The Rainforest Game:
The Shape of Change

The text of
Lesson 8: The Rainforest 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

In this simulation game students act out the lives of trees. Following different planting and harvesting policies, they learn about delays in managing a renewable resource. Math skills include recording data in tables, graphing, predicting outcomes and describing patterns of behavior over time. [1]

The Rainforest Game can be part of an interdisciplinary unit on rainforest resources and inhabitants. It can also complement other science, social studies, economics and ecology units on the sustainable use of any renewable resource.

The logistics of the Rainforest Game are somewhat more involved than others in ***The Shape of Change***. You may find it helpful to review or play The In and Out Game (Lesson 1) and The Tree Game (Lesson 7) first.

Materials

- Large display board or overhead projector
- Markers or chalk
- One copy of three worksheets for each student
    1. *What Happened to the Trees?* (page 12)
    2. *Yearly Forest Inventory* (page 13)
    3. *Mature Trees in the Forest* graph (page 14)

What Is Happening to the Rainforest?

The rainforest is disappearing at an alarming rate, exploited by people for its bounty of natural resources. The myriad of species living there, many as yet undiscovered by humans, are under severe pressure. Animals and plants may be headed for extinction or continued existence only in zoos and other micro-managed environments.

What can be done? This question has no simple answer. Raising awareness of the problem is a first step. People must realize that when an area is cleared, it may take many years to return to forest, if indeed it ever will.

Students generally recognize that the rainforests are threatened, but they may suggest a simplistic solution - stop cutting down the trees. However, many people depend on the rainforest for their livelihood and basic necessities of life. Because the resources of the rainforest provide so many products and opportunities, there will always be incentive to exploit them. When the removal rate is higher than the rate of renewal, the forests will inevitably decline over time.

Playing the rainforest game gives students a chance to experiment with different planting and harvesting scenarios and to establish equilibrium. The game applies to the sustainability of any forest or other renewable resource.

How It Works

Students will play a simulation game in which they pretend to be trees that grow from seeds to mature trees in four "years." Over the course of the game, students enact three different sets of planting and harvesting policies. After playing, they use a table and a graph to analyze what happened.

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Note: First play the game, and then complete the table. That way, students' attention will remain on the game. Completing the table may be difficult for some students and doing it after the game avoids distractions.

OVERVIEW OF LESSON SEQUENCE

1. **Policy 1**: Play years 1 – 5 of the simulation to demonstrate linear growth. The number of mature trees will grow at a steady rate.
2. **Policy 2**: Play years 6– 8 to demonstrate equilibrium. The number of mature trees will remain the same when the planting and harvesting rates are equal.
3. **Policy 3**: Play years 9 – 12 to test increased planting and harvesting. Delays will produce surprising results.
4. Students reflect on the game, complete tables, plot graphs, and draw conclusions.

Do not announce the purpose of each policy to students – let them learn it from experience.

Important: Students complete the table *after* they have played the complete game. We have inserted tables within the text so that you can anticipate what will happen, but *do not* share this information or interrupt the flow of the game with these details. Just let the students play and build their own intuitive understanding.

Procedure

1. After discussing the current condition of the rainforest, tell students that they are going to play a simulation game to examine what happens to a forest when trees are planted and cut down over time. Since real trees cannot grow in the classroom, students will act out the growth of trees in an imaginary forest. They will be told how many trees to plant and harvest each year.

2. Point out that it takes time for trees to grow, but this game will speed things up. They will pretend that a tree takes only four years to reach maturity: seeds are planted in year one, sprout and grow a little in year two, become taller in year three, and mature to full grown in year four. Students will pantomime these stages.

STUDENTS AS TREES

Year 1 Seed – curled up or sitting on the floor
Year 2 Sprout – kneeling
Year 3 Sapling **–** standing, hands at sides.
Year 4 Mature Tree – standing, hands clasped behind head, elbows out

3. At first, all the students in the class represent seeds stored in a warehouse. At the beginning of the game, there are no trees in the forest and many seeds in the warehouse.

4. **Policy 1.** Select one student in the class to be the Forest Manager. The responsibility of the manager is to count the number of mature trees and report that number to the class at the end of each year.

- To start the forest, select three students to be "planted" as seeds in the forest area of the classroom.
- For the first year, choose three different students to be "planted" while the original seeds "sprout."
- For the second year, plant three new seeds while the earlier plantings grow into sprouts and saplings.
- Continue planting three new seeds and growing the forest for a total of 5 years.
- At the end of the 5th year, ask the Forest Manager to count the stock of mature trees once again and report the results to the class.

Pause for a minute. Help students understand the behavior of the system by asking for a *brief* recap of what they have observed. It took four years for the first seeds to become mature trees. After that, adding three seeds per year caused the mature forest to increase by three trees per year. Although there is a delay between planting and maturity, the forest has a steady supply of trees at each stage of growth.

Note: This discussion should be very brief. It is intended to encourage students to start thinking about the issues. A more complete discussion and understanding will come at the end of the lesson. Throughout the lesson, the idea is to just let students play the game. They will stop and think about it later. It is OK to clarify the rules of the game, but resist every urge to step in and explain what is happening to the forest.

For your information only, below is a table showing the number of trees at each stage of growth each year. Notice that the first seeds planted (in bold font) move diagonally down the table as they become sprouts, saplings and, finally, mature trees in four years. *Again, do not share this table with students or interrupt the flow of the game with this information.*

Policy 1: Linear Growth

Year	**Seeds in Ground**	**Sprouts**	**Saplings**	**Mature Trees**	**Trees Harvested**
Start	**3**	0	0	0	0
1	3	**3**	0	0	0
2	3	3	**3**	0	0
3	3	3	3	**3**	0
4	3	3	3	**6**	0
5	3	3	3	**9**	0

5. **Policy 2.** Next, change the policy and try the following scenario:

- Beginning in Year 6, while continuing to plant three new seeds each year, *harvest* three mature trees per year to sell. (Remove three mature trees from the forest and return them to the warehouse as seeds.)
- Ask the Manager to count and report the number of mature trees now remaining at the end of Year 6. (There will be nine trees left.)
- Continue planting three seeds and harvesting three trees per year in Years 7 and 8.
- Ask the Forest Managers to count the number of mature trees and again announce the results to the class.

Pause briefly again. Ask students to predict the results of this policy. Continuing to plant three seeds and remove three trees each turn will produce equilibrium, or a stable situation in which numbers remain constant. Every year, three saplings grow and replace the three harvested mature trees. The number of new seeds in the ground matches the number of mature trees harvested, and everything is in balance (as shown below for your information only).

Policy 2: Equilibrium

Year	**Seeds in Ground**	**Sprouts**	**Saplings**	**Mature Trees**	**Trees Harvested**
6	3	3	3	**9**	**3**
7	3	3	3	**9**	**3**
8	**3**	3	3	**9**	**3**

6. **Policy 3.** Suggest that you have an opportunity to make more money by selling more trees. The forest area in the classroom has a surplus of mature trees, and since you have more seeds in the warehouse, you can also plant more trees per year.

- In Year 9, increase the harvesting number to five, and match that by planting five new seeds each year as well.
- Ask students to predict the outcome of that strategy.
- Play four rounds to see what happens.
- Once again ask the Forest Managers to count the number of mature trees. It may surprise the class that the number of mature trees has declined.

Policy 3: Increased Planting and Harvesting

Year	Seeds in Ground	Sprouts	Saplings	Mature Trees	Trees Harvested
9	**5**	3	3	**7**	**5**
10	**5**	5	3	**5**	**5**
11	**5**	5	5	**3**	**5**
12	**5**	5	5	**3**	**5**

7. After playing the game, ask students to reflect upon the events of the simulation using the worksheet, *What Happened to the Trees?* (Page 12)

- Students write a few sentences about the game.
- They draw a *behavior over time graph* of the number of mature trees in the forest as the game progressed.
- Writing a short, one paragraph summary serves two purposes: students settle down after an active game, and they organize their thoughts, preparing to analyze what happened.

A **behavior over time graph** is a *line graph* with time on the horizontal axis that sketches what students think happened to the number of mature trees over the course of the whole game. It shows a pattern of behavior.

8. Now students are ready to tabulate the results of the game on their *Yearly Forest Inventory* worksheets (page 13). Use an overhead projector or the board to help students complete the table by asking guiding questions.

? **How many plants did we have to start?**
We planted three seeds and there were no other plants, so we have the number 3 in the first column and zeros in all other columns. See below.

? **What happened in Year 1?**
The three seeds grew into sprouts and we planted 3 new seeds.

Year	Seeds in Ground	Sprouts	Saplings	Mature Trees	Trees Harvested
Start	3	0	0	0	0
1	3	3	0	0	0

? **Where do the sprouts come from?**
One year's seeds are the next year's sprouts. Then the sprouts become the saplings in the table for the following year. The year after that, they become mature trees. Therefore, a number entered in the seed column will move diagonally down to the right through the table until reaching the mature trees column.

? **Why did the first mature trees appear in Year 3?**
Trees take four years to mature from seeds. We had seeds in the ground to start. Review Years 0-3 as you enter the numbers of trees at each stage.

? **In Years 4 and 5, the number of mature trees increased each year. Why?**
Three seeds were being planted each year and no trees were being harvested so the forest grew steadily.

Year	Seeds in Ground	Sprouts	Saplings	Mature Trees	Trees Harvested
Start	**3**	0	0	0	0
1	3	**3**	0	0	0
2	3	3	**3**	0	0
3	3	3	3	**3**	0
4	3	3	3	**6**	0
5	3	3	3	**9**	0

? **Harvesting three trees per year began in Year 6 and continued in 7 and 8. What happened to the number of mature trees?**

It remained steady, in equilibrium, at nine trees because the harvesting rate equaled the planting rate. (Note: To compute these, the number of mature trees increases to twelve trees but is reduced to nine after three trees are cut.)

Year	Seeds in Ground	Sprouts	Saplings	Mature Trees	Trees Harvested
6	3	3	3	**9**	**3**
7	3	3	3	**9**	**3**
8	**3**	3	3	**9**	**3**

? **In Year 9, harvesting and planting were increased. What was the result?**

The number of mature trees declined for three years. This is because of the delay in the growth of the five new seeds. At first, only three saplings were still maturing, but five trees were cut down each year.

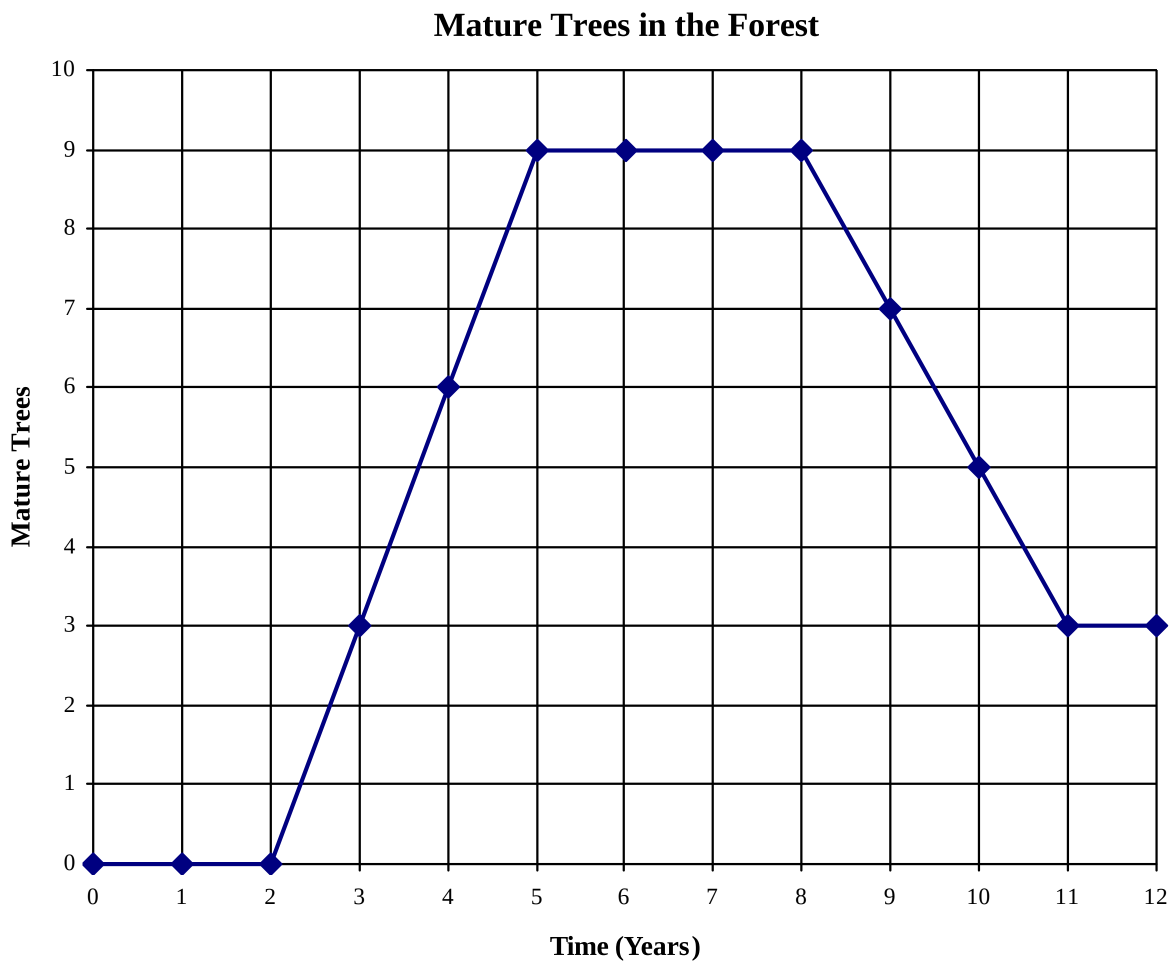
Year	Seeds in Ground	Sprouts	Saplings	Mature Trees	Trees Harvested
9	**5**	3	3	**7**	**5**
10	**5**	5	3	**5**	**5**
11	**5**	5	5	**3**	**5**
12	**5**	5	5	**3**	**5**

? **What happened in Years 10-12?**

The forest reached a new lower equilibrium at three trees.

9. When the table is completed, students use it to graph the number of mature trees on the *Mature Trees in the Forest* graph worksheet (page 14). The horizontal axis measures Time in years and the vertical axis represents the number of Mature Trees in the forest each year.

- Some students may need close guidance plotting the first few points.
- After students have plotted the points, ask them to connect the points to produce a *behavior over time graph*.



Bringing the Lesson Home

Students need to think and talk about their experience in the game to build understanding. Use the graph and the table to focus a discussion on the game and its implications.

? **What happened to the forest in this game?**
Use a question like this to start a class discussion. Some students will be quite articulate, but others may be confused about the exact nature of the dynamics in this game. The questions below help to bring home the important points.

? **What happened to the forest during the first 5 years?**
Once the first seeds had matured, the forest grew at a steady rate.

? **How did the graph show the stock of mature trees in Years 1-2?**
The line stayed at zero because there were no mature trees yet.

? **When did the stock of mature trees remain constant?**

It was constant when the number of saplings that became mature trees was the same as the number of mature trees cut. At that point, the number of mature trees was represented by a flat horizontal line on the graph.

? **What happened when the number of trees harvested was raised and the number of seeds planted increased to match the larger harvest?**

The number of mature trees declined steadily, reaching equilibrium at a lower number of trees than it held before the increased harvest.

? **Was this a surprise? Why doesn't the forest maintain equilibrium when you increase planting and harvesting at the same time?**

Even though planting was increased to match a rise in harvesting, there were three years when the forest suffered a net decline in mature trees. The delay in trees reaching maturity caused the outflow to be greater than the inflow.

Students are surprised by the effect of delays on the number of trees in the forest. By acting out the growth of trees and thinking about it together, students develop a good understanding of this important and sometimes elusive concept.

? **How does your final graph compare to your original sketch?**

Help students reflect on their thinking. How have their mental models changed during the lesson?

? **Sustainable yield means having enough of a resource in the pipeline to replace what removed from the system. How can a forest manager be assured of having enough trees year after year?**

The forester must plan to have a steady flow of new trees to replace those that are cut down.

? **Summarize in your own words what happened in this game.**

The supply, or stock, of mature trees was at zero for three years; then it rose by three trees each year. When harvesting began in Year 6, the number leveled off, or reached equilibrium, at 9 trees. In Year 9, after harvesting and planting rates went up, the stock of mature trees went down. It leveled off at 3 trees, a lower level than the first equilibrium period.

? **What would happen if we decided to harvest more than 5 trees in Year 9 (while also planting more seeds)?**

The delay, along with the more aggressive cutting policies would result in the ELIMINATION of the mature forest. For example, cutting nine trees in Year 9 would leave only 3 mature trees in Year 10, which then would all need to be cut in an attempt top maintain the more aggressive policy.

? **Are there other situations in which maintaining a steady supply of some resource is necessary?**

- ? *Other renewable resources such as livestock, fisheries, and aquifers experience similar delays.*
- ? *Stock in a warehouse, factory, or retail store follows a similar pattern*.
- ? *Veteran members of a sports team or organization also need to be developed over time.*

Note

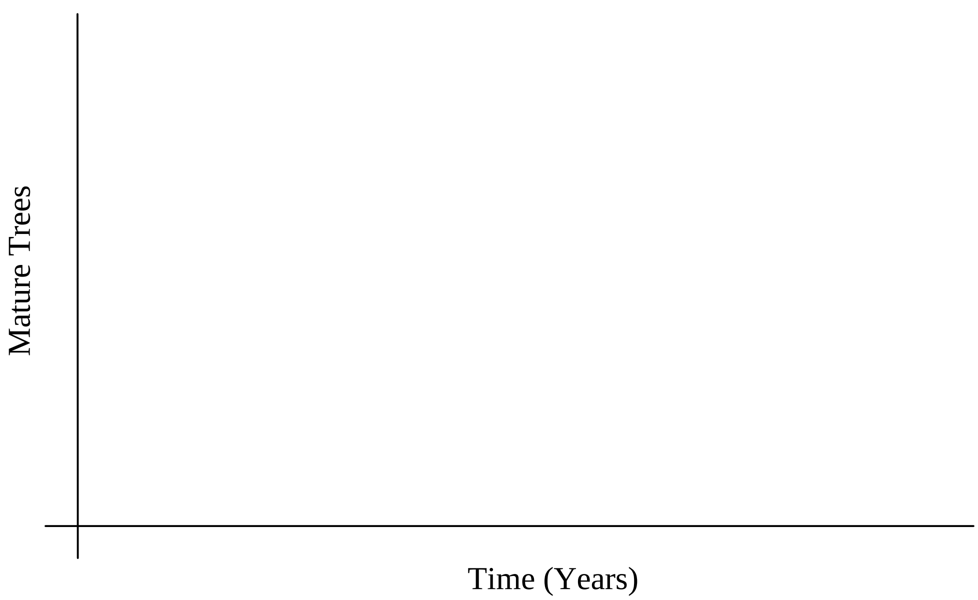
[1] This game was inspired by the classic system dynamics brain teaser described by Barry Richmond in *An Introduction to System Thinking ,STELLA,* High Performance Systems, Inc., Hanover, NH, 2001 (p.26)

Name________________________

What Happened to the Trees?

Write a brief paragraph about what happened in our "forest." What happened to the number of mature trees over the years?

On this graph, sketch a line for the number of mature trees over time.



Name___________________________

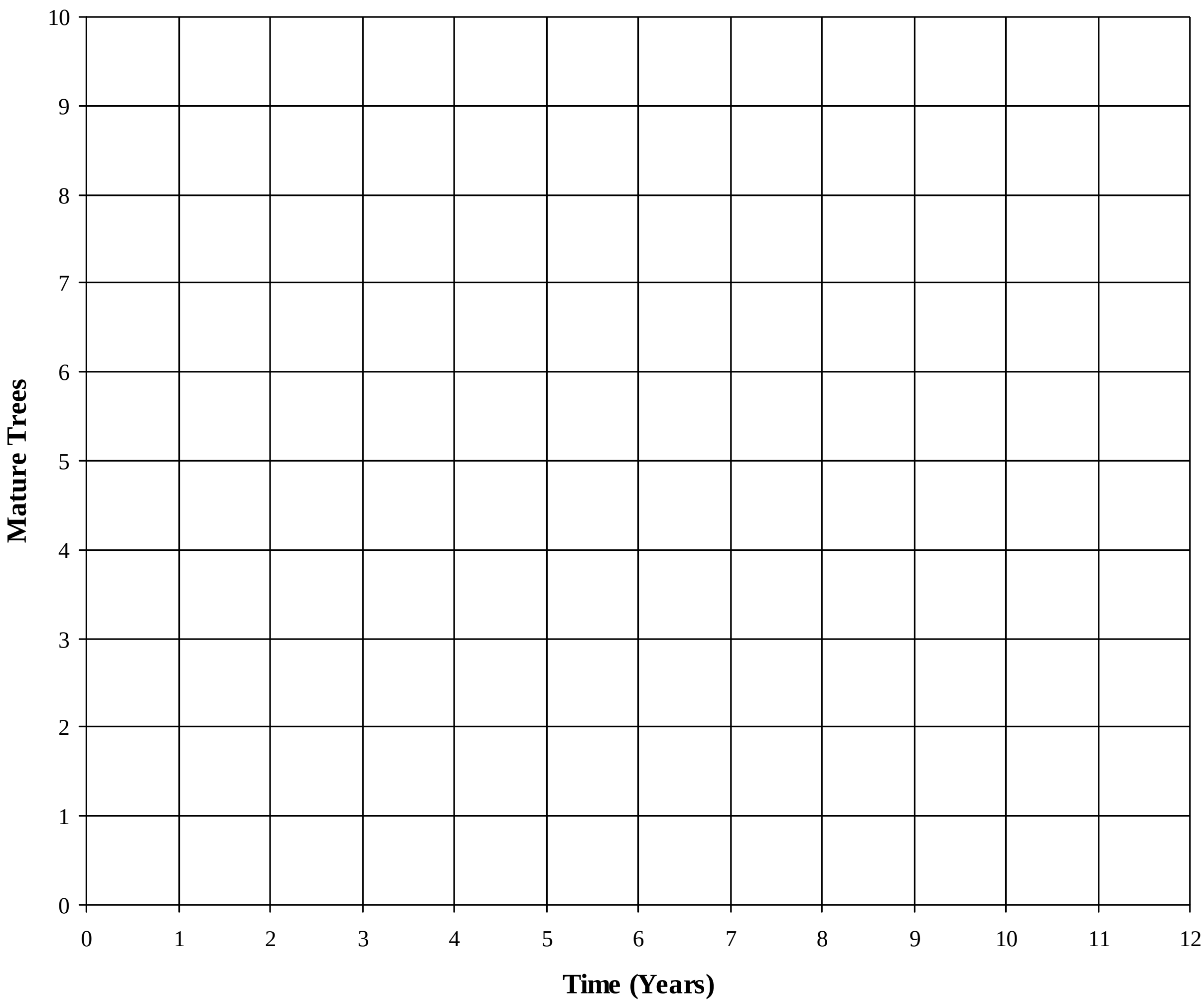
Yearly Forest Inventory

Year	Seeds in Ground	Sprouts	Saplings	Mature trees	Trees Harvested
Start					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					

Name________________________

Mature Trees in the Forest

Use your Forest Inventory data to plot the number of *mature trees* in the forest over time.



How does this differ from your original sketch? Why?

*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 8 of ***The Shape of Change***, students experienced the effects of delays as they acted out the growth stages of trees in a forest. Following various planting and harvesting policies, they saw their forest grow, reach equilibrium, and decline over time. See Pages 81-96 in ***The Shape of Change*** for the complete lesson.

Overview

The Rainforest Game is a very active classroom activity with students pantomiming the growth of seeds, sprouts, saplings and mature trees, while they are also observing the changes in their forest inventories under three different sets of planting and harvesting decision rules. Students will be surprised to see that the stock/flow map of the game is quite basic, however. The map has four stocks of trees linked together in a chain. Delays arise as the trees grow and move from one stock to the next over time.

Seeing the structure

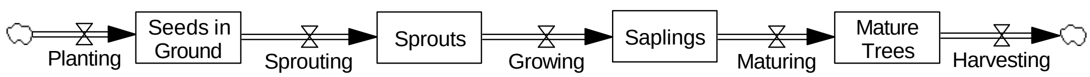
1. Review the growth stages of trees in The Rainforest Game. Referring to their Yearly Forest Inventory tables may help students identify each category of tree. Since these stages were accumulations that were changing during the game, they can be represented as stocks.

A Snapshot

One way to identify the stocks in a system is to think of a snapshot. If we could take a picture of the system at the end of any time period, what would we see?

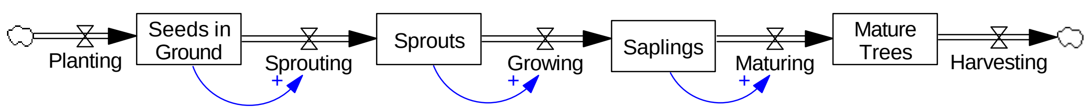
In The Rainforest Game, we would see the collections of seeds, sprouts, saplings and mature trees that had accumulated over time. We would see the stocks.

2. Ask students to describe how trees changed during the game. They will recall that seeds were planted and sprouted after one year. The sprouts grew to saplings during the next year, and matured to harvestable size in the following year. Connecting the stocks with flows shows that the trees moved from one stock to the next over time.



The "clouds" are the boundaries of the system. For now, we do not care where the seeds came from or where the harvested trees went.

3. Ask students how many trees from each stock moved to the next stage during each turn. Because the simulation is an idealized situation, *all* the seeds sprouted, *all* the sprouts grew, and *all* the saplings matured each year. Show this in the diagram by connecting the stock to the flow, indicating that the number of trees flowing out of the stock is influenced by the number of trees in the stock. In the game, all the trees flowed from one stock to the next until they were mature.

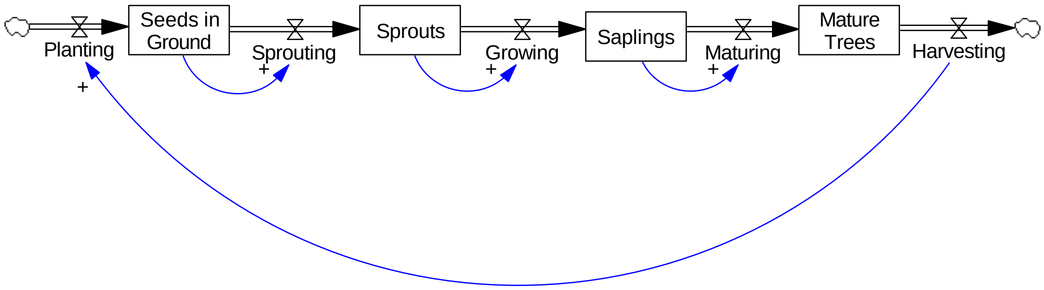


The " + " signs by the arrowheads mean that an ***increase*** *in the stock causes an* ***increase*** *in the flow. The more seeds there are in the ground, the more seeds will sprout each year.*

4. How many mature trees were harvested each year? That was a policy decision in the game that didn't depend on the number of mature trees. We don't draw a connecting arrow from the "Mature Trees" stock to the "Harvesting" flow.

But the harvesting decision *did* affect another part of the game. Ask students how the harvesting decision affected other parts of the system.

Once a stock of mature trees built up, harvesting began. The harvesting number equaled the number of seeds planted. When harvesting increased, the rate of planting was increased to match it. Ask students how to diagram this relationship.



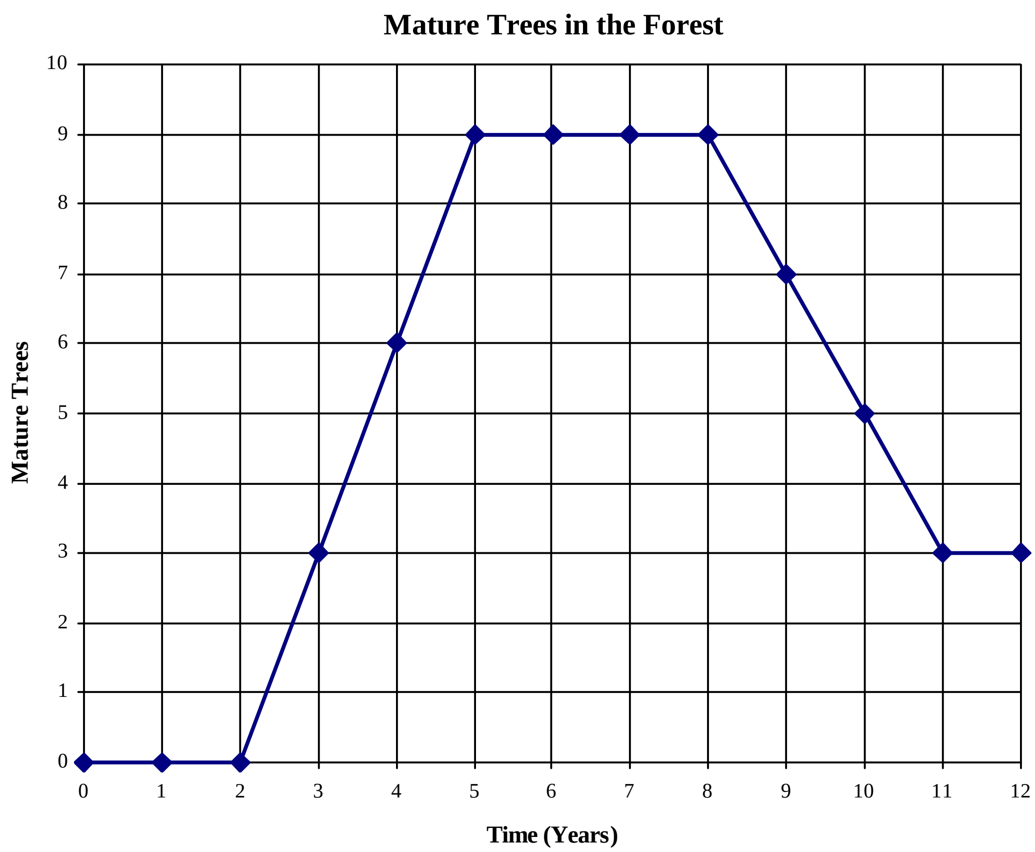
The arrow means that *information* about the harvesting rate affected the planting rate. An **increase** in the harvesting rate caused an **increase** in the planting rate. In the game, the lumberjack asked the planter to plant a new seed for every tree he cut down.

5. The map is now complete and reflects the structure of the game. The chain of stocks shows the delay as seeds grow into sprouts, saplings and mature trees over time. The connecting arrow from harvesting to planting reflects the policy decision to plant a new seed for every tree cut.

? Can you explain what happened in The Rainforest Game using our stock/flow map?

Every year, we planted a certain number of seeds in the ground. In a year, the seeds all grew into sprouts. After another year, the sprouts all grew into saplings. Finally, after a third year the saplings grew into mature trees. In our forest inventory we had four stocks of trees, one for each stage of growth; trees flowed from one to the next each year. Our policy was to plant a new tree for every tree that we harvested, as shown by the connecting arrow – the arrow shows that the planting rate was determined by information about the harvesting rate. During the game, we changed the harvesting and planting rates to test different policies, but the structure of the system remained the same.

During the game, we changed the harvesting and planting rates
to test different policies,
but the structure of the system remained the same.



? Looking back at our graph of the Forest Inventory, and relating it to our stock/flow map, why did it take so long to get a stock of nine mature trees?

We started with open land and planted three seeds. It took three years for those seeds to become sprouts, saplings, and finally mature trees. We had a stock of three mature trees in Year 3. Meanwhile, because we continued to plant three seeds every year, those new seeds were also progressing through the growth stages every year, from stock to stock. These new trees kept flowing through the system so that three new trees were added to the stock of mature trees every year. By Year 5 we had nine trees. The stock/flow map shows how it takes time for trees to grow. There is a delay of three years from planting to harvesting our trees.

When students relate their game experience to the graph and the stock/flow map, they begin to grasp the effect of delays on the behavior of a system.

? In Year 9 we increased the harvesting and planting policies. Why did the equilibrium value of the stock of mature trees drop?

As we saw in playing the game, even though the planting rate was increased to match the increased cutting in Year 9, the stocks of sprouts and saplings still contained only three trees which still had to mature through the system. In Years 9-11 we were cutting five trees while only three trees were flowing up into the stock of mature trees. For the stock of mature trees during those years, the outflow exceeded the inflow, so the number of mature trees decreased over time – much like the mammoths dying faster than they were being born in the Mammoth Game.

? Why doesn't the graph reflect a sudden drop in the number of mature trees rather than the gradual decline to three trees?

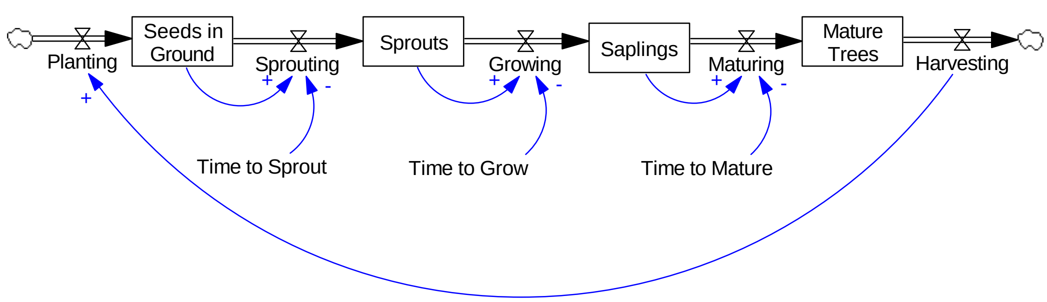
The graph reflects the total delay of three years during which the trees grew through the growth stages to maturity.

? **How is our forest game different from a real-world forest?**

In the game, our trees passed from year to year in discrete one-year intervals – every sprout became a sapling at the end of exactly one year, for example. Also, in the game, the growing time for all of the stages was one year.

In the real world, trees grow continuously throughout the year, not in one-year steps. Also, the growing times are not all equal. For example, while it may take a year for a seed to sprout, it may take twenty years for a sapling to mature.

We could specify growing times in our stock flow map:



*The "-" signs by the arrowheads mean that an **increase** in the delay times causes a **decrease** in the flows. If it takes longer for seeds to sprout, then fewer seeds will sprout each year.*

Notice that each section of this map is like the deaths structure in the Mammoth Game: a number of trees drains out of each stock each year, depending on the delay times. These are balancing feedback loops; they would produce curved lines on the graph, closer to real-world behavior.

It’s always a good idea to think about the simplifications we have made in a game or model.

? **Can you think of other examples where something moving from stock to stock causes a delay?**

- *There is a delay from when students enter kindergarten until they graduate, as they pass from one grade to the next each year.*
- *There is a delay in making school lunches. The food is brought to school, stored, prepared, baked, and finally served to students.*
- *There is a delay from the time you put a letter in the mailbox until it is delivered to your grandmother. The letter is sorted at your post office, put on trucks, sorted again at her post office, and delivered.*
- *There is a delay from the time we burn fossil fuels until greenhouse gases build up in the atmosphere.*

Stocks introduce delays into systems.

Accumulations build up and drain *over time*.