Exploring the Long Term Dynamics of Timber Supply in Virginia using the Virginia Timber Dynamics Learning Environment

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Abstract

A system dynamics model has been developed to explore causal links, dynamics, and environmental effects associated with timber harvesting in Virginia. The model, called the *Virginia Timber Dynamics Learning Environment* identifies the impacts of accelerating rates of forest clearcutting and information delays associated with forest inventory methods on land use policy, stream water quality, stream water quantity, forest type, forest distribution, timber supply, timber availability, and wood processing capacity. Harvesting rates from 1940 through 1997 are accurately predicted. This paper describes several trends in timber supply, timber availability, and wood processing capacity as identified by the model, and the sometimes counter-intuitive consequences of several timber management alternatives. Scenarios beginning in 1940 are projected through 2020.

The Situation

Virginia's forests are changing. Prior to European colonization, the land we call Virginia was dominated by a nearly contiguous forest. Much of this land was first cleared by Europeans for settlement and agricultural production. After enduring the civil war, and several generations of farming, much of it is again reclaimed by trees. Forests now comprise 61 percent of Virginia's land area, increasing from 35 percent in 1920.[1] This is partly a direct result of aggressive reforestation programs that, since 1930, have sought to reclaim abandoned agricultural land, and establish fast growing, high volume timber supplies on forest lands. This activity has helped reduce soil erosion and supply an expanding lumber, pulp and paper industry.

Abandoned farmland, aggressive reforestation, rapid advances in technology and mechanization, and accelerating demands for wood products have allowed Virginia's forest products industry to grow at an increasing rate. Forest products industries now add 9.8 billion dollars annually to the State economy, compared with 3.2 billion dollars annually just 12 years ago[2] Since 1950, rapid advances in technology and mechanics have allowed harvesting machinery to become more powerful and efficient. An accelerating demand for wood and paper products has allowed wood processing capacity to grow exponentially. In 1993 pulp mills in Virginia processed almost 4 million cords of wood, more than four times the amount processed in 1940. Since 1940 processing capacity is doubling every 51 years.

These events have fundamentally changed Virginia's forests. Since 1950 the pace of change has been accelerating. While measurements now show that standing timber volumes are three times greater

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[1] Statistics Compiled by The Chesapeake Bay Program Forestry Work Group.
[2] Virginia Forests Our Common Wealth, 1984, 1995.

now than they were in 1940, statistics from the 1992 US Forest Service timber inventory also indicate that, for the first time in recent history, the timber *harvesting rate* almost exceeds the timber growth rate. It is likely that timber harvesting rates will exceed timber growth rates by the end of the century. Moreover, population growth and material consumption are generating land use changes of unprecedented scale and speed. Forests are being sought and consumed for may reasons. Urban sprawl is encroaching on forested landscapes. Houses, office buildings, factories, and roads increasingly occupy once unbroken forest land. Many forests thought accessible for timber production as recently as 1990 are now part of urban areas where they are often occupied, fragmented, less available to timber cutters, and in general less dependable as part of a long term timber resource base. Population growth and material consumption are expected to continue at increasing rates.

These changes have renewed calls to sustain forests. Many people, including environmental activists, foresters, loggers, and mill owners, are unsure about how the accelerating pace of change will affect forest ecology, the forest environment, or timber supplies. US Forest Service Inventory data and other information are being reexamined in hopes of determining what the future may hold. The problem is that these data alone are only somewhat helpful. They provide a detailed snapshot of certain past events, but the events are seen as static and seemingly unconnected. These statistics don't tell us much about the *rate* of change. They don't tell us at all about what *causes* change.

This paper describes a system dynamics computer model that attempts to delve more deeply into the rates and causes of this change. The model approaches the question of change from a new angle. It identifies the structure and connections between parts of the timber supply system that help produce change. Using simulation, a dynamic, rather than static representation of on-going events is produced. A dynamic representation of on-going events is needed to understand the *rate* of change. A knowledge of the structure, or operational physics, of the timber supply system is needed to understand what *causes* change. Since the model identifies structural relationships, it may be used to simulate the effects of proposed management strategies before they are actually implemented.

Three Ideas of "Reality"

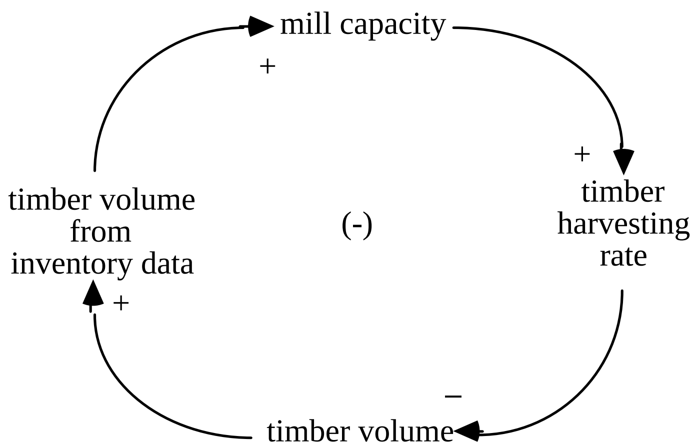
When we think about the timber supply, many of us think linearly. We imagine cause and effect in a straight line or "open loop," as shown in Figure 1. Timber volume creates opportunity for wood processing. The more timber available, the more we can process. Often, decisions to build new lumber or paper mills, that often risk millions of dollars in investment, research, planning, and development, are made using little more than cause and effect thinking. If analyses of forest inventories, available markets, and transportation systems show that a large stock of timber is available for harvesting, processing and delivery to consumers at a profit, then decisions are often made to proceed with mill construction. If larger volumes of timber are available, it is reasoned, then more processing capacity, and profit, can be created.

Figure 1: Linear Cause and Effect

timber volume from inventory data $\xrightarrow[+]{}$ mill capacity

A first step toward understanding the *structure* of a timber supply system is recognizing that linear "cause and effect," "open loop" thinking produces an incomplete, less useful picture of reality. A more complete idea of a timber supply system is illustrated as a "closed loop" as shown in Figure 2. Note that, in this representation, four major parts of a timber supply system interact in a *circular* way. Timber volumes influence construction of milling capacity, as in Figure 1, but unlike Figure 1 cause and effect do not stop there. Milling capacity influences the timber harvesting rate. Timber harvesting rate influences timber volume, or stock of available timber. Timber volume cycles back to again influence milling capacity. Rather than an "open ended" system where large amounts of available timber mean potentially larger processing capacity, in fact the system is "closed." Measurements showing large stocks of timber encourage increases in processing capacity for a while. Increasing processing capacity results in decreasing timber stocks, leading to measurements showing smaller timber inventories and a need to reduce processing capacity, or augment timber supplies in order to maintain production. The alternative is abandoning the closed loop, finding new timber reserves elsewhere, and starting the cycle again.

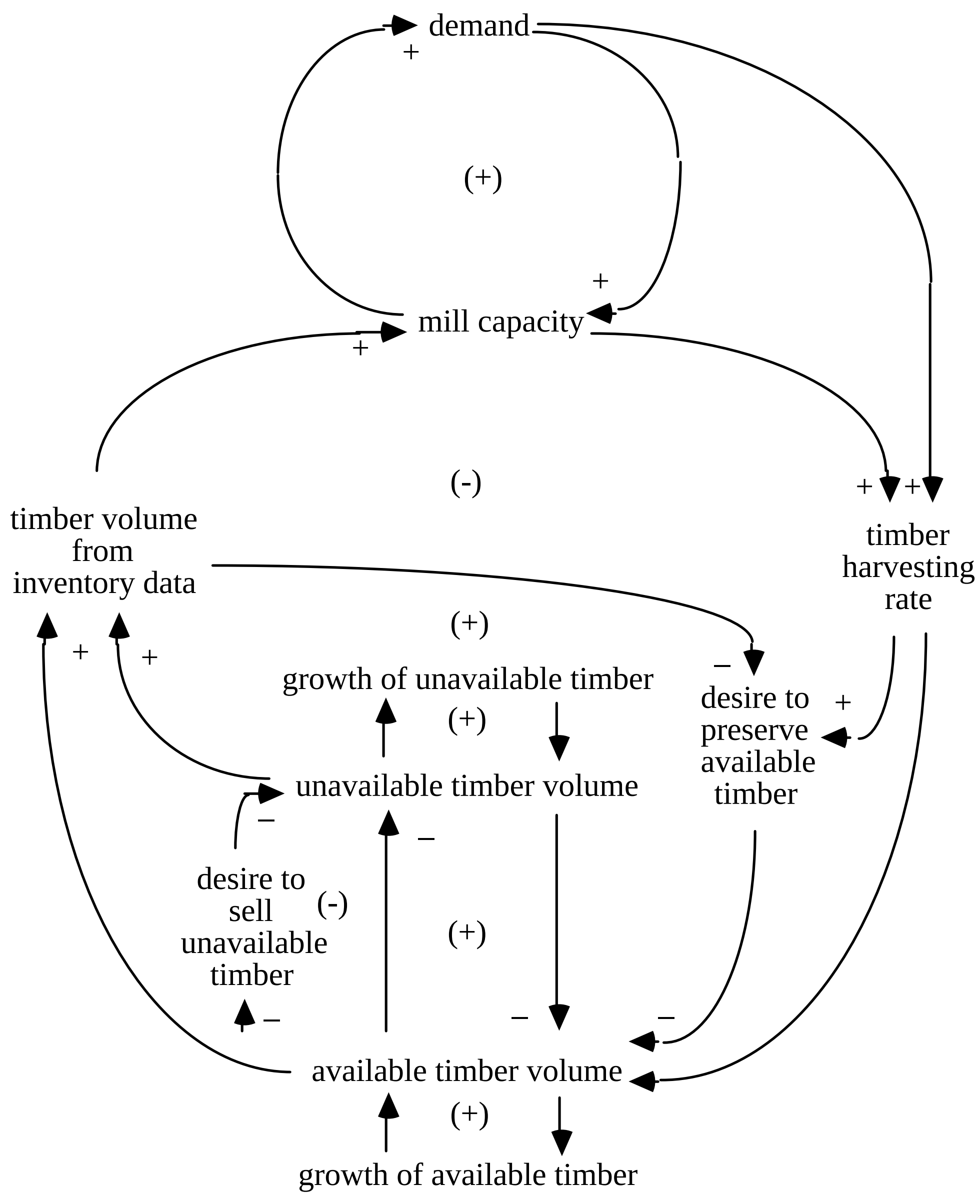
Figure 2: A Simple Timber Supply System



Visualizing timber supply dynamics as a series of connections within a simple closed loop system is a big improvement over linear thinking. Effects throughout the entire system may be seen. Increases in milling capacity *change the state of the system* causing decreases in timber volume and, if left unchecked, creating a need to decrease milling capacity to adjust to lower timber stocks. But what about population growth, forest preservation, and forest fragmentation? These realities suggest a slightly more complex system, still closed, but built upon several loops imbedded within one another. The effects and delays created in this "web of influence" help produce the timber supply dynamics Virginia is currently experiencing and the changes we can expect in the near future. Understanding these interactions can lead to decisions that help sustain forest resources and timber based industries.

Figure 3 illustrates a more complete system, the system chosen for simulation. When simulated, the eight new loops and six new variables, together with our simple timber supply system, produce changes over time that closely approximate trends measured by the US Forest Service timber inventory. A system structure is identified that helps explain observed *rates of change* in timber supply, milling capacity, harvesting rates, and inventory measurements as well as potential *causes of change!* Because system structure, rates of change, and causes of change are identified, they may be used to visualize potential future conditions, and test proposed policy decisions.

Figure 3: An Improved Diagram of the Timber Supply System



What Does the Structure of the System Tell Us?

Demand Helps Generate Capacity, Which In Turn Helps Generate Demand

Demand for wood and paper products helps create increased processing capacity. Processing capacity helps generate increased demand. These two system elements, Demand and Milling Capacity, interact and reinforce each other in a circular way. This dynamic relationship is represented by a *positive feed back loop* as shown in Figure 3.

Demand *pulls wood through the system.* Many managers believe that large timber inventories generate processing capacity growth. While they certainly allow it to happen, it is the increasing demand for wood products that helps drive the reinforcing, demand - milling capacity loop, by pulling wood through the timber supply system. More milling capacity is created in response to demand for wood products. Demand for wood products is reinforced by increased milling capacity.

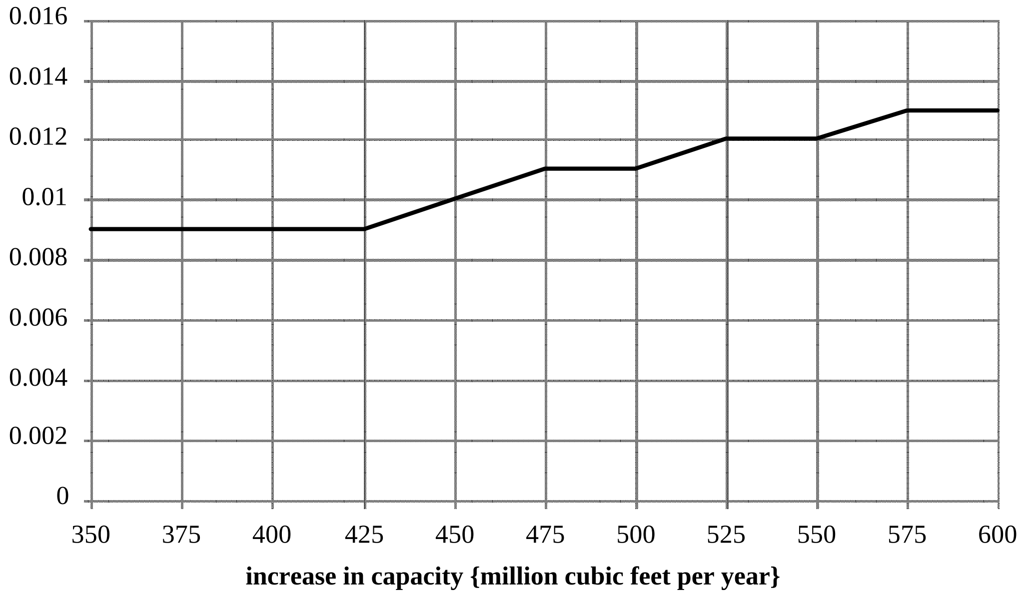
Milling Capacity is Growing Exponentially

Milling capacity, some might call it processing capacity, is growing exponentially in Virginia, the southeastern United States, and the world. The cause of exponential growth is represented in Figure 3 by the demand - mill capacity causal loop. Demand for wood and paper products increases, helping to create increased processing capacity, which, in turn, helps further increase demand.

Data from the US Forest Service timber inventory confirm this dynamic, reinforcing feedback loop. They show that 350 million cubic feet of timber were harvested in Virginia in 1940 compared with 599 million cubic feet in 1992. This increase in wood processing follows a trend line that describes an exponential increase in processing capacity that averages about 1.37 percent per year since 1940. This exponential increase means that, on average, milling capacity in Virginia is doubling every 51 years.

In fact, much of the capacity increase has occurred since 1970. Capacity grew at slower rates before 1970 and at faster rates after 1970. This suggests that growth in milling capacity is actually occurring at a “super-exponential” rate. The average exponential growth rate of 1.37 percent per year began at a rate closer to about 0.90 percent per year during the 1940’s and 1950’s, then increased to a growth rate near 1.30 percent by 1992. This means that capacity growth is not only accelerating exponentially, but the *rate of change* in acceleration is increasing. The curve that describes exponential growth is “bending upward” more sharply over time, suggesting faster rates of change in the future. This change in the super-exponential growth rate multiplier, generated as a function of milling capacity, is shown in Figure 4.

Figure 4: Milling Capacity Growth Rate Multiplier



Market Competition Accelerates Exponential Growth in Capacity

There is another important reason why milling capacity is growing super-exponentially: management decisions by timber harvesting companies help make it happen. As long as measured timber stocks remain large and demand remains positive, timber industries seek to increase milling capacity. Decisions by individual companies to curtail capacity growth do not materialize unless milling capacity begins to approach the measured stock of timber volume. The implicit goal for milling capacity is a capacity equal to measured timber volume. Increased competition among timber companies for timber resources often accelerates capacity increase as each company tries to "grow ahead" of its local competition.

Thus, as long as demand is strong, each company tries to beat its competition by using economies of scale to increase capacity and profit margins at faster rates. The combined effects of such "linear thinking" by separate companies, each trying to optimize profits and market share, can accelerate reinforcing feedback, producing aggregate levels of capacity that exceed available timber stocks if left unchecked.

Delays Help Create Short Term Oscillations in Milling Capacity and Wood Product Supply

Creating wood processing capacity takes time. Even when demand for wood products is high, processing capacity cannot be produced instantly. Plans must be made and money invested. People must be hired and construction work done. Delays that begin when increasing demand is recognized and last until capacity is available to satisfy that demand, help create oscillations in milling capacity and wood product supply. The estimated time delay for milling capacity growth toward a goal defined by increasing demand is about 10 years. It takes 10 years, on average, for aggregate milling capacity to respond to demand. Since we cannot use magic wands to increase or decrease milling capacity, this delay is built into the timber supply system. Over time, delays can cause milling capacity to lag behind demand, over-supplying demand as demand decreases and under-supplying demand as demand increases. Oscillations occur over the short term, as demand increases over the long term.

Timber companies spend a lot of time and money trying to shorten such delays, to match supply with demand. Again, linear thinking helps produce results that are often opposite those intended. For example, maintaining inventories "on the stump" is often thought a good way to cut costs and hedge against future demands. Timber is not cut until needed and mill inventories stay small. The trouble is, when demand increases, everyone needs timber and rushes to cut. Available timber supplies grow scarce signaling a need for more timber harvesting capacity. More harvesting equipment is put into service. Timber supplies are often satisfied as new timber harvesting capacity becomes available, triggering a need to decrease harvesting capacity. Harvesting equipment is sold and loggers loose jobs. These effects create larger oscillations in harvesting capacity, and therefore timber supply, than when larger inventories are maintained at processing facilities. Larger inventories tend to help dampen oscillations in timber supply.

Timber Inventories Compile Delayed Information

Timber inventories are conducted every 5 to 7 years. Thus, at any point in time, statistics estimating timber volumes, growth rates, and removal rates are 5 to 7 years old. This *delayed information stream* tends to underestimate actual timber volumes as timber volumes increase, and overestimate timber volumes as timber volumes decrease. Measured timber volumes lag behind actual timber volumes.

A lag in the information stream can affect management decisions. When aggregate timber stocks are increasing, more timber may be available than surveys indicate. When aggregate timber stocks are decreasing, less timber may be available than surveys indicate. Shortages may come more quickly than anticipated.

Two variables are used in the model to identify this effect. One tracks the timber volumes as reported by timber inventories, the other tracks the actual timber volume through time.

Available Timber Volumes Depend on Land Use and Social Norms

Fundamental changes in land use patterns and social norms, changes not documented by federal timber surveys, may significantly affect the actual supply of timber available for cutting. Much of the uncertainty about Virginia's available timber supplies, stems from an acknowledgment that land use patterns and social norms help determine true timber supplies, and an admittedly "fuzzy" understanding of their actual effects. Since land use patterns and social effects are important, and knowledge of these variables is sketchy, this model makes fundamental and explicit assumptions about these influences while providing convenient mechanisms for changing them if desired.

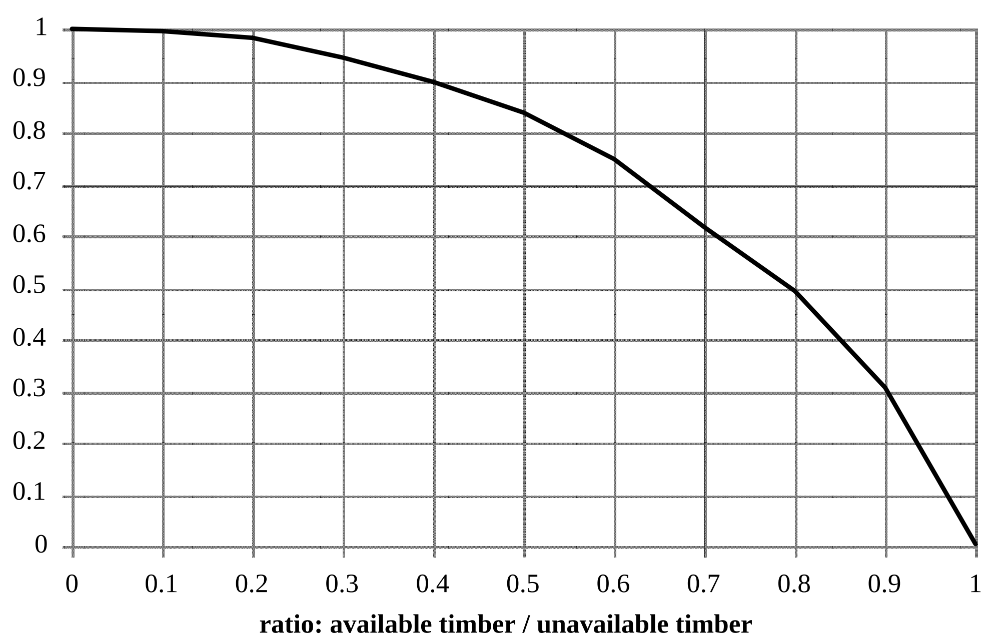
Land use changes are assumed to be part of the larger dynamics of the model. Changing land use patterns can help increase timber scarcity. As population increases, urban areas encroach on forests, and contiguous forest land is increasingly fragmented. These changes may decrease timber supplies and make them less accessible. Forests may be consumed as roads, shopping centers, office buildings, and homes are built. More money, time, and care may need to be spent when gaining access to and harvesting the remaining timber stocks in these areas. These changes are implicitly described by the reinforcing loops that determine milling capacity and demand.

Changing social norms can help increase or decrease the amount of available timber, and the amount of available timber can help change social norms.

As the saying goes, almost everyone has their price. As the amount of available timber decreases, timber becomes increasingly scarce. Prices go up, and with them, the aggregate desire to sell timber that had been previously unavailable. This tendency is described by the Desire to Sell Unavailable Timber Multiplier.

Figure 5 illustrates the assumed aggregate influence of the stock of available and unavailable timber on the social desire to sell previously unavailable timber. When the amount of available timber is large, relative to the amount of unavailable timber, the desire to sell unavailable timber is low. This makes sense intuitively. Plenty of timber is available and there is no incentive to move protected timber into the market. When the amount of available timber is small relative to the amount of unavailable timber, the desire to bring unavailable timber into the market for sale increases. As timber grows scarce price increases, and with it the incentive to move unavailable timber into the market place.

Figure 5: Desire to Sell Unavailable Timber Multiplier

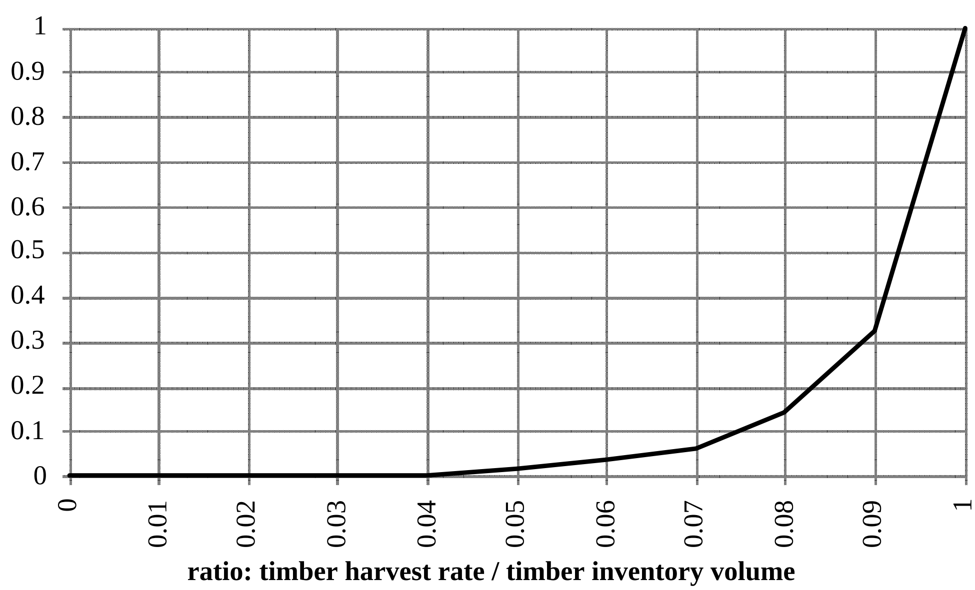


As timber harvesting rates increase, or timber stocks decline, social pressures for preserving forests and protecting available timber may increase. This tendency is described by the Desire to Preserve Available Timber Multiplier.

Figure 6 illustrates the assumed aggregate influences of the timber harvesting rate and timber inventory volume on the social desire to preserve forests, making them unavailable for timber harvest. When the timber harvesting rate is low relative to the measured timber inventory then little social pressure exists to preserve forest resources. This happens for two reasons: (1) relative harvesting rates are low *and* (2) relative timber stocks are high. Since harvesting rates are low relative to the forest base, little change is observed in the state of forest resources. Consequently, little need is perceived to preserve a threatened resource. It is important to note that the social need to preserve forests is tied to both the *timber inventory* and the *harvesting rate*. Dramatic change in either of these variables can trigger an increased need to preserve available forests. Also notice that the multiplier is sharply non-linear. This suggests that at low to moderate harvesting rates relative to timber volume, little pressure for preservation will occur. As harvesting rates increase, or timber volume decreases, (or both), pressure to preserve remaining forests may increase dramatically and quickly.

If (1) timber harvesting rates increase quickly, or (2) timber inventories decrease quickly, or (3) harvesting rates increase *and* timber inventories decrease simultaneously, then society's desire to preserve available timber resources can increase dramatically. We may be, in fact, poised at the brink of such an event as described in Scenario 1: The Status Quo on page 11. On the other hand, if (4) harvesting rates do not change quickly, or (5) timber inventories do not decrease quickly, or (6) harvesting rates decrease and timber inventories increase simultaneously, then society's desire to preserve available timber resources can decrease dramatically, see Scenario 3: Decreasing the Rate of Timber Removal Can Sustain Forests and Forest Industry, on page 15. The Desire to Preserve Available Timber Multiplier implies that society reacts to rapid changes in both increasing timber harvesting rates and decreasing timber volumes by demanding increased preservation of forest resources.

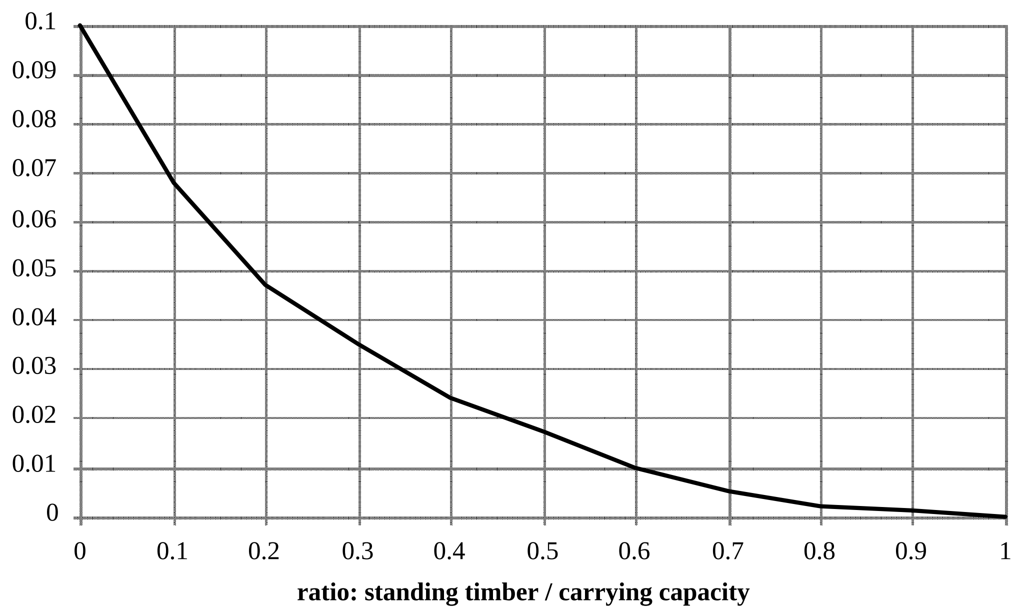
Figure 6: Desire to Preserve Available Timber Multiplier



Aggregate Timber Growth Rates Decrease as Wood Volumes Approach Biological Potential

The timber volume growth rate, represented as a percentage of standing timber volume, decreases as timber stands approach their biological potential. Timber growth continues as biological potential is approached, but at slower rates relative to standing timber volumes. For our purposes this relationship is described by the Timber Growth Rate Multiplier shown in Figure 7. Over time, timber volumes grow in an S-shaped pattern; increasing rapidly, then gradually level off as they approach biological carrying capacity. Harvesting increases this aggregate growth rate multiplier, as the ratio of standing timber to carrying capacity declines, allowing young stands to develop.

Figure 7: Timber Growth Rate Multiplier



Harvesting Rate is Determined by Product Demand and Milling Capacity

Both product demand and milling capacity help determine the timber harvesting rate. Demand signals a need to supply timber resources to wood processing plants. Milling capacity determines the speed at which trees can be processed into wood and paper products. It takes demand and capacity to generate harvest. Harvests will not occur if demand exists without capacity or capacity exists without demand.

These two variables feed off of one another. They are mutually reinforcing, producing a positive feedback loop that can be self-supporting. The demand - milling capacity positive feedback loop tends do *drive* the timber supply system, pulling timber resources into the wood processing stream. Since this loop often drives the system, policy changes that affect these two variables can significantly influence all variables. Policy interventions in this loop can *leverage* effects throughout the system.

Scenario Analysis: Simulating Change Over Time

Scenario 1: The Status Quo Ensures a Decline in Forests and Forest Based Industries

Scenario 1 begins with conditions as they were in 1940. As the simulation unfolds, system elements interact as shown in Figure 3, creating changes in mill capacity, timber volumes, timber measurements, growth rates, and removal rates. The result is a simulated change over time that closely approximates the reality we have experienced since 1940, and suggests the future path of change if present policies continue.

The simulation suggests that, if present circumstances and policies stay the same, the stock of available timber begins declining in 1988 and will become exhausted by 2040.

Simulation results are displayed in Figure 8 and Figure 9. Rates of change in mill capacity, available timber, unavailable timber, standing timber, timber inventory volume, growth, removals, available growth and unavailable growth, are displayed.

Under present circumstances timber volumes increase dramatically between 1940 and 1987. Processing capacity also increases exponentially during this time. As processing capacity increases, harvesting rates accelerate and available timber stocks decline, as shown in Figure 8. By 1987 the rate of timber removal begins to exceed the rate of growth, as shown in Figure 9. It takes time to collect data and publish timber inventories so measured timber volumes are delayed by five to seven years. Therefore, removal rates begin to exceed growth rates in published timber inventories by about 1994. The rapid increase in harvesting rates helps increase the perceived social need to protect forests. By 1999 this facilitates an increase in the amount of timber moved into the “unavailable” or preserved category, accelerating the decline in “available timber.” The amount of unavailable timber continues to grow, peaking in 2015. As processing capacity continues to expand, pressures for more timber resources increase. Prices increase dramatically, increasing desire to sell previously unavailable timber. Unavailable timber resources decline between 2015 and 2040. Processing capacity continues to grow, peaking in 2025. As available and “unavailable” timber resources become increasingly scarce, mills begin to close. Processing capacity declines from 2026 through 2100.

Figure 8: Scenario 1 Processing Capacity and Timber Volumes

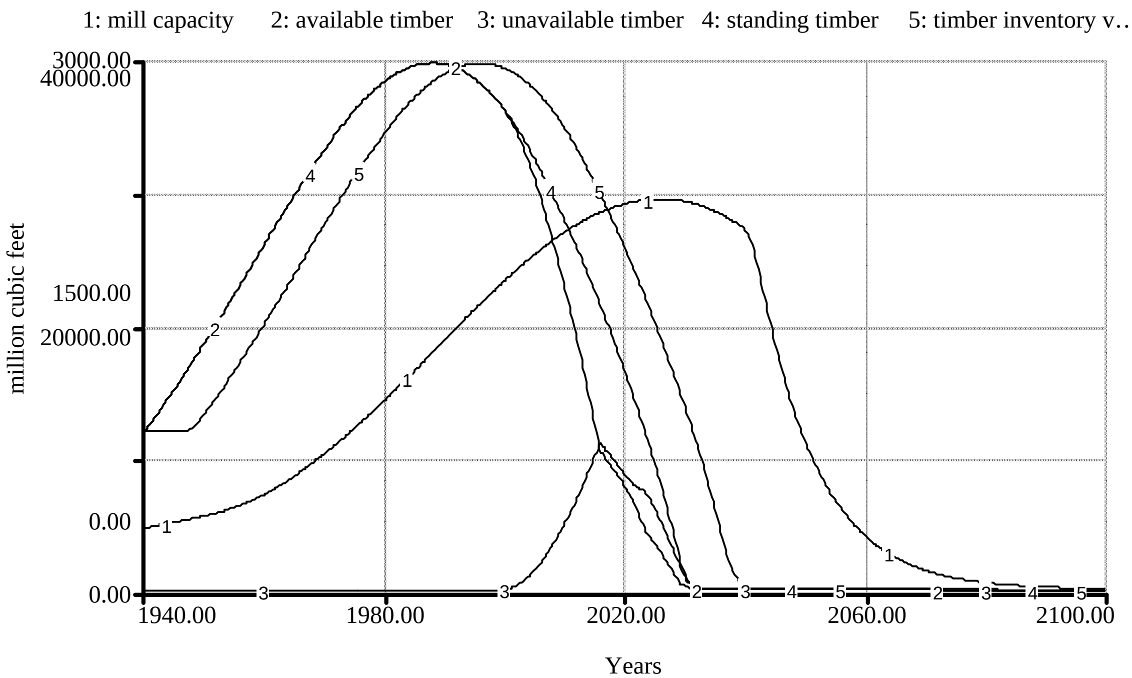
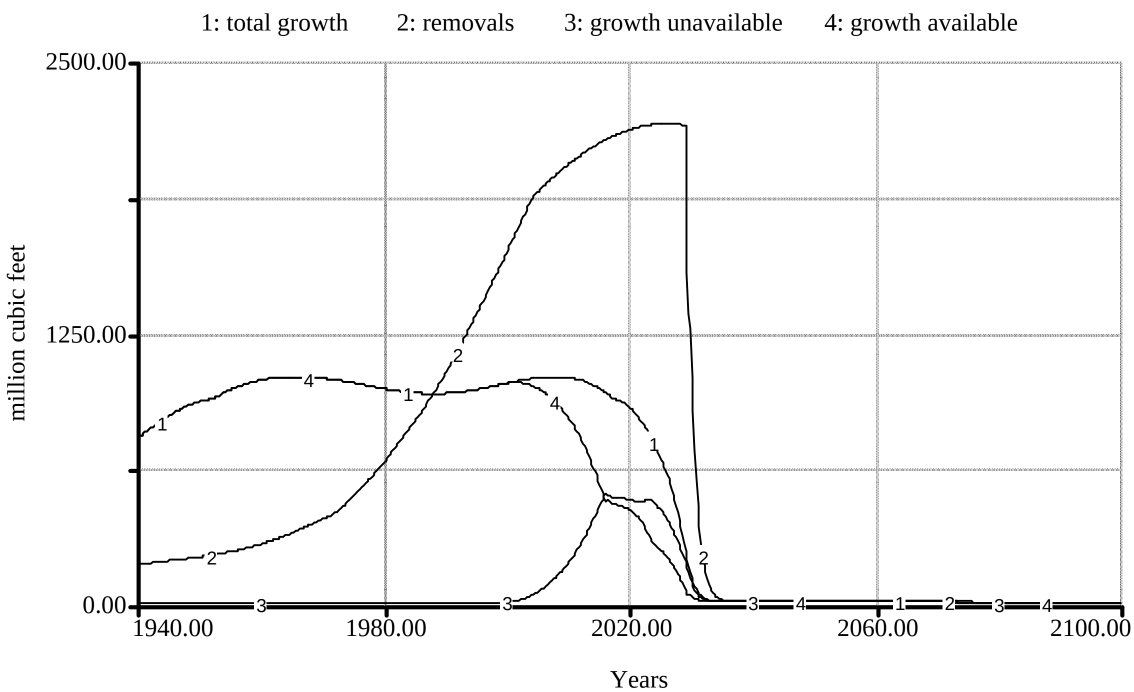


Figure 9: Scenario 1 Timber Growth and Removal Rates



Scenario 2: Working to Improve Timber Growth Rates Provides at Best Only Marginal Help

Scenario 2 is identical to Scenario 1 with the exception of one policy change. In Scenario 2 it is assumed that research institutions and timber industries invest in large scale programs that improve tree growth rates through advances in genetics and technology. This results in improvements allowing tree growth rates to double by 2100. These assumed improvements in growth rate are simulated using a growth rate multiplier shown in Figure 10.

Scenario 2 begins with conditions as they were in 1940. As the simulation unfolds system elements interact as shown in Figure 3, creating changes in mill capacity, timber volumes, timber measurements, growth rates, and removal rates.

The simulation suggests that, even with the assumed improvements in growth rate generated by rapid advances in genetics and technology, noticeable improvements in timber volume do not occur. The stock of available timber begins declining in 1986 and is nearly exhausted by 2038.

A primary reason improved timber growth does not appreciably increase the timber supply is that the relatively small increases in growth rate are outstripped by increased harvesting rate and mill capacity. Though advances in genetics and technology do improve timber volumes, ultimately trees cannot grow faster than accelerating mill capacity and harvesting rates. Any marginal increases in volume are rapidly consumed to satisfy increasing demand. In fact, Scenario 2 suggests that improved timber growth rates may help accelerate capacity expansion, triggering faster harvesting rates and increasingly rapid declines in overall timber volume.

A secondary reason improved timber growth does not appreciably increase timber supply is that the largest improvements occur later rather than earlier. Even with massive investments of energy, money, and infrastructure, genetic and technological improvements take time. By 2036 there is a timber growth rate increase of greater than 20 percent, but by then available timber resources are largely consumed, see Figure 10.

Simulation results are displayed in Figure 11 and Figure 12.

Figure 10: Scenario 2 Assumed Improvement in Timber Growth Rate from Advances in Genetics and Technology

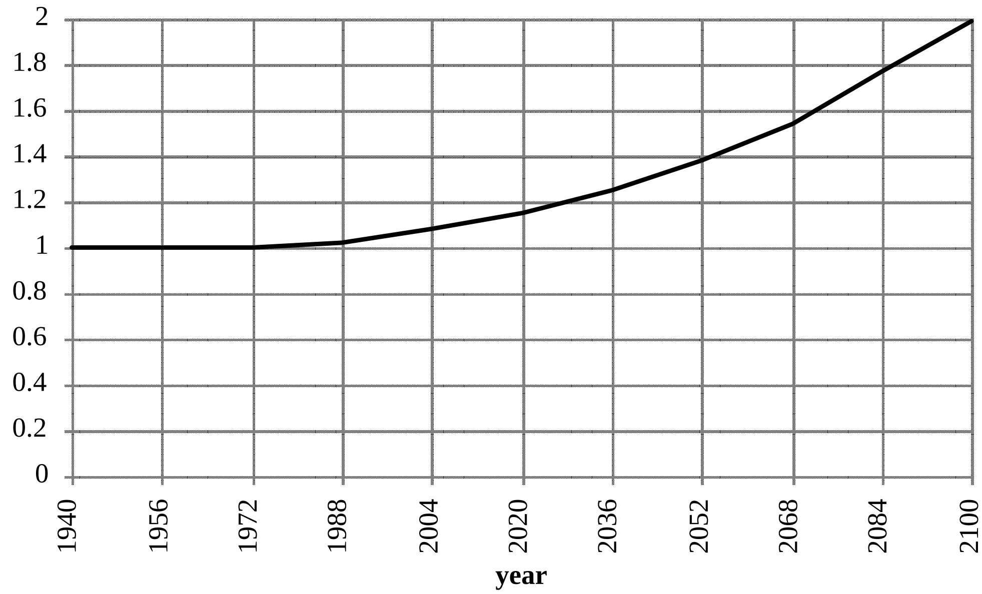


Figure 11: Scenario 2 Processing Capacity and Timber Volumes

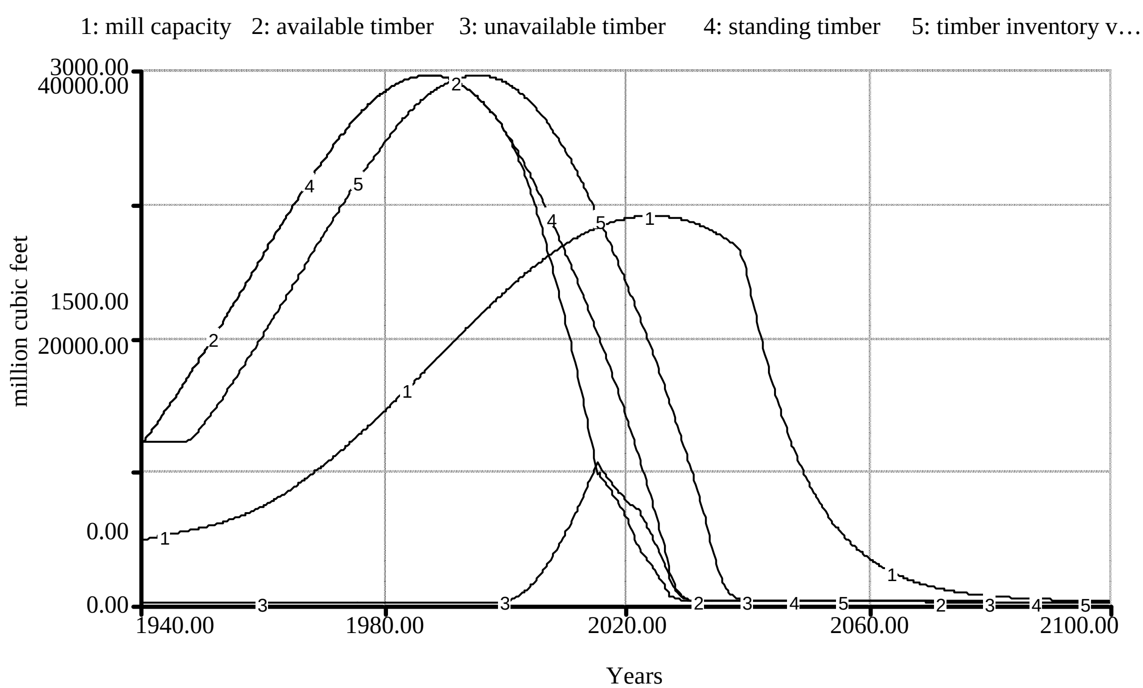
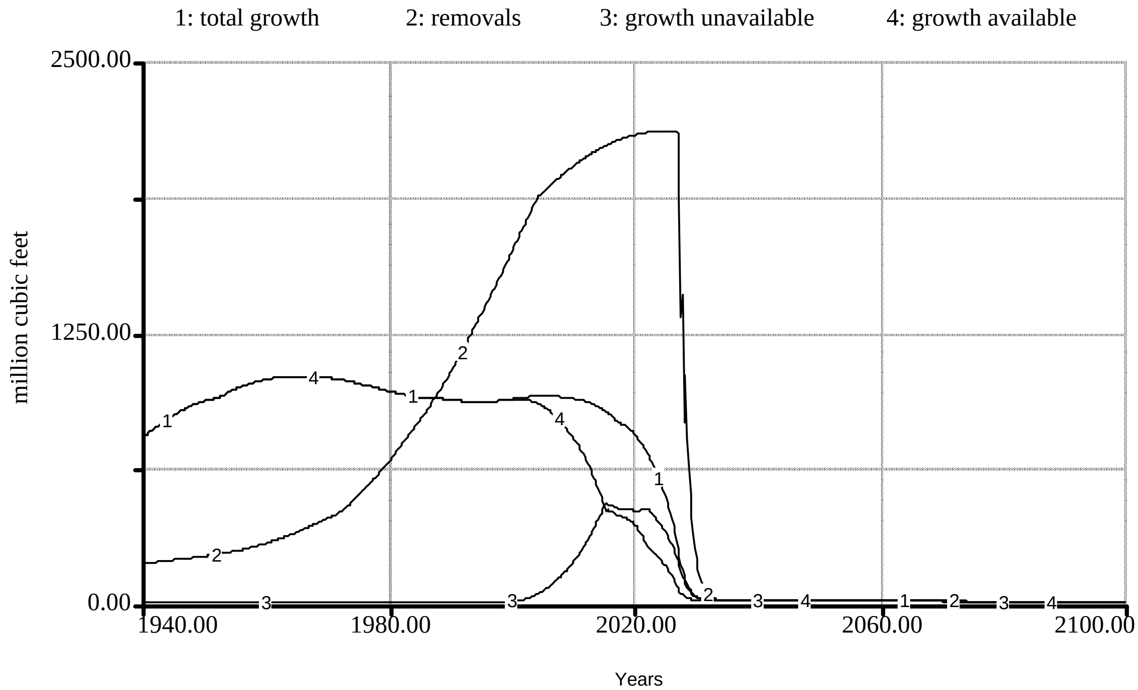


Figure 12: Scenario 2 Timber Growth and Removal Rates



Scenario 3: Decreasing the Rate of Timber Removal Can Sustain Forests and Forest Industry

Scenario 3 is identical to Scenario 1 with the exception of one policy change. In Scenario 3 it is assumed that forest industries choose to decrease the amount of virgin material used to manufacture new product. This strategy allows milling capacity to expand while reducing the percentage of capacity supplied by newly cut trees.

Scenario 3 assumes that, as processing capacity grows, the percentage of processing capacity supplied by new timber decreases over time as shown in Figure 13. This decrease can be achieved by combining (1) increased recycling of wood and paper products with (2) a shift to manufacture of high quality wood products and stewardship of high quality forests.

Increased recycling of wood and paper products can reduce the rate of timber cutting. The trend in reduced relative demand for new timber outlined in Scenario 3 suggests that by 2004, 20 percent of milling capacity will be supplied by recycled wood and paper and 80 percent by new timber. By 2036, 60 percent of milling capacity will be supplied by recycled wood and paper and 40 percent by new timber. By 2100, 70 percent of milling capacity will be supplied by recycled wood and paper and 30 percent by new timber. These numbers are *percent* change in total mill capacity supplied by virgin and recycled material. Total mill capacity may increase during this time.

Encouraging a shift to the manufacture of high quality wood products, such as fine wood furniture, and stewardship of high quality forests can reduce the rate of timber cutting, reduce processing capacity, and help sustain the slower growing hardwood forests that are native to Virginia. High quality wood products require high quality wood. High quality wood can only be produced by careful management of hardwood forests over long, 80 to 150 year, timber cutting cycles. With this approach, at any point in time more high quality forest is present on the landscape. High quality wood products require less raw material and add more economic value per unit of raw material than paper, chip board, lumber, or other “low end” wood products. Because less raw material is need to add economic value, high quality wood products can sustain smaller scale local economies. Increased economic value, decreased materiel throughput, and the sustained presence of high quality forest can be simultaneously achieved. Scenario 3 assumes that a shift to manufacture of high quality wood products in local economies combined with stewardship of high quality, native hardwood forests will help reduce demand for newly cut trees.

Scenario 3 begins with conditions as they were in 1940. As the simulation unfolds system elements interact as shown in Figure 14, creating changes in mill capacity, timber volumes, timber measurements, growth rates, and removal rates.

The simulation suggests that timber resources and processing capacity are suatained as the percentage of milling capacity supplied by recycled material and the manufacture of high quality wood products and stewardship of high quality native hardwood forests increases. Timber volumes are sustained through 2100 at close to 1996 levels. Growth rates again exceed removal rates beginning in 2034. Processing capacity is sustained and may expand to 3,000 million cubic feet per year by 2100.

Reductions in the percentage of milling capacity supplied by new trees, through increased recycling of wood and paper products and shifting to production of higher quality wood products dramatically changes future conditions. Since harvesting rates are reduced relative to milling capacity, standing timber volumes are sustained. Timber stocks recover from the present impacts of accelerating harvesting rates. Growth rates exceed removal rates by 2034. Lower harvesting rates lessen the social desire to protect timber resources. More timber remains available over time. Since recycled wood and paper is increasingly used to supplement raw material needs in wood processing plants, processing capacity expands to satisfy demand, constrained by the inherent biological limits of native hardwood forests, rather than timber supply shortages. Timber supplies and local timber based industries are sustained through 2100.

Figure 13: Scenario 3 Assumed Reduction in Demand for Trees due to Recycling, as a Percentage of Milling Capacity

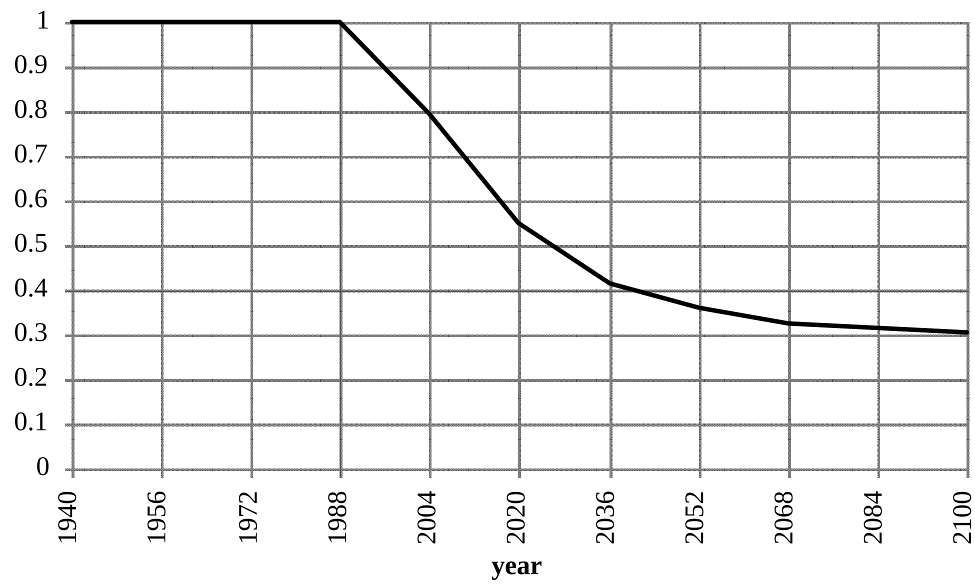


Figure 14: Scenario 3 Processing Capacity and Timber Volumes

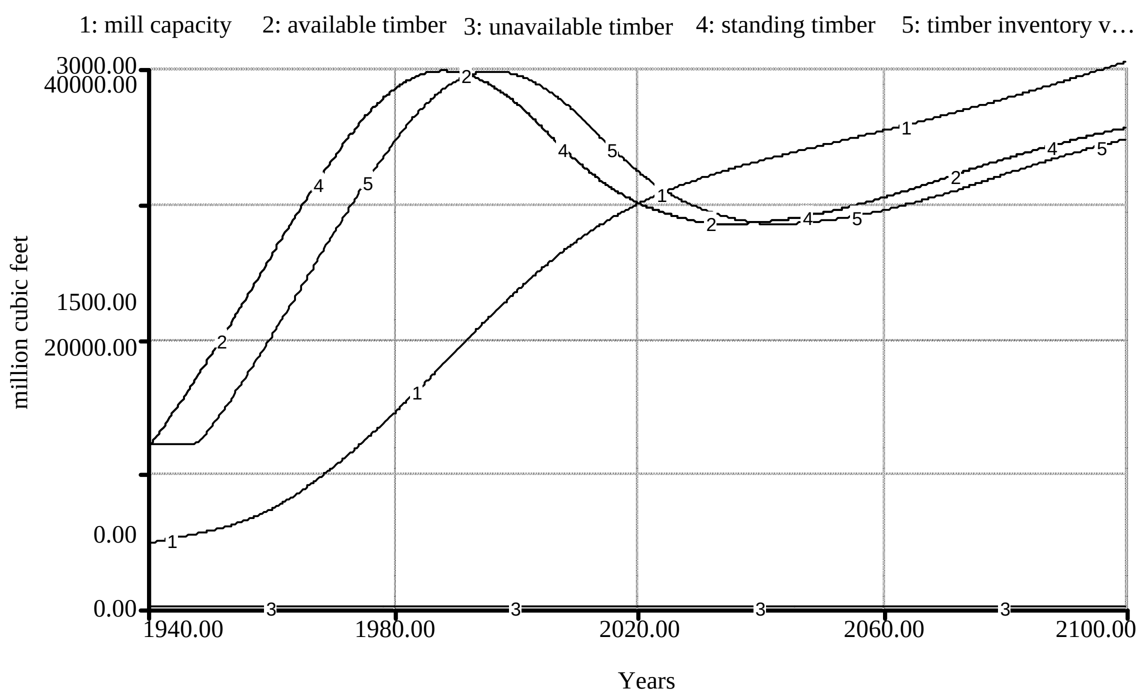
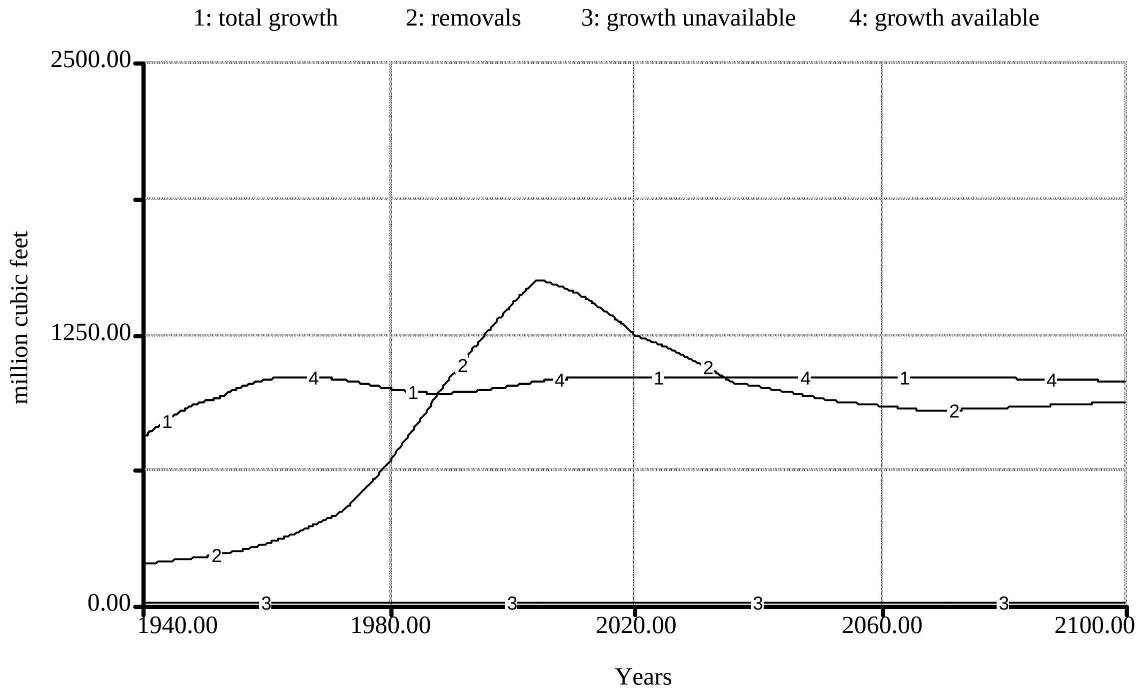


Figure 15: Scenario 3 Timber Growth and Removal Rates



Where Are the Leverage Points in the System?

Simulations of Virginia Timber Supply Dynamics clearly suggest that modifying the rate at which new wood moves through the production-distribution system can have profound social, environmental, and economic effects.

When harvesting rates exceed growth rates, wood processing capacity expands beyond sustainable levels, signaling increased need to protect forest resources from depletion. As wood supplies become increasingly scarce, forests deteriorate, wood processing capacity declines, and local timber based economies collapse. Neither timber supplies nor timber based industries are sustained over the long term.

When methods such as recycling, sustaining native forests, and the manufacture of high quality wood products are used to reduce the amount of new timber needed by wood processing plants, timber resources and forest industries are sustained over the long term. Forest industries are appropriately constrained by the natural limits of native hardwood forests, rather than by dwindling timber supplies. Within biological limits, wood processing capacity is able to expand and shift to meet demand, and is sustained over the long term.

Simulations also suggest that improvements in tree genetics and technology, by themselves, do little to sustain forests and forest industry over the long term. When aggressive genetic and technological improvement programs are initiated, growth rates of a few tree species are improved. These changes do little to sustain forest resources and timber industries over the long term since any improvements in supply from increased growth rates help to reinforce demand-mill capacity feedbacks, accelerating harvesting rates and working to push available processing capacity beyond sustainable levels.

The greatest leverage seems to lie in developing policies that *reduce* the rate at which new timber is *pulled* through the production-distribution system, rather than focusing on ways to *increase* supplies of timber that supposedly may be *pushed* through the system. Management strategies that reduce harvesting rates, while allowing processing capacity to expand to meet demand within the bounds of biological limits, hold the most promise for sustaining both forest resources and timber based economies.

Bibliography

Boyce, S.G. 1985, *Forestry Decisions*, Gen. Tech. Rep, S.E. 35, USDA Forest Service, Southeastern Forest Experiment Station, 318 pages.

Forrester, Jay W. 1961. *Industrial Dynamics*. Productivity Press, Cambridge, MA. 464 pages.

Meadows, Dennis L. 1974. *Dynamics of Growth In A Finite World*. Wright-Allen Press. Cambridge, MA. 637 pages.

Senge, Peter M. 1990. *The Fifth Discipline*. Doubleday Currency, New York, 424 pages.

US Forest Service Bulletin SE 151, 1992.

US Forest Service Bulletin SE-95, 1986.

US Forest Service Bulletin SE-44, 1977.

US Forest Service Bulletin SE-8, 1966.

US Forest Service Release Number 54, 1949.

The Virginia Timber Dynamics Learning Environment: Core Model Diagram