The Tree Game:
The Shape of Change

The text of
Lesson 6: The Tree Game
From the books

The Shape of Change

and

The Shape of Change: Stocks and Flows

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The Shape of Change

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Introduction

Students explore what happens to the number of trees in a forest over time as a forester plants and harvests a certain number of trees each year. Playing the game, students experience resource management and the need for long term planning. The Tree Game complements science, social studies, economics and ecology units on renewable resources and sustainability. Math skills include computation, graphing from tables, and understanding the causes of patterns of change over time.[1]

How It Works

Students play a game that simulates the growing and harvesting of trees. The game is set up so that the company's stock of trees increases at a constant rate: the forester plants the same number of new trees each year. However, the trees are harvested at an increasing rate: the forester doubles his cutting rate each year. In addition to giving students an intuitive understanding of linear and exponential change, the game illustrates the difficulties of supplying a natural resource product in an environment with rapidly growing demand.

Materials

- Approximately 150 wooden craft sticks (Popsicle® sticks) for each team of students
- One container for each team to hold the sticks
- One copy of two worksheets for each student:
    1. *Forest Inventory Table* (page 8)
    2. *Forest Inventory Graph* (page 9)

Procedure

1. Ask each team of 3 or 4 students to count 120 sticks into their container. The remaining sticks should be put aside in a neat pile on the table.

> This is a **simulation**. Since we have neither the time nor the resources to experiment on a real forest, we use sticks to play out our forest management policies in class.

2. Explain to the class that the container of sticks represents a forest which will undergo some changes.
    - Each year trees will be added and removed according to a certain rules.
    - The sticks that are added represent new trees planted; the sticks that are removed represent trees that are cut down to provide lumber for housing, production of paper, etc.

3. Explain that each person on the team will have a job. Post the job descriptions on the board for quick reference.
    - The Forest Managers will plant new trees each year. (The manager starts with a small pile of sticks to add in.)
    - Lumberjacks will cut trees down each year. (They will remove sticks.)
    - Record Keepers will keep track of the inventory data in a table.

4. Explain the rules of the game to students.

Rules of the Tree Game

1. You start with a forest of 120 trees.
2. Each year plant 4 new trees.
3. The first year, cut 1 tree. This represents the wood that is used for building houses, making paper etc.
4. The second year, cut 2 trees; the third year, cut 4 trees, and so on. In other words, the number of trees you remove from the forest *doubles each year*.
5. Each year, the managers add sticks, the lumberjacks take away sticks, and the record keepers record the data on the *Forest Inventory Table.*
6. Be as accurate as possible.

5. Students record their data on the *Forest Inventory Table* (page 8). (Although data is collected in teams, each student completes an individual worksheet.) Point out that part of the table has already been filled in on the worksheet. Ask students to play the first round (the first year) to confirm the results.

   Starting with 120 trees, students plant 4 trees and cut 1, leaving them with 123 trees to begin Year 2, as shown below.

Year	Number of Trees in the Forest	Number of Trees Planted	Number of Trees Cut Down
Start	120	4	1
1	123		

6. Teams can then continue to play and record their results. Help any teams that need clarification. Here is a completed table.

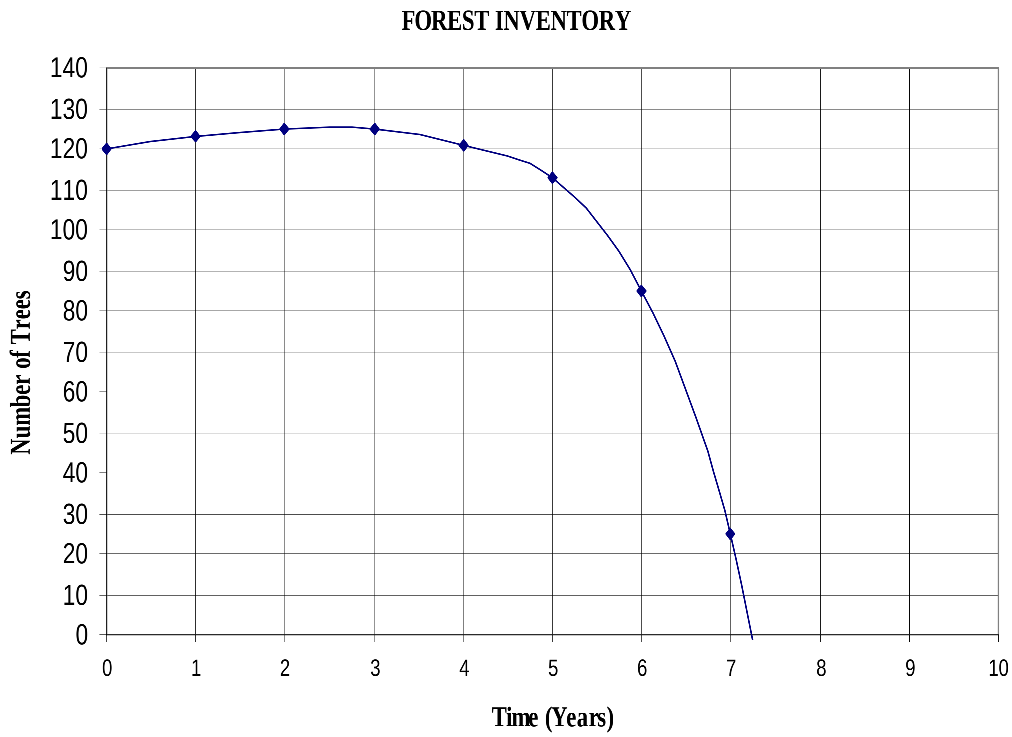
Year	Number of Trees in the Forest	Number of Trees Planted	Number of Trees Cut Down
Start	120	4	1
1	123	*4*	*2*
2	*125*	*4*	*4*
3	*125*	*4*	*8*
4	*121*	*4*	*16*
5	*105*	*4*	*32*
6	*77*	*4*	*64*
7	*17*	*4*	*Not enough left*

Note: Often students will start to see patterns and fill in the table based on that pattern, rather than actually counting sticks. Depending on the age of the students, it helps their understanding if they can force themselves to keep using the sticks for a while.

7. By Round 7 of the game, students will report that they have no trees left.

? **Why did students run out of trees to cut?**
The increasing demand outstripped the supply. There were not enough trees left to cut in Year 7. The forest is gone.

8. Ask each student to use the data from the *Forest Inventory Table* to plot the *Forest Inventory Graph* (page 9). Students connect the points with a smooth line to show what happened to the stock of trees over time.



What happened to the forest?
Students use line graphs to reveal and examine patterns of change.
We call these *behavior over time graphs*.

Bringing the Lesson Home

Post several student graphs and use them to focus the discussion on what happened in the game. The following questions should arise, often raised by the students themselves.

? **How does the graph show what happened to the stock of trees in the forest over time?**
The stock of trees grew slightly at first but then rapidly decreased until there were no trees left by the seventh year.

? **When did the forest grow? Why?**
The forest grew for the first two years because students were planting more trees than they were cutting down each year.

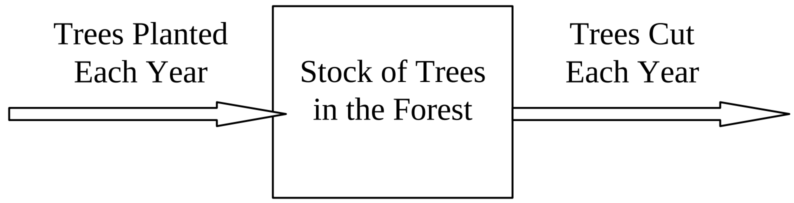
? **When did the forest decline? Why?**
The forest began to decline in the fourth year because students were cutting down more trees than they were planting each year.

? **Did the forest ever stay the same? Why?**
The forest stayed at 125 for Year 3 because students planted 4 trees and cut 4 trees. There was no change in the total number of trees that year.

? **Why did the forest grow in size for a while and then start to decline?**
At first the planting rate exceeded the cutting rate so the forest grew. However, because the cutting rate doubled each year, it soon overtook the planting rate. Then the forest declined.

? **Why did the rate of decline increase as time went on?**
The number of trees cut doubled every year to meet the rising demand for lumber. As more and more trees were cut, the decline steepened.

? **What caused the changes in the stock of trees?**
The total number of trees in the forest was determined by BOTH the planting and the cutting of trees over time. This is an important concept.



There is a **stock**, or quantity, of trees in the forest. It is increased by the number of new trees that **flow in** through planting. It is decreased by the number of trees that **flow out** through harvesting. Like water filling and draining a bathtub at the same time, they can happen simultaneously.

? **In our game the cutting rate increased to satisfy a rising demand for goods, while the planting rate remained constant. In real life, would the owner of the forest have planted more trees?**

Encourage students to think about what they would do.

? **In real life, can a forester harvest trees a year or two after planting like we did? If a tree actually takes more than 20 years to mature, how would this delay affect the forester's long term planning and planting rates?**

Again, this is a brainstorming question with many possible responses. In general, the delay from planting to harvesting makes the real-world system much more complex than the game. If there is a rise in demand, the forester will have to wait 20 years to harvest his new trees, so he must always try to plan ahead. (The Rainforest Game, Lesson 8, addresses this issue.)

? **Does the Tree Game remind you of other similar situations?**

- *Christmas tree farming –harvesting and planting to meet projected demand*
- *Rainforest cutting – clearing forests faster than they can grow back*
- *Managing other renewable resources or agricultural products –balancing how much is produced and how much is used*
- *Managing your money –balancing what you earn and what you spend so you won't run out*

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[1] The Tree Game was adapted from Activity 27 "Timber," in *Counting on People: Elementary Population and Environmental Activities.* Zero Population Growth, 1994.

Name____________________

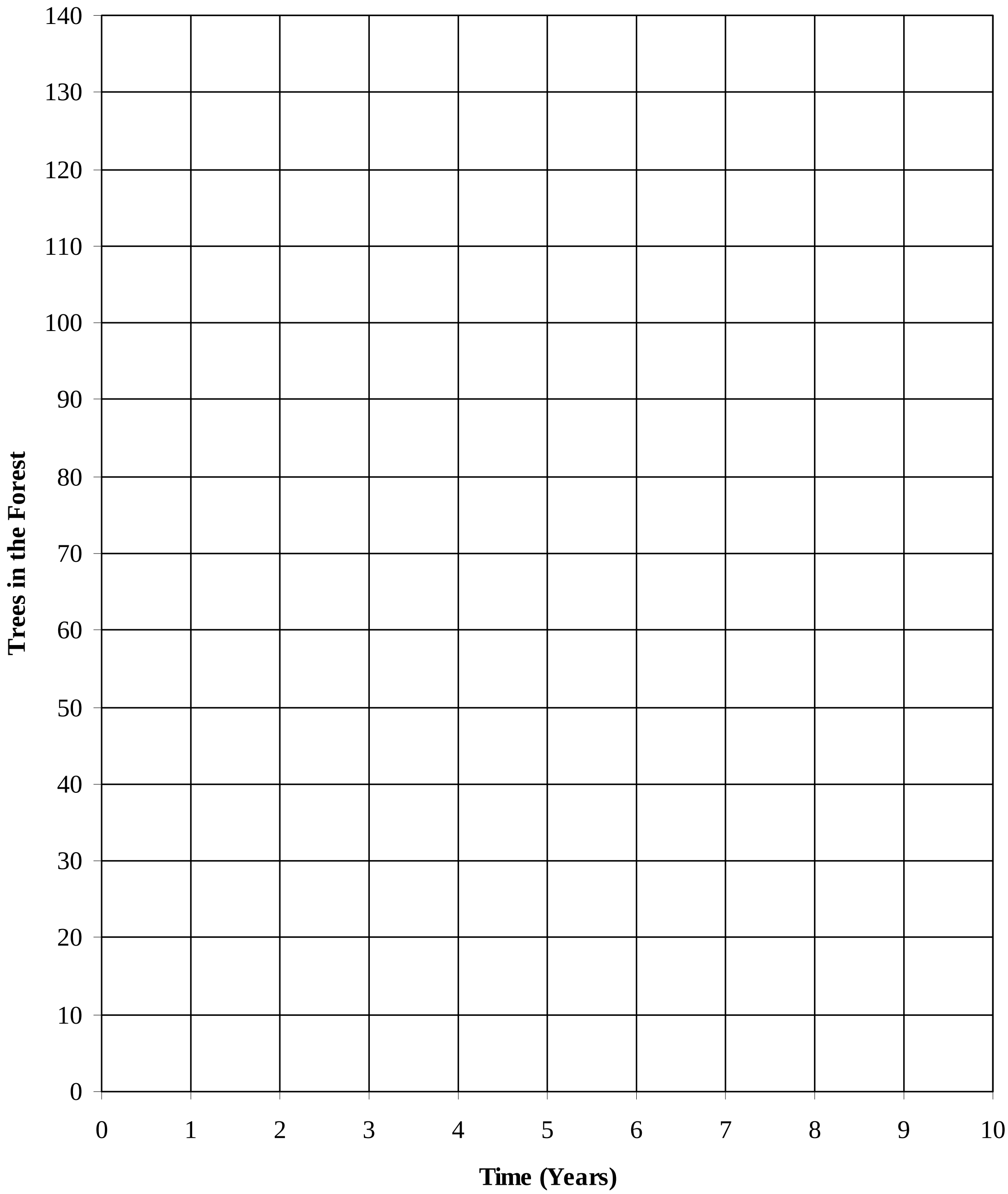
FOREST INVENTORY TABLE

Record the number of trees you plant and cut each year.
Then count how many trees remain in the forest to start the next year.

Year	Number of Trees in the Forest	Number of Trees Planted	Number of Trees Cut Down
Start	120	4	1
1	123		
2			
3			
4			
5			
6			
7			
8			
9			
10			

Name___________________

FOREST INVENTORY GRAPH



How many years did it take for the forest to disappear?

Was the forest always shrinking? Explain.

All of the lessons in ***The Shape of Change, Stocks and Flows*** *build directly on classroom activities and lessons presented in* ***The Shape of Change****, also by Quaden, Ticotsky and Lyneis (2004), available from The Creative Learning Exchange. These lessons also build on one another sequentially.*

The Shape of Change

In Lesson 6 of ***The Shape of Change***, students simulated the planting and harvesting of trees in a forest. They graphed their stock of trees over time to observe the effect of their policies on the sustainability of the forest. See Pages 65-72 in ***The Shape of Change*** for the complete lesson.

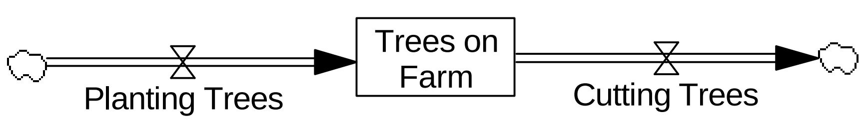
Overview

Two ideas underlie this lesson. First, the lesson illustrates another way that stocks and flows can work together: an outflow from one stock is controlled by a second stock.

Second, students get more practice anticipating and observing how a stock changes with different inflow and outflow rates. In the In and Out Game, for example, it was simple to predict how many players accumulated in the stock because the flows were constant and easy to compute. In each of the succeeding lessons, however, the rates of flow have changed over time. Students have had to think more carefully about how the changing inflows and outflows affected the quantities in the stocks. They have done this by relating their classroom game experiences to the graphs they produced and to their stock/flow maps. In the process, they are building their own intuition about how and why quantities increase and decrease over time.

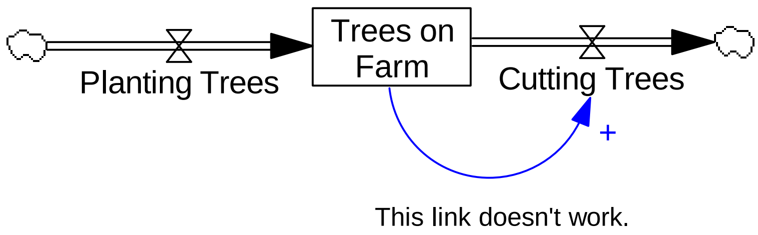
Seeing the Structure

1. Ask students to draw a stock/flow map of the game. Students will have no difficulty coming up with trees, trees planted, and trees cut. Draw the following map and ask students why it is an **incomplete** representation of the tree game.



2. This map shows that both flows are constant. However, in the game, the flow of plantings was **constant** at 4 trees per year, while the flow of cutting **changed** each year by doubling.

3. Ask students how to represent the doubling of the outflow. Some students will suggest feedback from the stock to the outflow. Help students understand that this is **incorrect** by drawing the connector and tracing the loop.

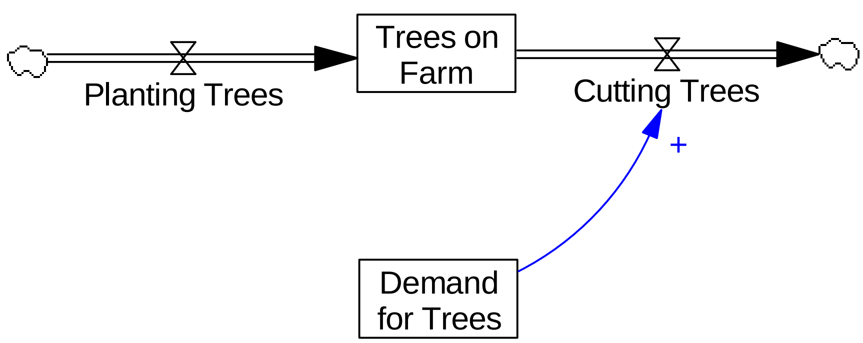


This map says that the number of trees on the farm determines the number of trees that are cut each year. An **increase** in the stock of trees results in an **increase** in the flow of trees cut. This **increase** in the flow will result in a **decrease** in the stock. This in turn will **decrease** the flow. (This is just like the balancing loop for deaths in the Mammoth Game that caused exponential decay.)

However, in the Tree Game, as the stock of trees on the farm **decreased**, the flow of cutting continued to **increase**. This link doesn't work.

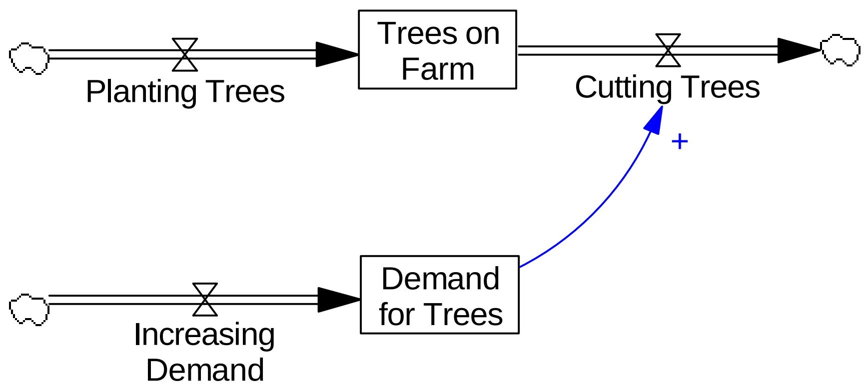
Always tell the story of each connection as you draw it.
Does it make sense?

4. Ask students what determined the increase in cuttings. The cuttings increased because more people wanted the trees. Help students identify this desire for trees as the concept of demand. Demand is represented by a stock that controls the rate of cutting trees. An increase in the demand causes an increase in the number of trees cut.

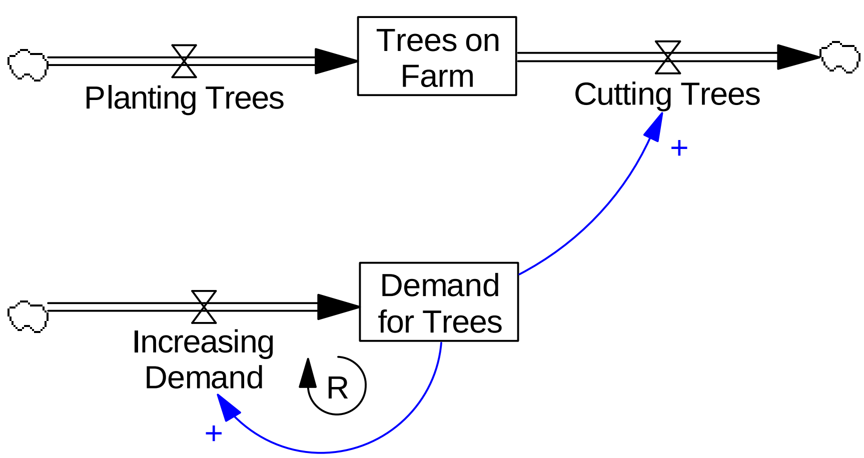


Often a flow is influenced by another stock.
In the game, the number of trees cut each year depended on the demand for trees, not on the stock of trees. Perhaps a growing population needed more lumber for housing.

5. In the game, the demand continued to rise. Ask students for suggestions to represent increasing demand. Add an inflow to show how demand was building over time.



6. Remember that the flow of increasing demand was not constant. Rather, in our game, it doubled every year. A feedback loop is needed, like the doubling process in Making Friends. (This is a very simplified view of demand, defined as doubling in this game. When the need for lumber increased, people who bought our trees came back to buy more.)



By now, students recognize this structure as a reinforcing feedback loop causing exponential growth.

7. Ask students to pair up and practice telling the story of this map, relating it to both the game they played and the graph they drew. Have one or two students share their stories with the class. Here is an example:

   We have a stock of trees that is growing at a constant rate of four trees per year. In the first year, we cut one tree and sold it. In the second year we could sell two trees, so we cut two trees. People liked our trees and told their friends about them, so each year more and more people wanted our trees. As a result, we cut more and more trees. We ran out of trees because we cut them down faster than they could grow back.

? Why did the stock of trees increase slightly at first?

The stock of trees increased because we were planting more trees than we were harvesting for the first two years.

? Why did we run out of trees? We had plenty of trees in the forest at first.

When the demand for trees increased beyond four trees per year, we were cutting down more trees than we were planting every year. The outflow of trees exceeded the inflow, so the stock of trees decreased. No matter how many trees you start with, if you cut them faster than they can grow back, you will eventually run out of trees.

? This stock/flow map describes the structure of the Tree Game. Is it a complete reflection of reality?

Our map, like the game, is a greatly simplified version of reality designed to examine how our policies affected the sustainability of our forest. We did not include the concept of profit and market forces. In the real world, the demand would be influenced by the supply, closing a feedback loop that would cause supply and demand to balance back and forth with delays in the system. These and other elements would make the map more realistic but also much more complex than necessary to examine the basic idea of stocks, flows and sustainability.

? Are there policies that might prevent the depletion of the tree supply?

To keep a sustainable stock of trees in his forest, a forester could either increase the inflow by planting more trees or decrease the outflow by cutting fewer trees. Balancing inflows with outflows is the only way to achieve sustainability.

? Does this apply only to trees in a forest?

Every resource is a stock that is controlled by inflows and outflows, whether it is a stock of fish in the ocean, money in a bank account, or even goodwill with your neighbors.

There are many real-world examples of people using resources faster than they can be replenished.

Learning about stocks and flows can help us understand the concept of sustainability.