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# Exploring the Dynamics of Economic and Ecological Sustainability In the Northern Forest

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## Abstract

The Northern Forest, which spans the U.S. states of New York, Vermont, New Hampshire, and Maine, is being pulled in three directions. There is increasing pressure on the forest to provide habitat and recreation, leading to a push for more "big old trees." The forest-products industry, particularly the sawmill sector, is continuing to grow and many rural communities want to retain or expand industry jobs. At the same time, urban growth may be reducing the forest-land base.

In partnership with a cross-stakeholder advisory team, we explored the relationship between the pulp and paper mills, the sawmills, the landowners, and the forest resource, focusing on the behavior of the fast-growing sawmill industry and its renewable timber supply. Questions we asked together included: What are the sawmills' likely transition from the current mode of exponential growth towards balance? Will the capacity smoothly approach an equilibrium or will it (as it already did from 1900 – 1935) overshoot and sharply contract, to the detriment of the industry, economy and ecosystems? What policies would lead to one future over the other?

Results show the necessary conditions for a behavior mode of overshoot-and-oscillation and identify leverage points for improved system performance.

The paper further describes the most challenging work we currently face – using the analysis and a model-based workshop to catalyze support for positive change amidst a geographically distributed, near-term-oriented group of policy-makers who represent stakeholders from loggers to mill executives to environmentalists to landowners to government officials.



## Acknowledgments

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## Introduction

The Northern Forest is the largest area of intact forest remaining in the eastern United States. It stretches 400 miles across New York, Vermont, New Hampshire, and Maine from Lake Ontario to the Atlantic Ocean. After a century of relative stability, the last 15 years the global economy has brought dramatic change to the Northern Forest. Paper companies that dominated the region economically for decades have become part of multi-national corporations, sold millions of acres of land, and closed mills. Some of their former lands have gone into development, some into conservation use, some have fallen into the hands of long-term investors or short-term "timber liquidators." Industry employment has declined sharply, with environmentalists frequently bearing the blame. From being a national and world leader in the paper industry a century ago, the Northern Forest now plays a minor role. The future of the large paper mills is uncertain. Participants feel that the forest economy is increasingly out of their control.

At the same time sawmills in the region have been increasing in capacity, setting up an almost contradictory concern. Can the forest supply a growing sawlog harvest rate? This concern is amplified by those who keep their eyes on other pressures coming from outside the forest region -- acid rain that slows tree growth, environmental pressure to restore wilderness, and land development for second homes and tourism.

The processes that determine the economic character of the region are complex and changing fast. Local ecological conditions, regional labor pools, federal environmental laws and global finance all influence decisions made about mills in Berlin, Gorham, and Groveton. These decisions have implications for the communities -- human and ecological -- that depend on the forest.

Like many inhabitants of forest regions around the world, the people of the Northern Forest are struggling to balance the forest's ecological integrity with the forest industry's continuing success. The goal of the Sustainability Institute's Forest System Project is to provide tools and resources that focus on the long-term health of the overall ecological and economic system and help the region find a balance that works for all players.

## The Model Development and Engagement Process

We began by gathering a team of advisors from the Northern Forest region. Led by Steve Blackmer of the Northern Forest Center, the team spanned the diverse stakeholders in the region – a recently retired pulp mill executive, several environmentalists, several forest-policy non-profit leaders, an industry consultant, and an academic. This group described to us their long term concerns for the region and their theories about the long-term drivers of change in the region.

We followed up by immersing ourselves in the data sets that describe the trends in lumber and paper price, forest stands, mill capacities, jobs, and costs. Then we interviewed a wide range of players in the Northern Forest system. From pulp mill and sawmill managers to landowners to environmental researchers to government policy analysts, we have listened to descriptions of how decisions are made and how the system works. We mapped the interconnections. For example, increasing mill capacity drives the regional harvest rate, which decreases the available inventory of harvestable trees and raises timber prices. Higher timber prices increase raw material costs at mills, decreasing profitability and sparking investments in cost-reducing technologies. And so forth.

The data and the descriptions of the forest system's interconnections gave us the information we needed to create a simulation model to help us understand how the parts of the system interact, how these interactions bring forth the system's behavior, what kinds of futures are likely, and where are the leverage points for change.

The process of building this model has been a joint effort, passing back and forth between the modelers and our advisors in a long series of team meetings and follow-up interviews. We presented the model's assumptions, behaviors, and "what-if" tests to our advisory group and asked, "Does this behavior make sense to you? What doesn't? What surprises you?" Based on the responses we re-examined the assumptions in the model and revised it to better represent the system.

While a model is never truly "done" or "correct," at this point we have completed a version in which we have enough confidence that we are working to disseminate the insights that arise from it. We believe that people will learn the most not by hearing us lecture about our conclusions, but by discovering the conclusions first-hand in a participatory, interactive, model-testing workshop – ideally, an enormously condensed version of the overall model-building process we undertook with our advisors. In the workshop, participants brainstorm the key inter-relationships in the system and then suggest "what-if" tests to try in the model. On a shared computer screen projected on the wall, or on individual, self-operated computers, they watch possible futures play out. Since the model and its assumptions are transparent and easily changed, they can discuss what happened in the system and why, and they can search for changes or policies that can produce more desirable futures.

# The Challenge Facing The Northern Forest

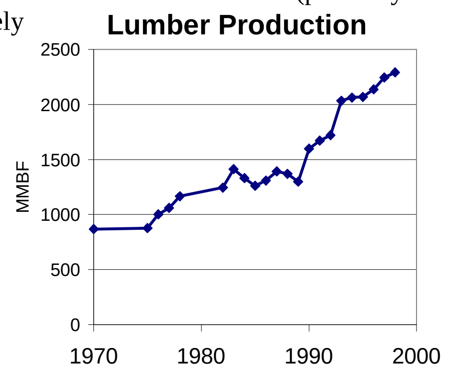
Our advisors tell us that the Northern Forest is pulled in three directions by three forces– *industry, environmental goals, and urban development/fragmentation*. Our model represents all three of these forces, their effect on the forest, and the forest's consequent effect back on them.

## *Industry– Mills and Landowners*

For the last 250 years two wood-using industries – sawmills and later pulp and paper mills -- have been important throughout the Northern Forest region. Northern Forest land is largely held in private hands, so the majority of the harvest decisions are made based on economic and value choices of landowners, not by public policy.

### Sawmills

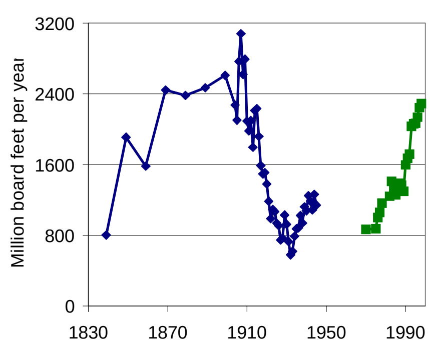
There are several hundred commercial sawmills in the four states and many "mom and pop" micro-mills. They turn out both structural lumber (primarily softwoods) and lumber for finish work that values cosmetics (primarily hardwoods). In addition to the U.S. mills, many sawmills in Canada rely on sawlogs from the Northern Forest. Canadian mills account for approximately 25% of Northern Forest sawlog consumption.



Data: U.S. Census -- Lumber Prod. and Mill Stocks

The sawmills are placing increasing pressure on the forest:

- Lumber production in the four states has been growing at about 3.5% per year, doubling every 20 years.
- Sawlogs and veneer logs were approximately 42% of total regional harvest production in 1999.[1]
- Demand is particularly strong for the unique "northern hardwoods."
- Mills have adapted to saw smaller and smaller diameter logs for lumber production. The average sawlog in the early 70s had a 14-15 inch diameter. Today the average is closer to 7-8 inches with some as low as 5 inches.



Source: USDA, Steer, 1948 and US Census

Taking a longer term perspective, the lumber production has already grown, contracted and now is growing again. There are many good "event-based" explanations for the period of contraction.

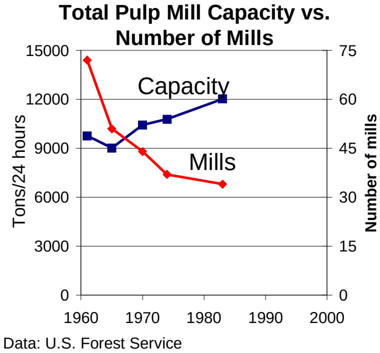
- Capital equipment shifted to other regions, particularly the Pacific Northwest.
- The 1912-1920 spruce budworm outbreak.
- The 1929 stock market crash.
- Timber diverted to growing regional paper industry.
- Land cleared for farming.

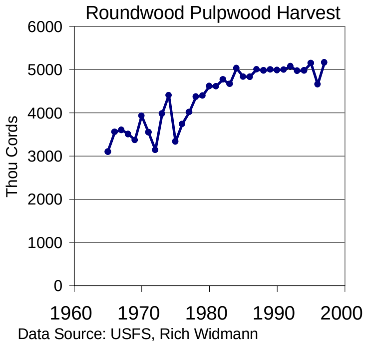
One of our goals will be to develop a theory of the cycles of growth and contraction that is driven by the long term balancing of the resource and mill capacity.

## *Pulp and Paper and Other Fiber Industry*

While the Northern Forest's pulp and paper industry may no longer be a significant player in the international market, it continues to be an important industry in the counties of the Northern Forest. The pulp plants are struggling to compete with new efficient plants elsewhere in the world, but the value of their embedded capacity gives incentive to continue working the mills as long as possible.

Competitive pressure has led to considerable consolidation in the industry. The remaining mills have continued to invest in new technologies to increase efficiency and remain able to compete. The resulting picture is a decline in the number of mills, but an increase in regional production capacity. Over the last ten years, the pulpwood harvest (the main pressure the pulp mills place on the forest) has leveled off. In 1999, the pulpwood harvest accounted for approximately 38% of the region's timber sales.[2] Since global pulp price is both cyclical and declining, the picture for the pulp mills in the region remains uncertain.




However, the fiber resource of the region is attractive to other industries, which may be drawn into the region to replace the pulp and paper mills.

- Expensive oil in the late 1970s led to installation of wood-fired stoves, furnaces, and electric generators throughout the region. The collapse of those high oil prices then led to an approximate 47% reduction in fuelwood harvesting from 1980 to 1997. However rising oil price could revive this market.
- Currently, fuelwood harvesting accounts for 20% of the harvest (12% residential and 8% business).[3]
- The region could also become attractive to other fiber-using mills. Late in 1999, several companies announced the planned construction of two oriented strandboard plants in the Northern Forest region.[4] Small, efficient "chip mills" might also be attracted, if an underutilized fiber inventory began to grow and accumulate in the forest.

## Landowners

The vast majority of the forest is privately held, with about half the forest area owned by small businesses and families. These owners follow a wide variety of management and harvesting philosophies, from "leave the woods for the wildlife" to "sell to the first logger who knocks on the door with an attractive offer." Since there is fairly rapid ownership turnover (average tenure is about seven years), these lands are not likely to be managed in any consistent way over long periods.

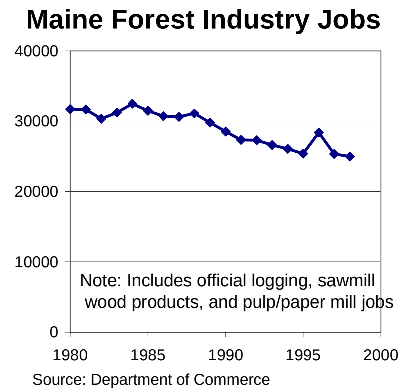
For the lands owned in much larger parcels by commercial entities, two important shifts in ownership are underway:

- Forest industry companies have been selling their land to investment groups and have shifted to managing their remaining land as an independent investment. This management style requires an annual cash-flow that justifies the investment.
- There has been a modest increase in the amount of conservation land, which is harvested on a long rotation, and reserve land (e.g., Adirondack park, the White Mountains, Baxter State Park), which is not harvested at all.

*Jobs*

Despite the increase in overall production from both pulp mills and sawmills over the last 30 years, employment in the industry has declined steadily. This is largely the result of investments in labor-efficient technology to decrease cost-per-unit and increase competitiveness.

Job loss has pressured communities in the region to generate additional primary or secondary forest industry jobs or to find other economic bases entirely -- one of which is tourism, which gives rise to the next set of divergent pressures, for uncut forests, intact ecosystems, and "big old trees."

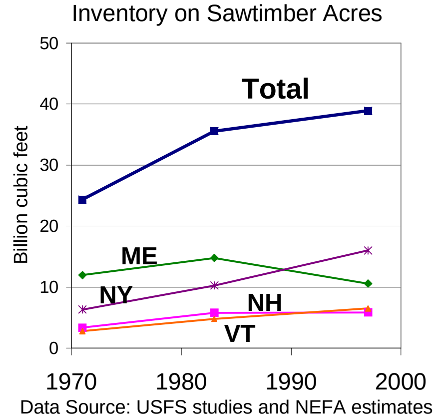



## *Environmental: Ecological Integrity and Resource Sustainability*

About 80 million people live within a four-hour drive of the Northern Forest. This largely urban population values the forest for tourism and scenic purposes. Over the last couple of decades there has been a shift from perceiving the forest primarily as a source of wood products to meeting a wide variety of ecological and recreational goals.

The community pressuring for recreation and ecological values would like to see:

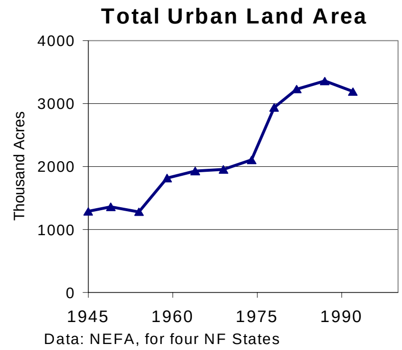
- *Resource Sustainability* – Overall standing biomass inventory on sawtimber acres (of harvestable size class) has begun to level across the region and has fallen in Maine, leading to concern about over-harvesting.[5]
- *More "Big Old Trees"* – For both habitat (age class diversity) and esthetic reasons, many people want older, larger trees, not plantations, certainly not clearcuts.
- *More Reserve Land* – Non-harvested land provides wilderness and, eventually, "big old trees."
- *Protection of Ecological Services* – More scrutiny of logging practices and other management would protect ecological services such as water storage, water purification, wildlife habitat, air filtering, and carbon dioxide storage.
- *Continued Access for Recreation*.




## *Urban development and fragmentation*

The last pressure (and the most irreversible) on the forest is the loss of the forest base itself to urban development and fragmentation into small parcels. This is happening primarily in the southern areas of New England as the urban areas push north and west.

Over the last century the forest actually increased in overall acreage as abandoned pastureland and cropland converted to forestland. However, this conversion is diminishing and now, for the first time, there is a net loss of forestland. In New Hampshire the rate of loss is 1% per year.

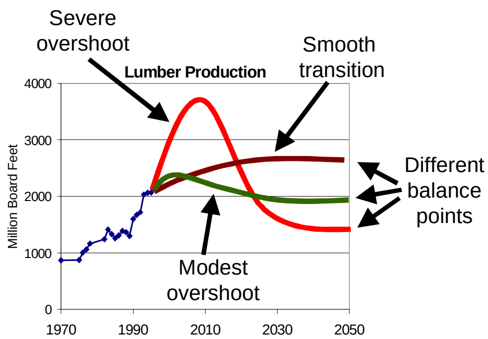


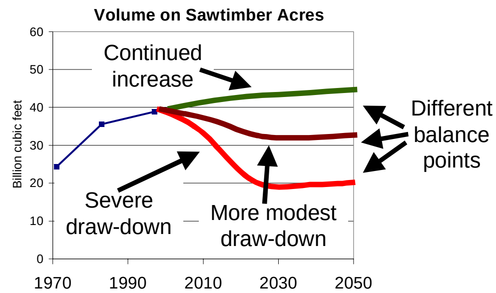

## *The Questions Motivating the Model*

Industry is presently increasing its demand for sawlogs. Increased demand for fiber may follow. At the same time, people in the region are demanding environmental services such as reserve land and big old trees. Thus, as we look to the future of the Northern Forest, the central question emerging from these various trends is:

***How can we resolve increasing industrial and environmental demands in the face of a limited and even shrinking forest base? What can regional leaders do to balance the competing pressures on the forest?***

We can imagine various futures for future lumber production and the volume on harvestable (sawtimber) acres, different transition paths, leading to different balances between the size of the industry and the size of the forest.




## Transition Paths

Will a falling forest inventory drive the mills to slow their growth, creating a smooth transition from growth to balance? Or will mill investors (particularly in sawmills) "overshoot" their long term sustainable level? In the forest, will the transition create a "draw-down" of the resource, necessitating a draw-down in economic activity? The diagram above outlines three possible scenarios for the transition in the industry and forest, ranging from a smooth transition to a severe overshoot.

## Final Balance

Whatever the transition pattern, where is the regional forest products industry heading? Towards a larger industry and smaller forest, or the opposite? Or are the two not mutually exclusive? The diagram above shows various possible outcomes.

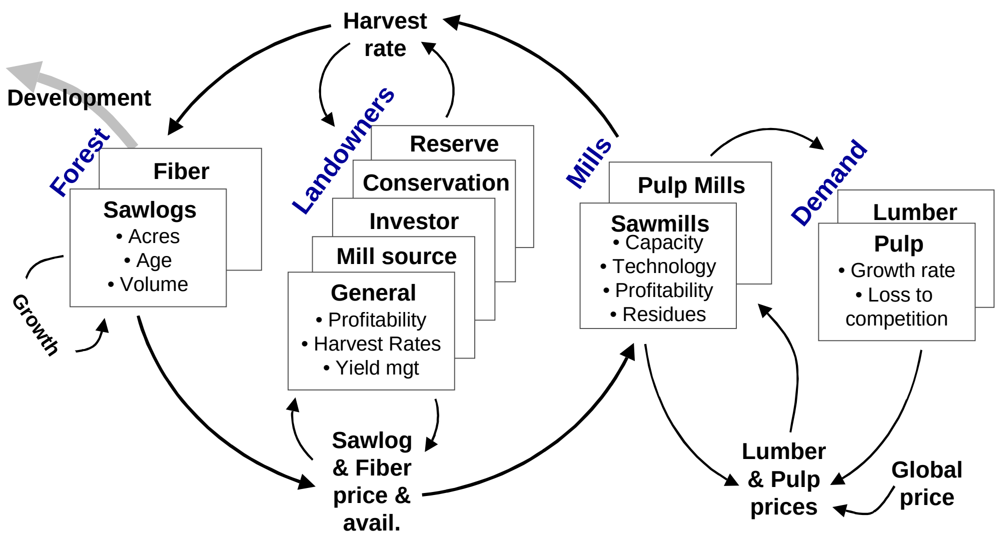
It is extremely difficult, probably impossible, to answer these important questions in our heads. To do so would involve keeping track of growing trees of different ages, of markets for standing and processed timber, of the decisions of landowners and investors, of changing mill technology -- all of which influence each other. Furthermore, this is a slowly unfolding system. Trees take decades to grow. Mills, once built, can keep run, if they are maintained and upgraded, for a century. The *dynamics* -- the changes over time -- as the mills affect the trees and the trees affect the mills are very complex. That's why we use a computer model to help us understand how the system is likely to unfold, and how various changes might change the way it unfolds.

# Modeling the Long Term Resource and Industry Interaction

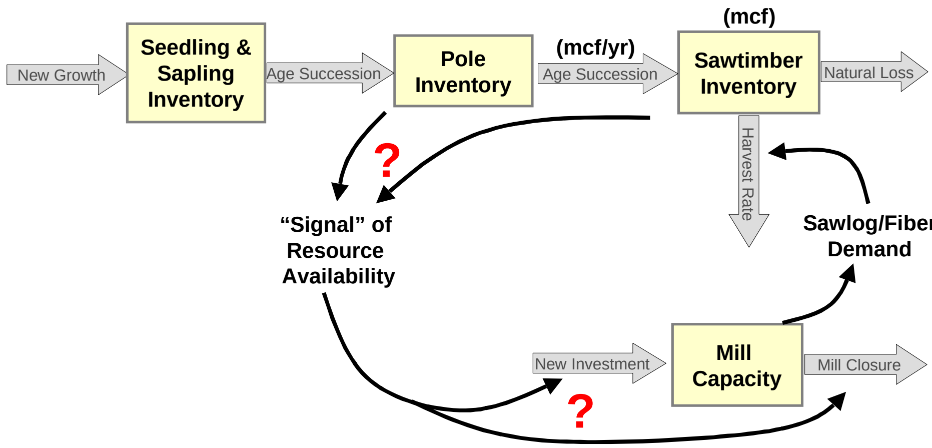
The diagram below shows the overview of our model.

## Structural Overview

There are four main sectors of the model, the *Forest*, which tracks total acres, average age/size of trees, and total standing inventory of fiber and sawlogs, the *Landowners*, who make local decisions on allowing harvesting and influencing prices, the *Mills*, who set the regional demand for fiber and for sawlogs, and ultimately the *Demand* for the lumber and pulp products, which sets the final product price.




At the heart of this model is the interaction between the forest aging chain and the regional mill capacity. The forest aging chain captures the aging delay in a forest – from seedling and sapling, to pole size, and finally to sawtimber size. The sawtimber inventory increases as trees mature from pole size and as already sawtimber-size trees continue to put on volume. Sawtimber inventory decreases through natural losses and through harvesting.




The regional harvest (for both sawlogs and fiber) is largely driven by the regional mill capacity (sawmills, pulp mills, and other fiber industry). New investment in the region in the form of new mills or more efficient technology in existing mills will increase the regional capacity, while mill closures will decrease it.

We assume that when there is no perceived supply limitation (no signal that there might be scarcity of fiber or sawlogs), then the forest industry will continue to invest in new capacity as long as there is sufficient demand and the mills are profitable.

A critical feedback in the system is how scarcity signals, whenever they are perceived, are communicated to the mills and how the signals influence mill investment, mill capacity utilization, and mill closure. From what we have been able to learn through interviews, the main feedback between the level of forest inventory and the mills is through the landowners and how they make decisions about whether to harvest, how much to harvest, and what price to charge for the trees that feed the mills.

### *Landowners*

We have divided the landowners into five classes based not on *who the owners are*, but *how they manage* their forestlands.

- The first two, general and mill-integrated, harvest in response to the demand and price for timber.
- The second two, investment and conservation, harvest based on a planned rotation, with only small variation to accommodate changing price or demand.
- The fifth, reserve, does not harvest at all.

One of the most interesting changes now going on in the Northern Forest is the great reduction in mill-integrated landholdings, and the rise in investment and conservation holdings. However the majority of the land continues to be held by general private owners, often in small plots with relatively rapid turnover of ownership.

| | **General (NIPF)** | **Mill-integrated** | **Investment** | **Conservation** | **Reserve** |
|---|---|---|---|---|---|
| Description | Small landholdings, typically with short tenure | Lands managed to make sure a mill is fully supplied | Lands managed to provide a steady return on investment | Lands managed for timber & ecological value | Ecological reserve |
| Est. % of Forest | 52% | 13% | 20% | 5% | 10% |
| Harvest Approach | Not planned, responds to price | Responds to mill demand | Plans a rotation, proactively contracts with mills | Plans a rotation, proactively contracts | No Harvest |
| Harvest "Rules" | Some % are willing to harvest, and they manage over a "planning horizon." They limit harvest by raising price | Harvest to keep price down and supply steady | Harvest at rotation goal, but will lower goal to meet ROI needs or if mills are facing supply scarcity | Harvest with a long rotation goal, will not harvest until forest ages | |
| Yield Management | None | May put land into plantation | Will invest in more thinning if pulp price is good (of less if price is bad) | Maintains a steady level of thinning | |

## The Base Run

The base run of the simulation model is a "no-major-change" scenario, assuming that people continue to behave in the future as they have behaved in the past. The resulting model run is not a prediction or forecast for the region, but rather a base against which many alternative assumptions can be compared. When anyone disagrees with an assumption in the base run or suggests a policy change, we can quickly alter the assumption or test the policy to see what difference it makes.

In the base run we are testing to see what would happen in the future:

1. if the primary signal about scarcity from the forest to the mills is the rising price of sawlogs or fiber and
2. if the mills invest in capacity as long as profits are good and slow down new investments, increase their investment in cost-saving technology, and speed the closure of old mills as profits go down.

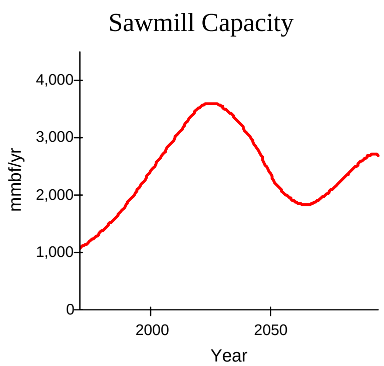
How is the sawlog or fiber price set? We assume that price begins to rise when demand by the mills exceeds the annual amount that landowners are willing to sell, the "annual market volume." The annual market volume is determined by two factors – the planned rotation harvest from the investor and conservation lands and the amount that the general and mill landowners are willing to harvest at the current price. We assume initially that 45% of the general landowners are willing to harvest in a given year, and that their planning horizon is ten years. These landowners will sell above their planned amount if the mills or loggers are willing to pay a higher price.

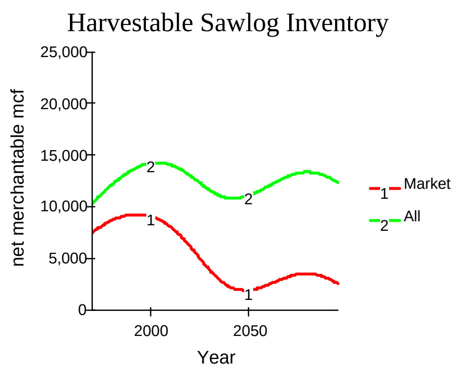
Two additional base run assumptions are that urban development removes forest land at a rate of 0.25% per year starting in 2000 and that lumber demand grows at 3% per year starting in 1970, slowing to 2% by 2010.

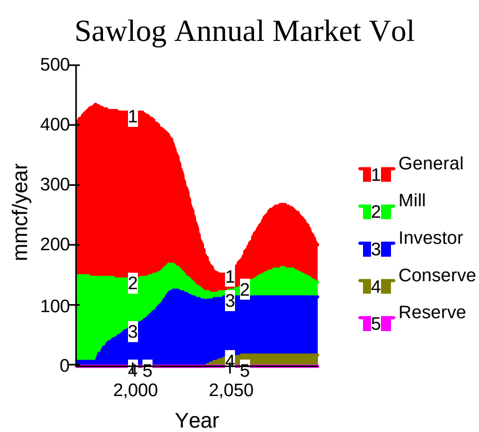
## *Resulting Behavior*

### *Sawmills and Sawlogs*

If we run the model under the above assumptions, starting in 1970, the sawmill capacity “overshoots” a sustainable level, as shown by the strong growth in the industry, followed by a peak and eventual contraction. Why does this happen? Basically because the mills draw down the inventory of accessible, harvest-sized trees. The harvestable sawlog stock, which is the net merchantable cubic feet of sawlogs that are of harvestable size, has two components: a market stock containing the general lands, mill lands, and investor lands and an overall forest stock which also includes the reserve and conservation land. As one can see, the market sawlog stock is significantly drawn down by the end of the run. Interestingly the overall volume standing in the forest has remain reasonably constant, because the reserve and conservation lands increase in volume. The result is a bi-modal forest, partly covered with large or maturing trees that are “off limits” for harvesting, and partly covered with saplings and poles that are cut quickly once they reach marketable size.



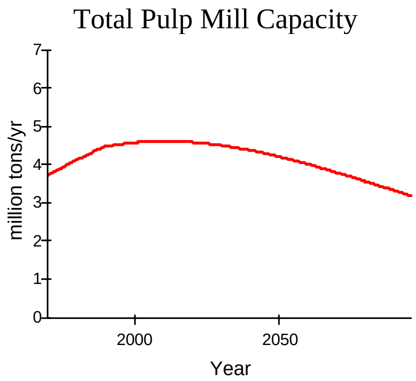



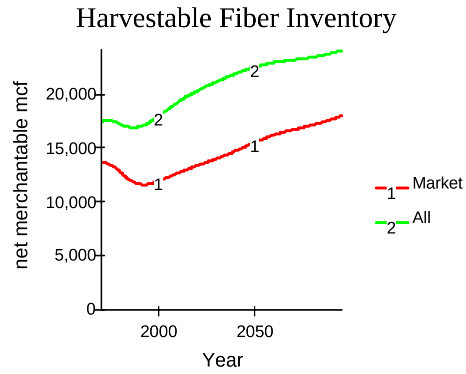

Looking to the “annual market volume,” which is the cubic feet of sawlogs that landowners are willing to sell at the “base price” (note that this graph is in a “stacked” format), we see a significant shift. Early on, there is surplus on the mill and general lands. After that surplus is drawn down, there follows a several-decade-long period of scarcity. During this time most of the supply comes from the investor groups that have managed on a rotation basis.

### *Pulp Mills and Fiber Inventory*

In our base run scenario, we have assumed that the pulp mills are relatively “persistent” – companies continue to run the mills for many years despite low profitability. We assume that investment and closure decisions are more a function of the global industry than the local resource price.

The fiber inventory on the working lands initially falls (the forest is increasingly young), but never to the level that landowners feel that it is a scarce resource. The inventory begins to increase as the pulp mill production gradually falls off.



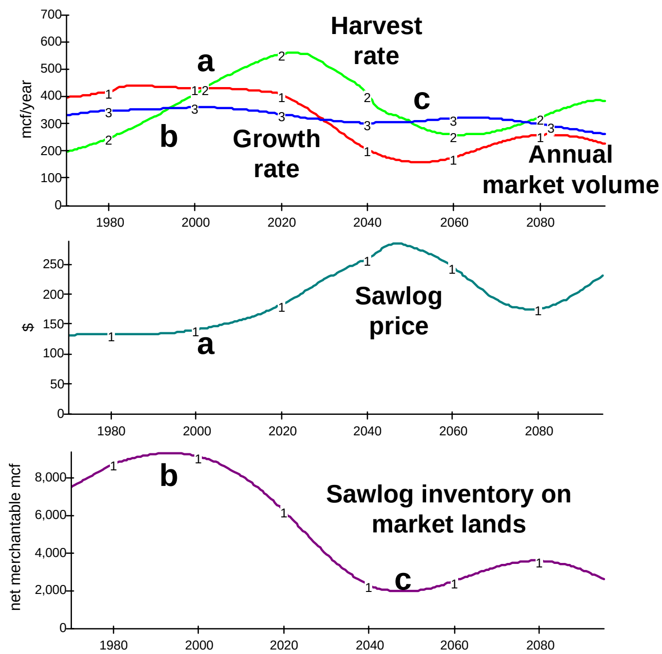




That said, similar dynamics (mill overshoot and resource draw-down) could play out for fiber-based mills if the region became increasingly attractive for oriented strandboard, fuelwood, or other fiber-using mills – possibilities that can be explored in further runs.

## *Exploring the Sawmill Overshoot*

Our method of analysis is most helpful when exploring dynamics that are driven by internal factors – in this case, the interaction of the forest resource and the mills. Because the future of pulp mills seems to be so dominated by external factors – in particular, global competition and global price – the bulk of the following analysis and policy testing focuses not on the pulp mills but on the sawmills.

So what caused the overshoot of the sawmill capacity and the draw-down of the sawlog inventory on the working lands? The following graphs illustrate the three main factors:




1. Some landowners are willing to sell (at the base price) based on their inventory, not on its sustainable annual growth rate.
   - In the top graph, for the first 30 years the *Annual market volume* (the amount that landowners are willing to sell at current prices -- #2) exceeds the *Growth rate (#3)*. People are willing to sell more than is coming available.
   - At point (b) in the top graph, the *Harvest rate* (#1) begins to exceed the *Growth rate* (#3), so the *Sawlog inventory* in the bottom graph begins to fall.
2. Some landowners will sell above the *Annual market volume* if the price increases.
   - In the top graph, at point (a), the *Harvest rate* (#1) exceeds *Annual market volume* (#2). That is, the mills want to buy more than the landowners are willing to sell. So landowners raise the sawlog price, starting at point (a) in the second graph. Price rises and sales of sawlogs follow the increasing *Harvest rate*.
3. Many balancing effects dampen the price signal, leading to a long delay before the mill capacity and *Harvest rate* come back into balance with the *Growth rate*.
   - In the top graph, it isn't until about 2045, at point (c), that harvest equals growth. This is the same time, in the bottom graph, that the Sawlog inventory stops its decline at point (c).

*Why does it take 55 years of over-harvest before harvest and growth meet?* Because the actors in the system are taking a number of corrective actions to keep the sawlog-based industries profitable and growing even in the face of raw material shortage. For example:

***1. Landowners boost availability***

Higher sawlog prices offer higher potential returns for landowners, leading general, mill, and (potentially) investor landowners to increase harvesting, effectively increasing the available sawlog supply, dampening the price increase, and delaying any reaction from the mills. The greater this "elasticity of availability," the more the sawlog harvest rate tends to rise above the growth rate before the correction, leading to more mill capacity overshoot and more resource draw-down.

***2. Sawmills invest in technology***

Higher sawlog prices reduce mill profitability, leading the mills to seek ways to reduce costs. The primary strategy is to invest in cost-cutting new technologies such as mechanical sorters, hi-tech scanners, computerized log-positioners, automated measurement devices, thinner saw-blades, small-diameter saws, and curved-saw technologies, which together have reduced the number of workers needed to run the mills, minimized the sawdust and chips that are a by-product of the milling process, and expanded the pool of sawlogs that a mill can use. The result of these responses is to increase the raw material price at which sawmills can stay profitable. The mills can "ignore" the scarcity signal for longer and grow further beyond the sustainable supply, exacerbating the overshoot and deepening the resource draw-down. It is counterintuitive, but understandable, that the most lauded and exciting response to industry challenges – mill technology – actually can hurt the long term resource demand and supply balance.

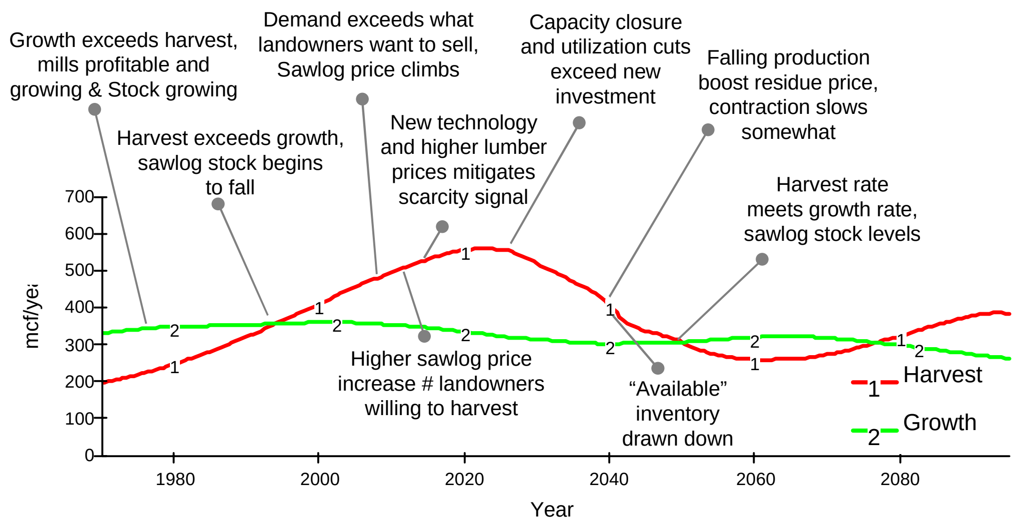
***3. Technology investment accelerates capacity "creep"***

To be economical, new technologies generally require higher throughputs than old technology, increasing overall mill capacity and driving the harvest above the growth rate even more strongly. The result is a "tragedy of the commons" where individual mills benefit by being the first to grow larger and reduce per-unit costs but all mills are eventually hurt by the effects on sawlog inventories, sawlog price, and profitability.

***4. The lumber and residue markets delay capacity correction***

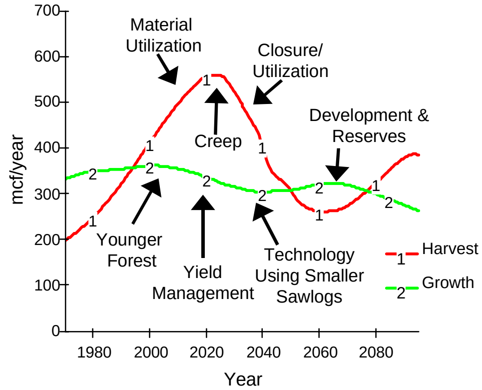
The residue (slabs and sawdust) from sawmills is typically sold to pulp mills, somewhat enhancing the profitability of the sawmills. When lumber production finally falls relative to lumber demand, and sawmill residue production falls relative to residue demand, lumber and residue prices can rise, buffering sawmill production yet again from the signal of scarcity. The result is more mill overshoot and more resource draw-down.

It is important to note that this industry exceeds its carrying capacity for decades **not** because anyone is particularly greedy or ignorant – but because all actors in the system are taking perfectly rational actions to preserve their livelihoods. The economic actors are caught in a "system trap." The system itself, through prices and profits, is not providing the signals people need, to know they are collectively generating a problem.



## Policy Runs

This undesirable future in which both the forest and the industry decline is not the only possible outcome, just the result of "business as usual." The most common suggestions for policies that could improve the Northern Forest economy fall into two categories:



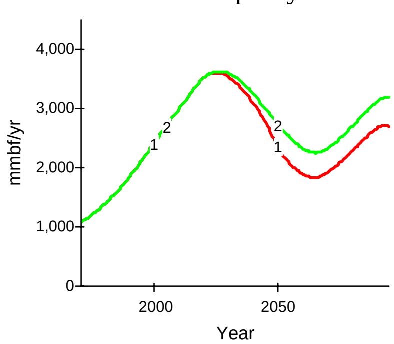

1. **Close the gap** between harvest and growth rates (the diagram to the right shows the various forces pushing the growth rate up or pushing the harvest rate down). Examples include:
   - Increasing forest growth rates
   - Banning sawlog exports
   - Better mill technology
   - Stop loss of forestlands to development
2. **Shift land ownership** so that the land is managed for different goals and by different plans:
   - More reserve land
   - The Triad scheme (plantation, selection, reserve)
   - Different management assumptions within a landowner class
   - Conservation Easements

These changes can be tested in different combinations and varying degrees. Here we will apply them one at a time, so we can understand their effects..

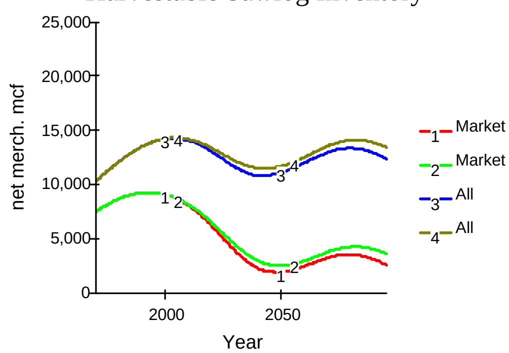
### *Ending Development of Forestlands*

Many people's first reaction to the base run is to guess that there would be no overshoot if there were no development and fragmentation of forestlands. So our first policy test is an elimination of the current 0.25% per year loss of forestlands. The result? The following graphs show the comparison between the base run (#1) and the run with no development (#2).

Sawmill Capacity




Harvestable Sawlog Inventory

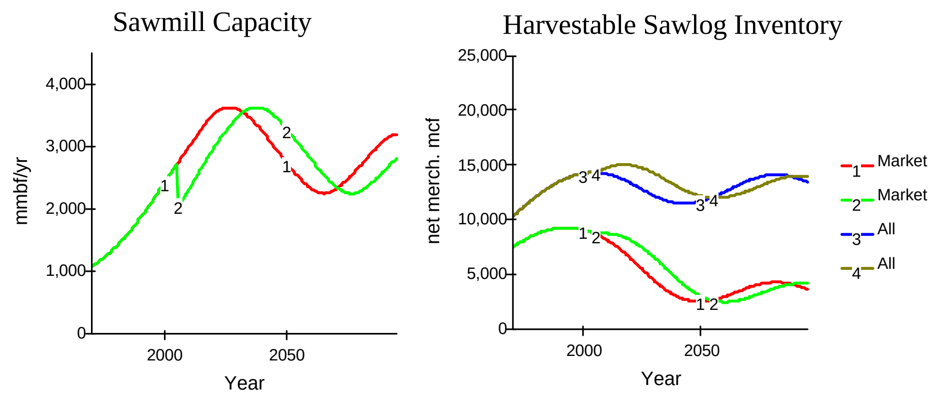



Eliminating development decreases the depth of the sawmill capacity decline – the larger forest can support a larger industry in the long term. But it does not eliminate the overshoot and correction of the industry – the harvest rate still exceeds the growth rate until the mills correct their overcapacity. Interestingly, the change does little to boost forest inventories (on the right) – the extra timber supply on the undeveloped lands is quickly utilized by the slightly larger industry.

In order not to confuse the effect of development with the other dynamics, all the remaining base runs and policy/uncertainty tests shown here will also assume no further forestland development.

### *Eliminating Canadian Exports*

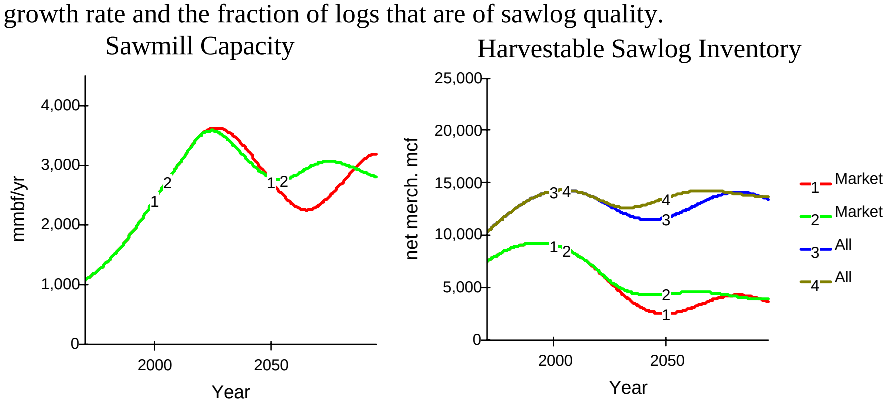
One of the popular complaints in the Northeast is that the growth in Canadian mills is driving the potential for regional over-harvesting. If only the Canadian mills were prohibited from using Northern Forest timber, says the theory, then the sawmill business south of the border would thrive. To test this proposition, we "shut down" all export to the Canadian mills in the year 2005. In the base run, the "Northern Forest" sawmill capacity includes mills on the Canadian side of the border, since they are dependent on U.S. forest as their primary resource base. So our "eliminate Canadian export" policy is modeled by shutting down capacity equivalent to the current export levels to Canada, about 25% of the total lumber production in the Northern Forest. The results? The following graphs show the comparison between the base run (#1) and the run with the export reduction policy (#2).




The reduction in export (modeled by a sudden reduction in sawmill capacity) does not solve the overshoot problem, it simply extends the length of time it takes for the industry to grow beyond a sustainable level. This occurs because the sawmill industry will grow (through investments and new technology) as long as demand is growing and profits are good. Eliminating exports allowed the local industry more room to grow, but it did no better at avoiding overshoot, because the basic system has not been changed. The delays in the price signal are still in place.

***Investing in Yield Management***

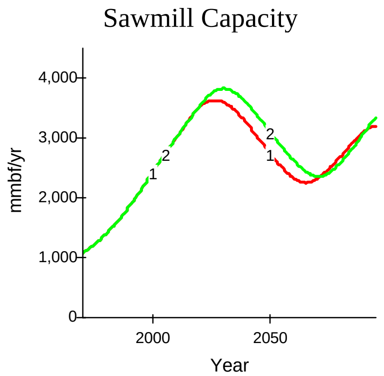
On the other side of the solution spectrum is the proposal that, if there is a forecasted gap between harvest demand and supply, landowners should simply increase their investment in yield-enhancing techniques such as thinning and plantation management. If the forest can just grow faster, the overshoot can be mitigated. In this scenario, we have assumed that in 2000 the mills start managing one half their land in high-yielding plantations, while investment landowners increase their investment in pre-commercial and commercial thinning. The result of these investments is to increase the growth rate and the fraction of logs that are of sawlog quality.

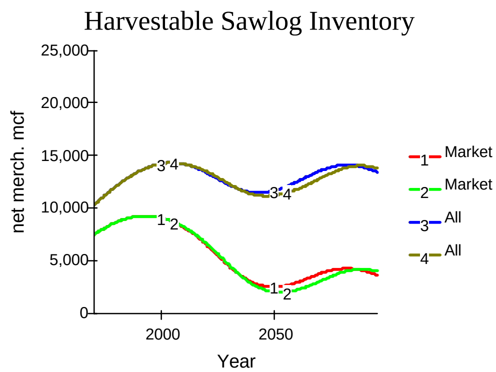



The result? Some improvement. Even plantations take about 40 to 60 years before harvest, so there is a long delay before significant benefits appear. More importantly, while yield management boosts the growth rate closer to the harvest rate, it does not help the system *maintain a balance* between harvest and growth in the long term.

***Boosting Sawmill Material Efficiency***

Many resource policy analysts (the authors included) have looked to improvements in technical efficiency as a solution to economic/environmental challenges such as we face in the Northern Forest. At the extreme, Hawken, Lovins, and Lovins calculate that "today's best techniques for using wood fiber more productively could supply all the paper and wood the world currently requires from an area about the size of Iowa."[6] What would be the effect of significant acceleration of technological gains in material use efficiency in sawmills? What would happen if the region's sawmills introduced thinner saw-blades, computer-controlled routing and sawing systems, and other scrapcutting improvements at an even faster rate than projected? The efficiency scenario (#2 in the sawmill capacity graph) boosts the rate of increase of the lumber recovery factor from 3.9% per decade to 6.1% per decade starting in 2000.



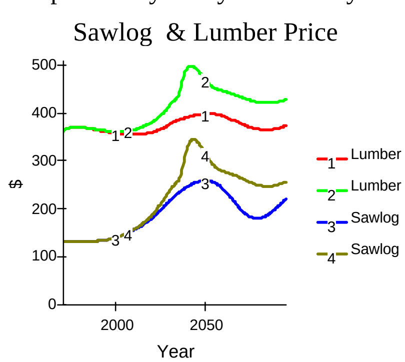



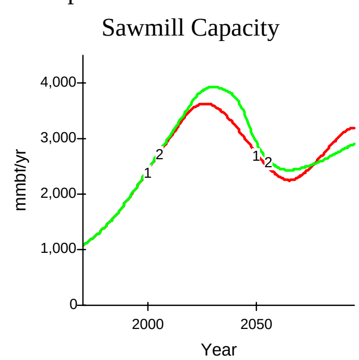

The result is that the mills grow larger and overshoot slightly more than in the base run, with the forest draw-down almost identical. What happened? The harvest rate is initially lower due to the improved mill efficiency. It takes less timber to produce every unit of finished lumber. However, two compensating effects in the overall system reduce the benefits. First, mills expand to use the newly available supplies. Second, the reduced raw materials costs allows the mills to stay profitable (and therefore expand) at an even higher sawlog price – the improvement has helped further dampen the scarcity signal from the forest to the mills. Mills expand for ten or so more years and sawlog price rises even higher before the correction.

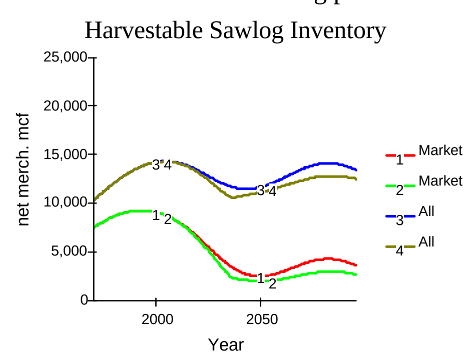
That's not to say that increasing wood use efficiency is a bad idea -- obviously to get more finished product out of every log is an improvement. But it is to say that it does not solve the system problem of stopping the growth of mill capacity before it exceeds forest capacity.

***Finding "Niche Markets" -- Passing Raw Material Costs Onto the Customer***

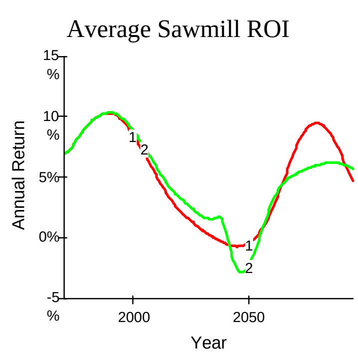
For niche products such as some hardwoods, it is possible for sawmills to pass increases in raw material prices to the customer through higher lumber prices. What if the mills succeeded with such a "niche market" strategy? To test this possibility we systematically raised the price that mills receive for their finished lumber as sawlog price rose.




Higher lumber prices boosts mill profitability enough to continue capacity expansion for another five or so years, drawing down the sawlog inventory somewhat faster and causing sawlog price to spike even more sharply. The result is a later and deeper net contraction (peak to valley) for the sawmill capacity and, at right, a more profitable short term followed by a less profitable long term. Finding niche markets delays and intensifies the difficult transition from growth to balance as the sawmills struggle to survive with low sawlog availability.



***Changing Land Ownership to Reserve/Conservation and Investor***

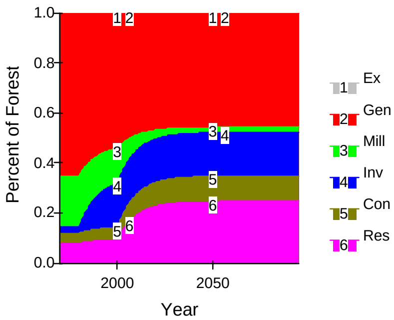
Many people look to different land ownership patterns as a leverage point in improving the behavior of the system. This section explores two possibilities – more land in reserve/conservation and more land owned by investors. The following table outlines the initial values for 1970, the 1997 values (which persist through the base run), and then two further scenarios, investor-dominated and reserve-dominated.

| | Initial values (1970) | 1997 (base case) | Investor-dominated | Reserve-dominated |
|---|---|---|---|---|
| General | 65% | 52% | 42% | 47% |
| Mill | 20% | 13% | 3% | 3% |
| Investor | 2% | 20% | **40%** | 15% |
| Conservation | 4% | 5% | 5% | **10%** |
| Reserve | 9% | 10% | 10% | **25%** |

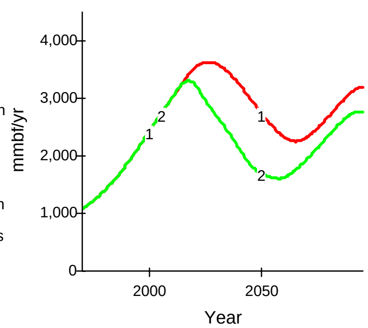
*Reserve/Conservation*

To shelter wildlife and restore ecosystems and to provide recreation and tourism, many people propose an increase in the amount of land managed by conservation groups and held in reserve. That policy, with no other changes, leads to a starkly bi-modal Northern Forest -- part big old trees, part quickly harvested poles.

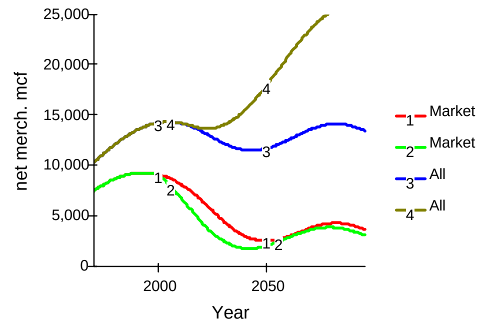
Land Class Status




Sawmill Capacity

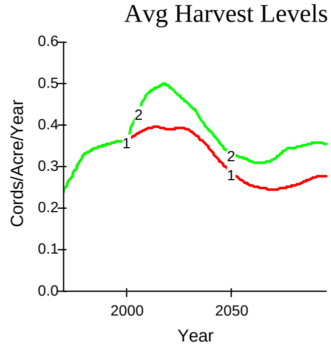



Harvestable Sawlog Inventory




In the "Land Class Status" graph (which shows percentages of forestland in a stacked format), the fraction held in conservation and reserve can be seen to increase significantly starting in 2005. With less timber on the market, sawlog prices climb earlier and sawmill capacity contracts earlier, but still with an overshoot. The harvestable sawlog inventory on all lands skyrockets relative to the base – the reserve and conservation lands are adding more and more "big old trees." In one sense, the policy has succeeded, increasing the amount of lands with significant inventories. But the sawlog inventory on the still-harvested lands seems to actually crash faster. What happened?

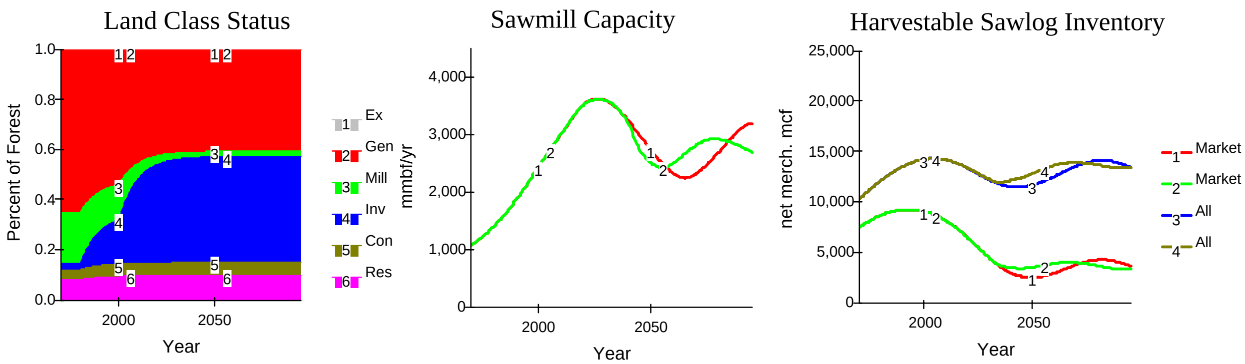
Avg Harvest Levels




One can see the answer by examining the harvest rate on the general lands. Once the shift to reserve and conservation land is implemented, the growing demand for sawlogs concentrates itself on a smaller "working forest," leading to more intense harvesting on those lands, particularly the general lands. The protected lands are old and well-stocked but the working forest is young and thinly stocked. One could guess that around 2030 to 2050, when mills are closing and the entire industry is cutting jobs and sawlog prices are very high, there would significant public pressure to harvest some of the attractive and valuable sawlogs in the reserve and conservation land. Such a challenge is similar to what has recently happened in the Pacific Northwest, where the private lands were logged very intensively, increasing the pressure to open up the public lands.

*Investor*

What if land ownership were increasingly dominated by investor-owners who managed their land by planned rotation for long term cash-flow? The key change is a boosting of investor land ownership to 40% starting in 2005.

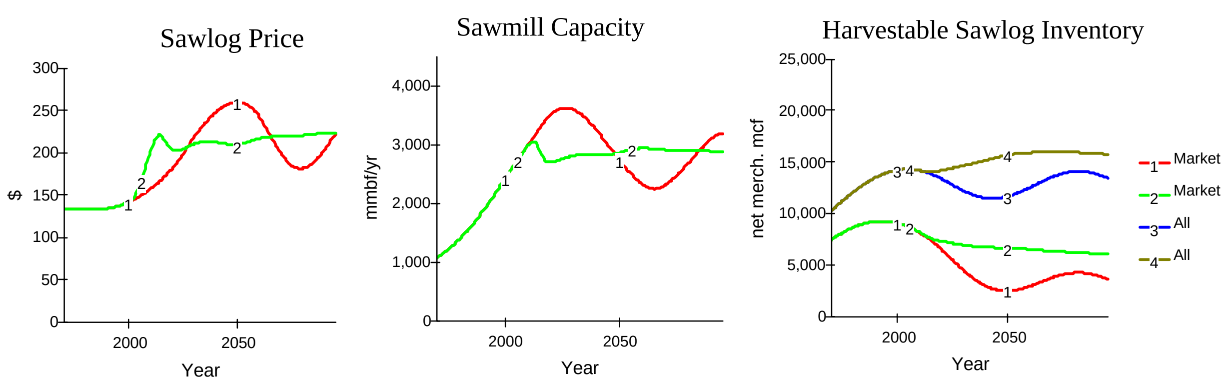



With more land owned by investors, more land is managed by rotation and less timber is available to come on the market in response to short-term scarcity. This sends sawlog price higher faster, driving a faster correction and crash by the mills. Sawlog inventories do not fall as much as in the base run, so the sawmills rebound earlier. By 2040, the supply from the general lands is all but decimated. Over 80% of the timber supply comes from the investor lands. The shift towards investor ownership improves the industry and forest rebound after the correction, but does not solve the initial challenge of protecting the unmanaged lands from draw-down.

***Changing General Owner Land Management Policy***

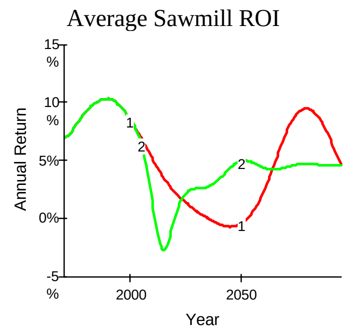
So what would happen if the general landowners operated closer to a planned management basis? In this scenario we extend their planning horizon to 15 years and decrease their sensitivity to price. These changes phase in starting in 2000.

- *Planning horizon* – The planning horizon is used to determine, for those landowners willing to harvest, how much of their inventory they are willing to sell in a given year at the base price. Our starting assumption is that the general landowners have an average 10 year planning horizon (1/10 of their inventory is the annual market volume). In this run we extend it to 15 years.
- *Sensitivity to price* - When demand exceeds the annual market volume, loggers and mills start offering higher prices. The variable "sensitivity to price" determines how much price has to increase in order to induce the landowners to offer more stumpage (for those already willing to harvest). Our base assumption is that the loggers and mills would have to increase price by 18% to boost the supply by 20%. In this run it takes a 50% price increase to boost supply by 20%.




The results? With the longer planning horizon and lower sensitivity to price, the sawlog price rises more quickly than in the base scenario. This causes the sawmills to reduce investment in new capacity much sooner than before. The market sawlog inventory stays higher than in the base run, but continues to decline at a slow rate, showing that industry is still harvesting above the sawlog growth rate.

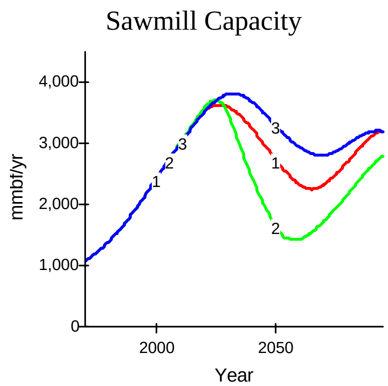
Interestingly, while sawmill growth is much more limited than in the base run, and mills are hit hard by the sudden reduction in supply from the general lands, they maintain a significantly higher profitability during this simulation and avoid the next boom bust cycle. In this way, the policy creates a "worse-before-better" future for the mills and largely avoids a significant draw-down of the forest resource.

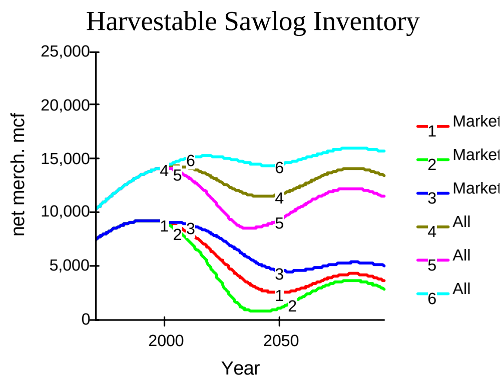



***Sensitivity testing***

What if we underestimated or overestimated the forest growth rate? What if it is 20% faster or slower than we thought? In this run we change the growth rate starting in 2000. One might think of the 20% slower scenario as a worst-case "acid rain" future, in which acid deposition accelerates the leaching of calcium out of the soil, slowing growth.

In these runs, to test the robustness of our results, we show the base run compared to both a 20% decrease in growth rate (green run #2) and a 20% increase growth (blue run #3).




The pattern of behavior does not change – overshoot and recovery for the mills, draw-down and recovery for the forest. What differs is the *scale* of the dynamic – the height and timing of the peaks and troughs. This helps build our confidence that different estimates of inherently uncertain key parameters may not lead us to different policy conclusions. (We have done many more of these sensitivity tests, not shown here).

## Insights

In system terms, when you have one large stock (mills) that both affects and is affected by another (trees in forests), you have a structure that is likely to oscillate, as each stock tries belatedly and inefficiently to adjust to the other. When both stocks contain long-lived, slowly growing entities, the oscillations are likely to be very long -- decades of growth, followed by decades of decline. A very difficult system upon which to base the economy of a region.

In the Northern Forest system, the overshoots are exacerbated by the sequence of decision-makers (landowners, loggers, mill managers, mill investors) who are trying to react to either abundance or scarcity of the forest resource. Some of the decisions they make, designed very rationally to keep themselves in business or to shore up falling profits, have the effect of making the oscillations worse. For example, when landowners (including the public) have enough standing forest inventory that they are willing to sell above the growth rate, and when mills are able to adapt to higher prices and continue producing even when landowners start to signal scarcity by raising price, then the forest industry will exceed the size that can be sustainably supported by the forest base.

The model demonstrates several factors that can make the magnitude of the overshoot more extreme:

- **A large initial standing inventory** allows the mills (and the harvest) to grow for a long time before the inventory is drawn down enough to create a sense of scarcity among the landowners. The larger the initial inventory (and the lower the "threshold" at which landowners feel that the inventory is becoming scarce), the larger the gap will be between the harvest rate and the growth rate when the system finally tries to come into balance.
- **The more "elastic" landowners are to price**, meaning that they are willing to sell more when price increases, the further down the inventory will be drawn down before the price signal is too strong to ignore.

- **The more that mills are able to absorb or adapt to price increases**, the longer they will be able to "ignore" the price signal, and the longer production and harvest will stay out of balance with the growth rate.
- **The faster that mills are growing**, and the longer the life of the capacity, the more funds will be invested in the region as sunk cost at the time when signals indicate that production is out of balance with the supply. This sunk cost creates an incentive to continue operations, even at a cash flow loss, to pay back the sunk investment. This increases the delay between when the mills receive a signal and when mills actually reduce production.
- Finally, **the more that price increases are able to be passed on to the consumer** without reducing demand, the less effective raw material price will be at reducing production (and harvest). If the consumer is willing to pay virtually any price (as is the case with some tropical hardwoods used for luxury manufacture), then only absolute shortage will result in decreased production.

The question posed at the beginning of this project was how people in the Northern Forest region can balance increased environmental and industry pressures, in the face of a potentially shrinking forest base. While there are many value choices to make in the region about the desired balance between ecological reserve, the average age of the forest, and the sawlog/fiber harvest, we have learned that no solution aimed at influencing this balance is effective without first stabilizing the system and protecting it against its inherent structural tendency to overshoot.

***How might we stabilize the system?***

Improving mill efficiency, banning exports, raising forest growth rate, all make only small changes in the basic overshoot scenario. They do not affect the basic system flaw – the long-delayed feedback between forest inventory and mill capacity –that determine the system's basic tendency to oscillate. But other changes do.

Capacity overshoot results from the system responding to growth in demand, so if there were stable consumer demand for lumber or fiber products, there would be no danger of overshoot. (As long as the demand stabilizes below the long-term growth of the forest.) Alternatively, if the industry did not use profits to increase capacity and production (if industry had no inherent urge to grow), there would be no increase in harvest rate and therefore no danger of overshoot.

If capacity re-investment and consumer demand for lumber and fiber continues to increase (which would result not only from global demand, but from decreasing supply in other forest regions), then we need to look for leverage points within the regional forest system that would help stabilize the system.

We have found the most powerful leverage points in the ways that the system sends and responds to scarcity signals. There are two ways for a signal of scarcity to travel from the forest to the mills. If **price** is the primary signal, then in order to help stabilize the system, it is necessary to raise price strongly and quickly as the harvest rate exceeds the forest growth rate. Two ways to do this (at least in theory) are to encourage landowners towards a longer planning horizon, so that their desired sales are more in line with growth, and to reduce the landowner tendency to sell more if price is high. It is also necessary for the mills to deal with the signal directly at the mill end by reducing overall resource demands, not by compensating for the signal by cutting costs.

The other alternative is to design signals **other than price**. People in the region can agree to cap the harvest rate (maximum allowable cut) below the growth rate. Long rotations can be followed faithfully no matter what the short-term market is doing.

Various combinations of these leverage-point policies -- slow demand growth, slow industry growth, enhance the timing and strength of the price signal, manage the forest from resource-based signals rather than price-based signals -- can produce model runs in which the overshoot and decline of forest-based industries is damped or completely absent. A profitable, stable, sustainable forest economy is possible. There is no single "magic bullet" way to produce it; there are many possible ways. It is up to the people and the industry players in the region, not the modelers, to work them through. We do not have a "favorite policy" to recommend; however there is one we have explored with the model that we think will work. It is not the *only* stabilizing policy, but we will use it as an illustration that stabilizing policies do exist.

***Looking to the landowners***

The more landowners manage their harvests based on growth (such as in a planned rotation or a long planning horizon), the more likely there will be a balance between growth and harvest. But how to make this happen, particularly for "general landowners," with their small holdings, short tenure, and large numbers? The closest policy we have heard of is the movement for cooperatives such as Vermont Family Farms, which help multiple small landowners operate as large planned forests.

Long planning horizons help improve the transition from growth to balance. However we are concerned about the resiliency of this policy during periods of price extremes. When sawlog price increases, profit opportunities may pressure landowners to pull out of the co-ops and sell more timber. And why not? They have little incentive to plan for a continued flow of cash. When sawlog price falls, on the other hand, investor landowners who are failing to meet their profit-based cash flow goals may be driven to either sell land or cash in their inventories. Either way, our proposed policy may be vulnerable at the extremes.

***Levels of balance and distribution***

Leaving aside the question of overshoot and transition, the forest-industry system can stabilize in a wide range of balance points, most of which trade off the average age of trees in the forest with the size of the industry and harvest. Several decisions strongly affect the balance, including investments in yield management, amount of land in reserve, rotation length, and the rate of urban development and forestland fragmentation.

One future, with most land managed in longer rotations leads to a relatively uniform forest. In another, a split of land in reserve and land in short-term management leads to a strongly bi-modal forest. The proposed "Triad" scheme (reserve, selection, and plantation) and other plans might fall in the middle.

## Next Steps

We see three different kinds of next steps to take with this model and the insights it is beginning to produce:

First, in order to build confidence in the model and expand its ability to test various policies, we need to **extend the model to the complete commodity chain.** We need to include the loggers as another capital sector between landowners and mills -- this may affect the speed and accuracy with which the price signal comes from forest scarcity to mill investment decisions. We need also to represent in more detail the "downstream" flow of forest commodities from mill to consumer -- not only to represent price signals and feedback more accurately, but to begin to explore the competitiveness of the Northern Forest in the global forest products markets.

Second, we need to **make the model more public** and put it in the hands of Northern Forest stakeholders. This will not only give us constructive criticism and help us hone the model's clarity and accuracy, it will also, most importantly, begin the public dialogue that is necessary for the region to confront and decide on the issues raised by growing imbalance between its forest resource and the capacity of its forest-based industry.

The best way for someone to learn about the drivers of overshoot and draw-down in this system is to experiment with the model behind this paper. Therefore, we have constructed a relatively user-friendly interface so that a non-modeler, with a little coaching and support, can explore the various graphs in the base run and then compare them against various "what-if" tests they can select from the model's "control panel". We have embedded the model testing in a one-day to two-day workshop that we are presently running for various groups of policy makers, business people, and community leaders around the Northern Forest.

We hope that the workshops will help people to improve their intuition about what interventions are likely to help the overall Northern Forest forest and forest-based economy in the long term. At its best, the experience will lead to quotes such as the following, from a workshop participant, "I'm going back to my work having seriously questioned a couple deeply-held assumptions about how some policies are going to help or hurt the environment and the industry."

Our third "next step" will be to **reach out to other forest regions**. Many of the insights we have generated in our research in the Northern Forest may be applicable in other regions. We are presently exploring how a similar model-building and workshop-designing effort might be applied to the Southeast U.S. region with its growing stock of chip-mills.  We would also be interested in projects that would allow us to apply this modeling technique to the forests of the Pacific Northwest and to tropical forests.

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[1] Wood Flows Report, Irland, 97 data.
[2] Wood Flows Report, Irland.
[3] Wood Flows Report, Irland.
[4] The Northern Logger and Timber Processor.
[5] Some analysts have expressed concerns about comparing these data year-to-year.  The early 1970s data points actually come from a range of dates between 1968 and 1973 and the early 1980s data actually comes from a range of dates between 1980 and 1983.  What matters for this analysis is the general trend of behavior over time.
[6] Hawken, Lovins, and Lovins, "Natural Capitalism."