TJHSST Senior Research Project

Modeling the Tragedy of the Commons Using Agent-Based Modeling

2008-2009

Josh Lee

October 30th, 2008

Abstract

The Tragedy of the Commons is a social scenario wherein a community of individuals acting selfishly will ultimately lead to the downfall of the community as a whole. My project models the tragedy of the commons using agent-based modeling. By modifying the environment - for example, by modifying the way populations behave, or by instituting some other influence in the environment which would alter the behavior of my populations - I hope to make the environment both prosperous and stable.

Keywords: tragedy of the commons, agent-based modeling

1 Introduction

1.1 Rational

The Tragedy of the Commons is a problem which is highly pertinent to the world at large today. Any environment facing a limitation on its growth must either deal with the tragedy or submit to its consequences. For example, one way our nation deals with pollution is by putting garbage in designated areas. However, those areas are a finite resource. When individual groups each contribute to the issue of pollution, it mounts into an exponentially larger issue. Finding a practical solution to this problem would help deal with many similar situations worldwide.

1.2 Purpose and Goal

My program is a basic representation of the tragedy of the commons. It consists of grass, cattle, and people. Grass grow at random throughout the model with each time step. Existing cattle move at random, eating any grass they find and gaining energy from it, and giving birth whenever they meet the energy requirement to do so. People behave similarly to cattle, moving, eating cattle, and reproducing. Following these populations on a graph reveals certain trends - namely, that grass, cattle, and people population vary directly with one another. Growing grass populations results in decreasing cattle populations, which results in growing people populations. These trends vary with one another infinitely, either without change or until a population goes extinct.

The environment may be modified in terms of these variables: grass growth rate, amount of energy eating a section of grass provides, and amount of energy eating a cow provides. Increasing these variables tends to increase the magnitude of the population oscillations. A wide enough oscillation swing may cause a population to go extinct. The purpose of my project is to find and implement a solution which will stabilize the population. Though my program models a specific instance of the tragedy of the commons, my model will actually be general enough so that a solution pertinent to my model should be applicable to other scenarios as well.

The tragedy of the commons fits into the larger world of experimental economics. In the past, economic theories have assumed humans will adhere strictly to those choices which would ultimately benefit them the most. Experimental economics questions this attitude and reevaluates, taking into consideration the impact of non-rational factors such as greed and altruism. My program's aim is to look at a basic, widespread real-life situation and find a solution to its relevant issues. Increasing the complexity and realism of my model will reveal more about the behavior and thinking of humans in similar situations.

2 Background

2.1 Similar Projects

The article "Understanding the Tragedy of the Sahel" provides the foundation for the work I am doing. The work described in that article pioneered the concept of modeling the tragedy of the commons through agent-based modeling. My project aims to duplicate that project as a foundation and then build upon it.

"The Tragedy of the Commons" describes certain thinking about the tragedy of the commons and the approach that must be taken in seeking to solve it. The article examined the tragedy as a basic, general issue, and then examined very specific real-world examples of it.

2.2 Relevant Theory

1. "Understanding the Tragedy of the Sahel," Corey L. Lofdahl

The Sahel is an arid region in Africa. During the 1980's, its inhabitants (people and animals) suffered from drought, desertification, and famine. Lack of rain in this region limits the availability of factors such as forage area for animals and the quality of the soil. The limited nature of these factors and the fact that all depend on them to survive are both characteristic of the tragedy of the Commons.

This experiment attempted to examine the Tragedy of the Sahel using systems dynamics. The goal was to examine the issue using a more comprehensive and realistic method than had been used in the past, and hopefully to illuminate the root problems in the system and potential solutions. The initial model took into account three different types of "agents" - people, cattle, and grass. Cattle would eat grass to sustain themselves, and people ate cattle to sustain themselves. This scenario essentially regulated itself - for example, high populations of human or cattle caused grass levels to fall, which would cause famine, thus "correct" the population.

To curb the cruel nature of this self-correcting environment, outside influences introduced the Sahel to modern technology. This had the unintended affect of overpopulation the Sahel - limited amounts of grass could no longer have as a strong a stabilizing effect on cattle (and, thus, people) populations. Then, when a drought occurred, the now-higher population had, essentially, farther to fall. In other words, the populations still fluctuated as before, but with higher peaks and valleys.

This Sahel representation illustrates the complexity of the tragedy of the commons. With so many factors intertwined, something as apparently beneficial as technology ended up merely exacerbating the issues and destabilizing the environment.

2. "The Tragedy of the Commons," Garrett Hardin

The paper establishes the tragedy in basic, human-related terms: people undergo work to survive, and require energy to do this work. An *ideal* situation would be: the maximum amount of goods for the maximum amount of people. However, these two goals are at direct odds with one another. A perfectly efficient, non-wasteful human would do nothing for pleasure, doing only the work required to live and taking in no more energy than necessary. A society with the maximum number of people - ie one consisting only of these perfectly efficient individuals - will not meet the "maximum goods for each person" requirement. The ideal situation is in reality an impossibility.

Determining the optimum for a scenario involving the tragedy of the commons is complicated. Whatever this optimum is, though, it will not include the maximum population possible. The ideal society would grow until it reaches this optimum; then, no individual in the society would take a greater cut than necessary to sustain the society at the same population level (doing so would fulfill the prophecy of the tragedy of the commons). Obviously, this is a "moral" issue for societies to deal with, and not one which can be solved simply through the implementation of technology.

This moral self-limiting as a society might seem counter-intuitive. It certainly flies in the face of Adam Smith's concept of the "invisible hand". Adam Smith believed we should let the market go free, and that it would essentially guide, regulate, and optimize itself. The correct solution which this paper suggests depends of course on the specific scenario at hand, but ultimately it has to do with self-regulation.

3 Development

3.1 Overview

My program will be written using the software NetLogo. NetLogo is ideal for the type of project I am doing because it allows me to set up different types of agents (in my case, cattle and people) and prescribe different behavior for each type of agent. It then sets up a visual representation of the environment - a simple window - and allows my agents to behave within the environment as

I have coded them to.

NetLogo also allows for the easy graphing of various factors within the environment, including population counts. Thus, I can keep track of the population trends and ensure that they are as I expect them to be. What I expect is for the graphed population count lines to oscillate, rising and falling, regularly, in inverse proportion to one another.

The ultimate aim of my project is to modify the environment so that the population lines move to a point and then remain there over time, thereby indicating stability. Modifications to the environment might include direct modification of the behavior of the agents, or the introduction of specific types of technology to the environment such as water wells.

3.2 Research Theory

Grass - the foundation of the energy cycle within my environment - grow at random with each time step. They do this indefinitely. Cattle and people are created within the environment at its beginning, but thereafter, additional agents may be created only by reproduction. Cattle and people undergo the same procedure at each time step: move at random, consume if possible (if any energy-providing consumables are present), reproduce if possible (according to the amount of energy they require), and then die if they have failed to consume enough energy to sustain themselves. Additionally, moving and reproducing have a predetermined energy cost.

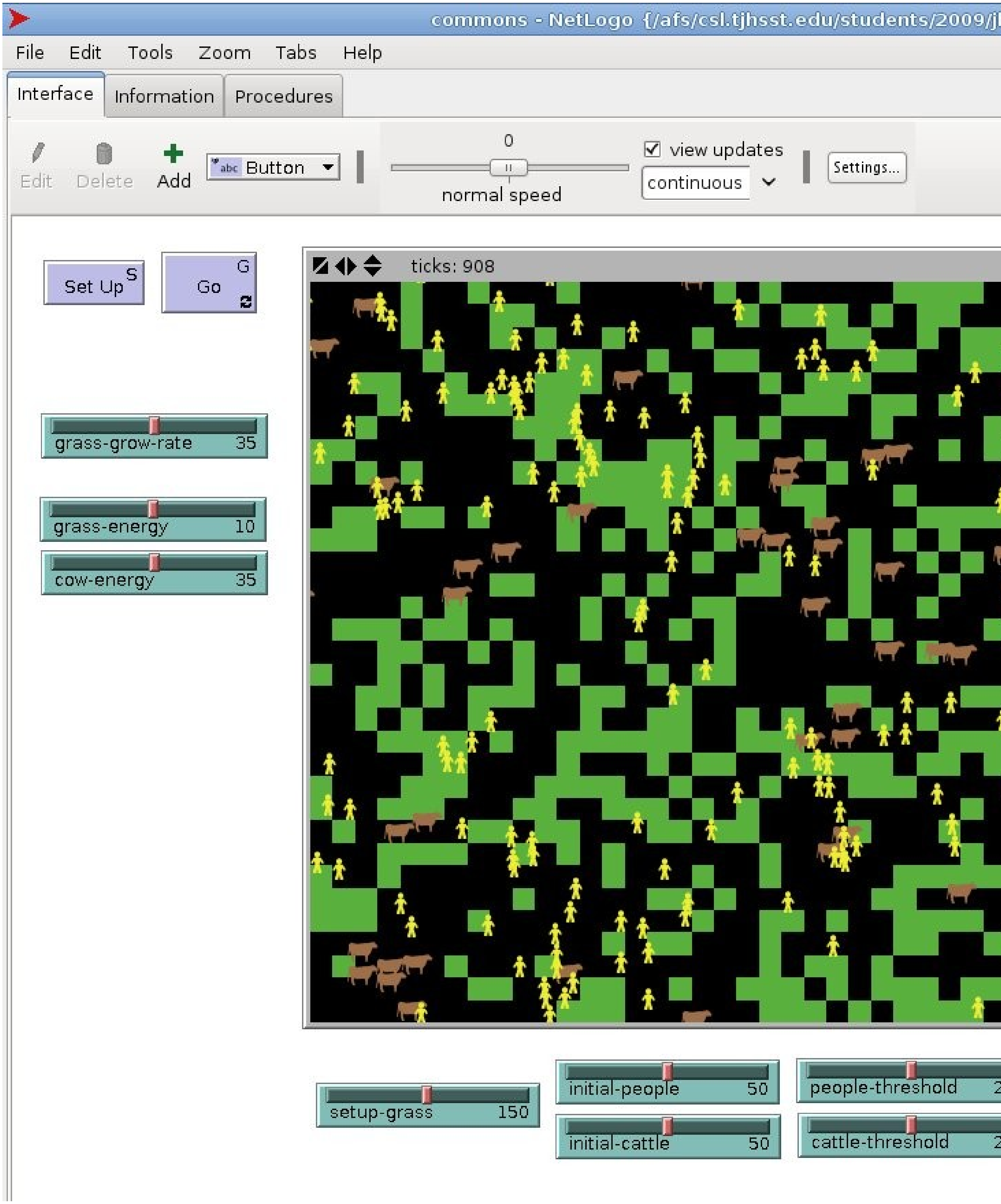
There are certain crucial factors which may be modified in real time as the model is running.

The most important ones are grass growth rate, the amount of energy the consumption of grass provides, the amount of energy the consumption of a cow provides. The survival and strength of the populations depends on the likelihood that any specific individual in the population will find enough energy to sustain himself. As an example, raising grass-growth-rates or grass-energy will essentially increase the amount of energy available to cows, which will cause cows to first decrease and then increase in population. Increasing the amount of energy available makes this effect more dramatic - the oscillations in population will be of a greater magnitude. Larger oscillations increases the likelihood that a population will go extinct. This happens when the population's death rate is so steep that the population can not recover before every unit dies out.

3.3 Testing and Analysis

If my program incorporates reasonably realistic behavior into my agents (cattle, people, grass) and then graph their populations, there are certain growth patterns I can expect to see. Namely, the populations should vary directly and inversely with one another. The environment may be tweaked to produce different effects. For example, setting grass to provide greater amounts of energy to the cows should result in greater population fluctuations over time.

3.4 Visual Recognition


commons - NetLogo {/afs/csl.tjhsst.edu/students/2009/j
File
Edit
Tools
Zoom
Tabs
Help
Interface
Information
Procedures
Edit
Delete
Add
Button
0
normal speed
view updates
continuous
Settings...
Set Up
Go
ticks: 908
grass-grow-rate 35
grass-energy 10
cow-energy 35
setup-grass 150
initial-people 50
initial-cattle 50
people-threshold
cattle-threshold

Example of the model and the typical patterns it exhibits over time.