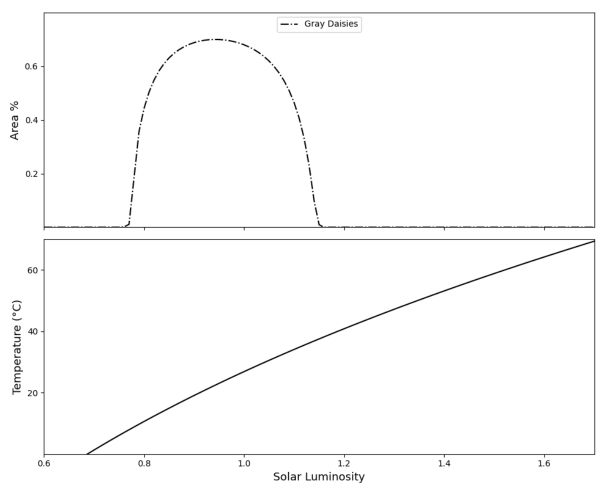
Fig. 1. Steady state responses of daisyworld. Areas of black and white daisies and effective temperature are plotted against increasing values of the luminosity parameter *L*. Dotted lines indicate the temperature of the planet without life. Fixed parameters used in generating these curves were: γ in eq. (1), 0.3; *P* in eq. (2), 1.0; *S* in eq. (4), 9.17×10^5 ergs cm^{-2} s^{-1}; albedo of bare ground, 0.5; q' in eq. (7), 20. (a) For a population of "neutral" daisies, albedo 0.5 (dotted and solid temperature curves are coincident). (b) For a population only of black daisies, albedo 0.25. (c) For a population only of white daisies, albedo = 0.75. This figure also shows that the effect of decreasing luminosity. Note that the system exhibits hysteresis. (d) For a population of both black and white daisies, albedos 0.75, 0.25.

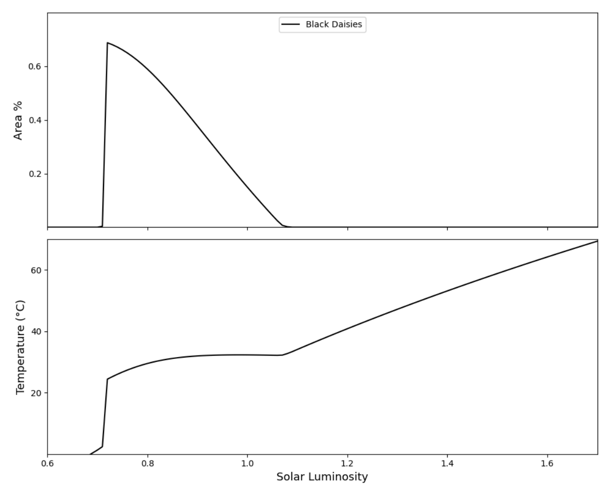
Reimplementation Description

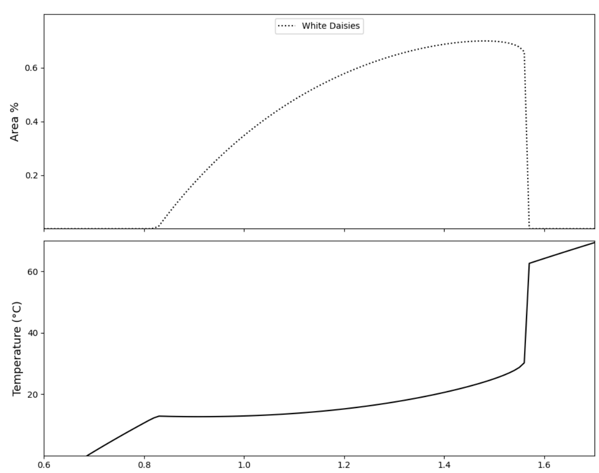
The *Daisyworld* paper provided the dynamical system equations, which we straightforwardly implemented in code. The world tracks only two variables, the populations of black and white daisies, rather than being an agent-based simulation. Each time step, the simulation calculates the temperature of the planet using simplified thermodynamic laws, then allows both types of daisies to grow based on their populations and temperature. We investigate the behavior of the system at multiple solar luminosities, like Watson & Lovelock (1983), by letting the system come to a steady state and then incrementing or decrementing the solar luminosity by a tiny amount. We did not make any changes to the original implementation, thanks to its simplicity and the thoroughness of the paper.

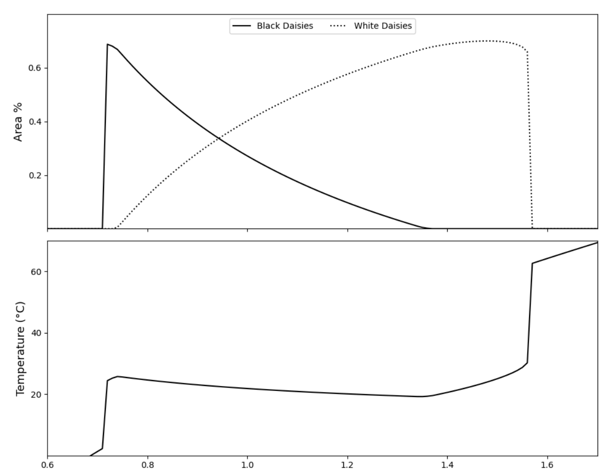
Replication Results

We have successfully replicated the original results of *Daisyworld*! Our first results, comparing only gray daisies, only black daisies, only white daisies, and white and black daisies, are below. Given the time steps within our graph, there are some slight adjustments from the original paper.

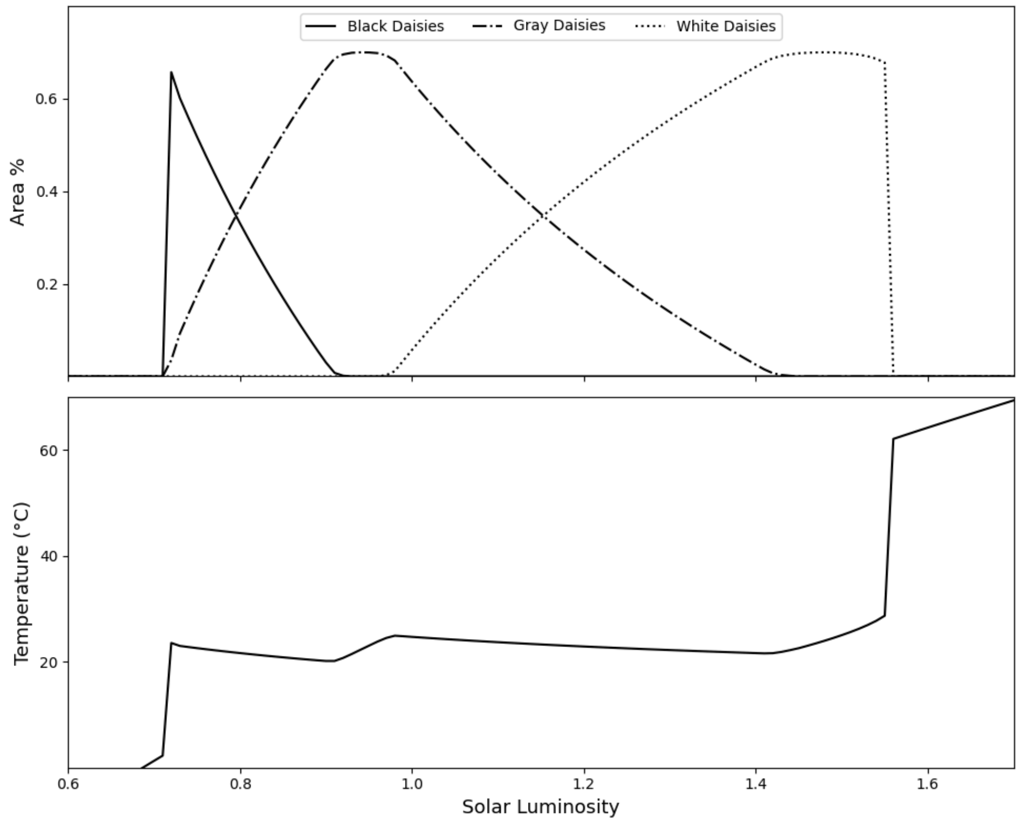








Along with replicating the original results, we've been able to move forward with one of our extensions: the introduction of a gray, or neutral daisy. While the original Daisyworld paper introduces the concept of a neutral daisy, they do not simulate its coexistence with the other flowers.



Like the original simulation where there are both white and black daisies, when there are white, black, and gray daisies, the temperature of the planet stays very stable for a wide (almost identical) range of temperatures. However, at higher solar luminosities, the temperature of this test exceeds the temperature on the white and black test, and conversely for lower solar luminosities. We interpreted this as gray daisies taking up the space that would otherwise be occupied by white daisies, lowering the white daisies' ability to effectively cool the planet.

Limitations and Road Bumps

We have successfully implemented all of the main tests from the Daisyworld paper and achieved the same quantitative and qualitative results. One limitation in our approach is that for the first test, when the world contains only gray daisies, our graph of gray population versus luminosity is a different shape as that in Watson and Lovelock (1983). This is because we let the simulation run for longer at each luminosity value in order to come to a steady state before increasing the luminosity. When the simulation is run for less time, as it was in Watson and Lovelock (1983), the gray daisies have more memory of their population from previous luminosity values, leading to lag. This was confirmed qualitatively by adjusting the parameters in our simulation.

Works Cited

WATSON, A.J. and LOVELOCK, J.E. (1983), Biological homeostasis of the global environment: the parable of Daisyworld. Tellus B, 35B: 284-289. doi.org/10.1111/j.1600-0889.1983.tb00031.x