The Great Lakes Entomologist

Volume 17
Number 4 - Winter 1984 *Number 4 - Winter 1984*

Article 12

December 1984

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Recommended Citation

Huff, Debra J.; Montgomery, Bruce A.; Witter, John A.; and Gregory, G. Robinson 1984. "The Economics of Spruce Budworm Outbreaks in the Lake States: An Overview," *The Great Lakes Entomologist*, vol 17 (4)
DOI: https://doi.org/10.22543/0090-0222.1529
Available at: https://scholar.valpo.edu/tgle/vol17/iss4/12

THE ECONOMICS OF SPRUCE BUDWORM OUTBREAKS IN THE LAKE STATES: AN OVERVIEW

Debra J. Huff, Bruce A. Montgomery, John A. Witter, and G. Robinson Gregory[1]

ABSTRACT

Economic effects of spruce budworm outbreaks in the Lake States were examined. The recent outbreak caused spruce and fir mortality on 420 thousand ha (1.05 million acres) of commercial forest land in the Lake States. Two models of Lake States spruce-fir markets were developed. A Static Economic Model established the nature of the Lake States spruce-fir market and a Comparative Static Model examined changes brought about by spruce budworm outbreaks.

Outbreaks result in short-run supply shifts which probably decrease total revenue to stumpage owners but do not affect demand. The magnitude of long-run impacts were dependent on developing Lake States markets and forest management techniques.

Further research is necessary on the value of short-run losses to stumpage owners so that the costs of forest management can be compared with outbreak losses. Long-run shifts in demand can be facilitated by attracting new industry to the area, developing new markets for the spruce-fir resource, and demonstrating that the spruce-fir resource can provide a continuous fiber source in the future.

These shifts would provide the price incentives that land managers require to undertake intensive forest management. Research on the development of new markets for the spruce-fir resource is needed. As markets develop, the long-run impacts become less severe. Technology transfer programs already exist to aid land managers in developing management strategies to increase yields of spruce-fir and minimize outbreak impact.

Outbreaks of the spruce budworm, *Choristoneura fumiferana* (Clemens), can cause extensive mortality and growth loss to balsam fir (*Abies balsamea* (L.) Miller) and white spruce (*Picea glauca* (Muench) Voss). In terms of the Lakes States forest resource, the quantity of this resource is changed in the short run and the species and age class composition may be affected in the long run due to spruce budworm outbreaks (Witter et al., in press). Although historical and current levels of physical damage have been evaluated, the effects of this damage on the Lake States forest products market have not. An understanding of market response to spruce budworm induced changes should be prerequisite to attempts at quantifying economic losses or undertaking spruce budworm related management activities. Quantification of losses may be over or understated if extrapolated from a locality to a region, as a result of the variable nature of the resource and local market conditions. Additionally, the effects of resource availability on the regional market should be examined before related expenditures are made. If the losses are not high in value, perhaps no action is desirable even though the physical losses are extensive.

Tree mortality occurred on 420 thousand ha (1.05 million acres) in the Lake States during the most recent budworm outbreak (Kucera and Taylor 1983). Very little detailed information on the biological impact of the spruce budworm on spruce-fir stands in the Lake States was available in the mid-1970's. In 1977 and 1978, researchers at The University of Michigan designed a seven-year study to quantify the impact of the spruce budworm in the Upper Peninsula of Michigan (Mog and Witter 1979). Detailed biological

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impact information has been published (Witter et al., in press; Lynch et al. 1982a-d; Mog et al. 1982). A detailed economic analysis concerning the value of these losses is being completed.

Mortality of balsam fir and white spruce was widespread in the Lake States during the 1970's, but the regional aspects of this loss have not been addressed. The objective of this paper is to provide an overview of the Lake States spruce-fir market and to identify changes that result from spruce budworm outbreaks. The material covered includes sections on the spruce-fir resource, static economic model, and market dynamics once budworm outbreaks occurred.

THE SPRUCE-FIR RESOURCE

The Lake States region is defined as Michigan, Minnesota, and Wisconsin. Most of the Lake States spruce-fir type is located in the northern portions of these states. Using United States Forest Service (USFS) data, the relevant Survey Units are Northern L.P., Eastern U.P., and Western U.P. in Michigan, Northeastern and Northwestern Wisconsin, and Northern Pine and Northern Aspen-Birch in Minnesota (Fig. 1). In the northern Lake States, over 6% of the commercial forest land area is occupied by the spruce-fir type (Jakes 1982, 1980; Smith 1982; Spencer 1982). Over 56% of this area contains stands over age 40. These stands are more susceptible to spruce budworm outbreaks than younger ones. An additional 405 thousand ha (1 million acres) are vulnerable to spruce budworm outbreaks where the spruce-fir-component represents less than 50% of a stand.

Growing stock volume is similarly concentrated in the mature and overmature age classes. Approximately 75% of the growing stock volume is concentrated in the over 40 year age class. Size class data indicates that only 23% of the acreage in the spruce-fir type contains seedling-sapling stands. The remainder is in pole size and sawtimber stands (Jakes 1982, 1980; Smith 1982; Spencer 1982). The concentration of the spruce-fir resource in mature and overmature stands not only provides a condition which favors spruce-budworm outbreaks, but may result in severe mortality.

Balsam fir, white spruce, and black spruce (*P. mariana* (Miller) B.S.P.) made up 11–12% of pulpwood production in the Lake States from 1976 through 1981 (Jakes 1982, 1980; Smith 1982; Spencer 1982). During 1979, 95% of the balsam fir pulpwood consumed in the Lake States was also harvested in the Lake States. Balsam fir and white spruce are also used as sawlog species in the Lake States but this market is currently a very small component of spruce-fir demand. Other markets exist almost entirely on a local level.

THE STATIC ECONOMIC MODEL

The Static Economic Model establishes the nature of the supply and demand for Lake States spruce-fir before the effects of spruce budworm outbreaks. Assumptions of the model are that the short-run market for the spruce-fir resource is pulpwood, other markets are inconsequential, there is perfect substitution among softwood species, hardwood and softwood markets are independent, and the market is not perfectly competitive. Both the short run and the long run are examined.

I. Short-Run Analysis

In economics, the short run is characterized by one or more fixed factors of production while in the long run, there are no fixed factors. Thus, in the long run, firms are able to adjust production to a degree which may not be possible in the short run.

A. **Short-Run Supply.** Supply is a function of the change in costs as quantity changes. Costs include pulpwood production costs and stumpage production costs. Both aspects of short-run spruce-fir supply, stumpage and pulpwood production, will be examined.

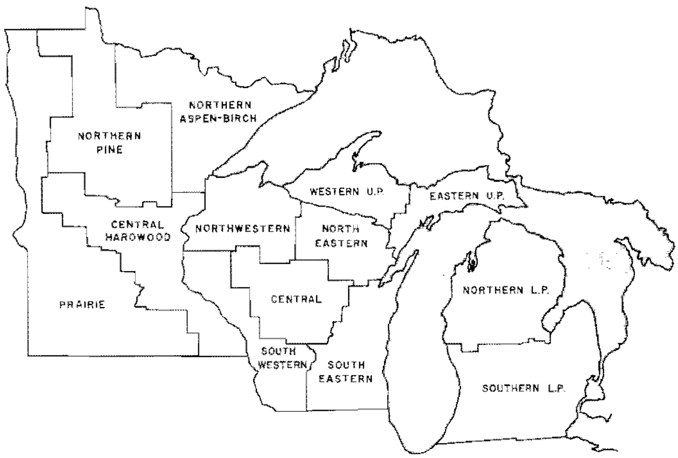

Fig. 1. USFS Resource Evaluation Survey Units for Minnesota, Wisconsin, and Michigan.

1. **Stumpage Supply.** Production of stumpage requires a lengthy growing period. Short runs of 50 years or more in the stumpage market are not unusual (Gregory 1972). The amount of stumpage offered for sale depends on owners' objectives and expectations (reservation price), silvicultural inputs, and biological or physical limitations (Row 1980).

Private owners of stumpage have a reservation price below which they will not sell (Gregory 1972). Adams (1975) noted that privately owned stumpage supply in the Lake States is considered price responsive or elastic. Price elasticity measures the responsiveness of quantity to changes in price. Therefore, private owners are expected to increase the quantity of spruce-fir stumpage supplied as prices rise. If the stumpage supply curve were inelastic, the increase in quantity supplied would be relatively less or non-existent as price rose.

In contrast, industrial owners may constrain price responsiveness in the short run to maintain a continuous fiber flow in the long run.

On USFS lands, the volume of stumpage offered for sale is determined by an allowable cut calculation. Minimum prices on USFS sales are based on production costs and product prices and are bid on in the open market. The volume of stumpage offered for sale does not normally change as a result of price behavior. Therefore, the supply from USFS land is essentially inelastic (price unresponsive). State and county lands are more price responsive than USFS, but less than private.

Thus, softwood stumpage supply is the summation of the elastic supply from private land, an elastic (but less elastic than private) corporate supply which is not a large part of the market, and a relatively inelastic public supply (Fig. 2).

2. **Spruce-Fir Pulpwood Supply.** The cost of stumpage and all other costs are added together to obtain the total cost of producing pulpwood. The supply curve for pulpwood is determined by the marginal or incremental costs of production. Usually, when owner preferences change, or the volume of available stumpage is changed, the cost curves associated with stumpage also change. This will also alter the costs involved in providing spruce-fir pulpwood. If the available volume of stumpage is decreased, the supply curve will shift from S to S′ (Fig. 3). The effect is the same if owner preferences change and stumpage is more valuable to them. Both instances reflect an increased cost of providing the stumpage.

The cost of getting the material to market, including harvesting, labor, and transportation, must also be computed into the pulpwood supply curve. Differences in the nature of

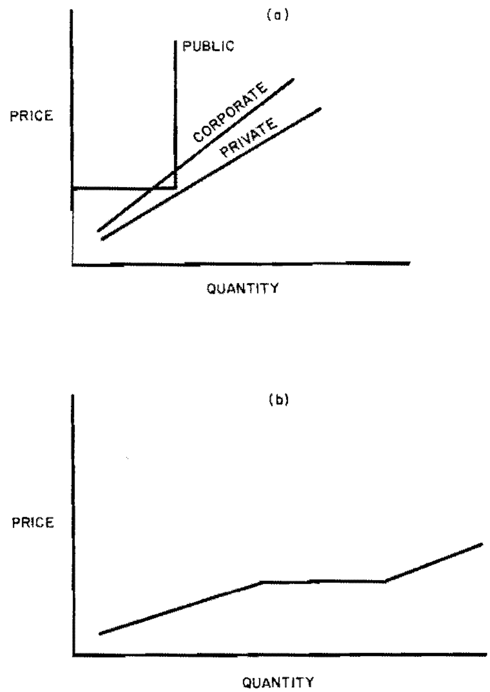

Fig. 2. Aggregate stumpage supply: (a) components, (b) supply curve after aggregation.

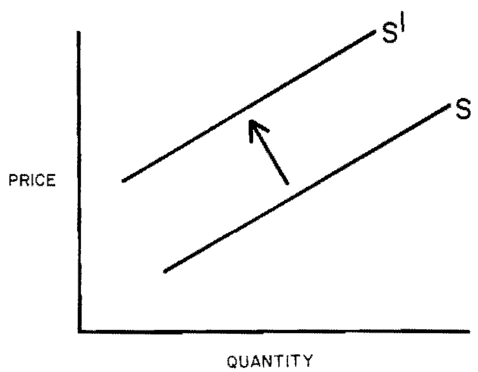

Fig. 3. Pulpwood supply response to a decrease in stumpage volume or an increase in owner reservation prices.

the resource, including species peculiarities, logger preferences, producer preferences, and risk will also alter the costs.

Costs can rise quickly in the short run due to relatively fixed amounts of equipment and wage-labor. To increase production in the short run, the producer must hire more labor, which is not always readily available, or pay overtime wages. Equipment capacity is not generally variable in the short run. The rapidly rising costs of producing pulpwood cause each individual producer's supply curve to be inelastic. Therefore, individual producers can only alter the quantity they supply in the short run by a small amount in response to a change in price. However, the large number of pulpwood producers who enter and exit the market quickly cause the overall pulpwood supply to be elastic even in the short run.

Pulpwood supply for all species in the Lake States has been relatively elastic (Adams 1975). A computer-based pulpwood supply curve for the Lake States was projected by Bradley et al. (1980). The curve illustrated the elastic pulpwood supply curve over time (Fig. 4). Specific pulpwood species which are abundant and relatively inexpensive to produce may have supply curves which exhibit even greater elasticities than the overall supply curve. Leuschner (1973) found this for aspen pulpwood in Wisconsin. The spruce-fir type is thought to be similar in pulpwood supply elasticity.

B. **Short-Run Demand.** Pulpwood constitutes the major demand for the Lake States spruce-fir resource, although other uses may develop in the long run. The discussion of short-run demand will consider only pulpwood demand but the analysis of long-run demand includes the possibilities of new markets. Demand for pulpwood is price inelastic in the short run. The very high expense of starting or stopping paper-making equipment precludes price responsiveness in the short run (Sherif 1983, Adams 1975). Capacity of paper-making machinery was found to be the sole determinant of pulpwood factor demand in Wisconsin (Leuschner 1973). Because specified mixes of fiber lengths (hardwood and softwood) are needed, separate demand curves are assumed for hardwoods and softwoods.

Demand for spruce-fir pulpwood is similar to demand for a product in a perfectly competitive market because spruce-fir pulpwood is easily substituted by other softwood species. Thus, the demand curve for spruce-fir pulpwood is close to a straight line (very elastic) up to fixed capacity limits. After current plant capacity limits are reached, greater quantities of pulpwood cannot be used regardless of the price. Demand will slope abruptly downward after capacity limits are reached and become relatively unresponsive to changes in price (inelastic). Demand may not be perfectly inelastic after the capacity limit of pulp and paper mills is attained because different markets (e.g., firewood) may respond (Fig. 5).

Few firms demand pulpwood in the Lake States. These firms are thought to maintain somewhat higher prices than equilibrium conditions would indicate. There are two possible reasons for this. First, higher current prices will provide greater incentives to private owners to maintain fiber production into the future. In this way a high price acts partially as an insurance policy. Second, pulpwood and stumpage costs are a very small portion of the total costs of operation. It may cost more to haggle each sale than to set a single price which is somewhat above the competitive equilibrium.

C. **Market Analysis.** The short-run market for spruce-fir is currently (1983) in disequilibrium. Biologically, the current annual net growth of the growing stock of balsam fir and white spruce forest types is over 120 million ft^3 annually while removals are just under 40 million ft^3. In many areas the spruce-fir group has the largest annual net growth for softwoods. Many owners claim that they would be willing to sell more spruce-fir stumpage than they are able to under present conditions, even if this resulted in lower prices. The situation seems to be approximately as shown in Figure 5.

For example, if the market price is P_o, a "surplus" results. The amount that market price P_o exceeds the equilibrium price is apparently paid as an incentive to stumpage producers or is a result of time lags in market price adjustments, or both. The surplus quantity is measured by the distance $\overline{Q_aQ_b}$ or $\overline{ab}$. If price does not respond, as stated, the surplus problem will be chronic.

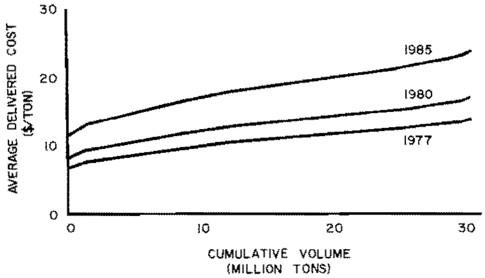

Fig. 4. Computer-based pulpwood supply curve projection for the Lake States.

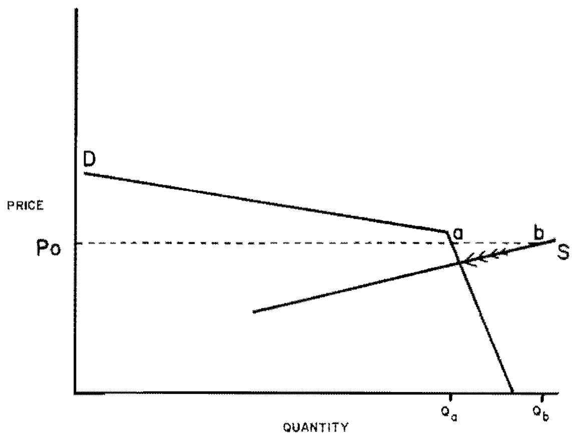

Fig. 5. The short-run market for spruce-fir pulpwood.

II. Long-Run Analysis

A. **Long-Run Supply.** In the long run, the production of spruce and fir is more flexible. Landowners and managers can choose to produce nothing, or as much as the land can produce. Decisions regarding production of spruce and fir, and all forest species, are a function of (1) costs involved, (2) physical or biological constraints, (3) long-term objectives, (4) technological change, and (5) the producer's expectations. All inputs and costs become variable in the long run. Profits and losses will also attract or drive out producers in the market, contributing to expansion or contraction of supply.

The supply curve for softwood pulpwood is a function of the total production costs, including stumpage. This supply curve is the horizontal summation of the component species' supply curves. This means that all softwood pulpwood species individual supply curves are added together to produce an aggregate species pulpwood supply curve. It is, however, assumed that costs for all species rise as quantity production increases so there are no horizontal supply curves.

The emergence of new markets may affect long-term objectives through changing expectations. If new markets induce higher prices, expansion of spruce-fir production may increase overall supply. A specific product supply curve may shift in the long run. Developing lumber markets may divert some of the resource previously used for pulpwood, and the resultant rising prices would encourage an increase in spruce-fir production. Expansion of the pulp and paper industry in the Lake States is also anticipated; this would provide some additional positive incentives for management of the resource.

Future developments in timber supply are rarely foreseeable. Often the time spans contemplated are so long that unexpected factors may become the most important ones (Montgomery et al. 1975). Technological changes that may decrease the cost structure of producing pulpwood or create new markets for the resource are difficult to predict but would have major influences on future supply. As in the short-run supply analysis, stumpage supply and the spruce-fir pulpwood supply will be examined separately.

1. **Stumpage Supply.** Long-run stumpage supply represents the relationship between the volume of stumpage supplied at a given price and time. Three main factors affect this relationship: forest management, land, and ecology.

a. **Management.** Forest management decisions are an important factor in assessing the long-run stumpage supply curve. Supply may be affected by decisions regarding regeneration, harvesting, and objectives.

Regeneration decisions by land managers will determine the composition of the timber supply in the future. Conversions to other species would shift the long-run supply curve for spruce-fir pulpwood stumpage, reflecting an increase in costs and reduced yields. This indicates a decreasing quantity supplied if prices remain constant.

Conversions from the spruce-fir type are based on future price expectations, owner needs and preferences, and site quality. Converting sites occupied by spruce-fir to other species would be expected on the best sites. Eventually, less productive land would be left in the spruce-fir type. This would result in a smaller quantity of spruce-fir available at given prices. Presently, conversions are occurring on a small scale and are generally concentrated on forest industry lands and to a lesser degree, on government lands. With increased management in the Lake States, spruce-fir sites are often converted to species other than balsam fir. Privately held lands are not often converted, perhaps due to the investment involved. As a result, private non-industrial landowners in the Lake States are expected to continue to produce the spruce-fir type in the future.

Harvesting methods can also affect spruce-fir regeneration. Fir commonly occurs with aspen (*Populus* spp.), or paper birch (*Betula papyrifera* Marsh). Once clearcut, these stands usually develop a well-stocked aspen stand from sprouts. Spruce-fir stands which are salvaged or harvested may convert to aspen, birch, or conifers but eventually come back to spruce-fir (Flexner et al. 1983). Cost-free changes, such as perpetual spruce-fir natural regeneration, increase the volume of spruce-fir in the long run. This means a greater quantity would be available at given prices.

Management objectives are highly variable among ownerships and each ownership affects long-run supply differently. Government decisions are often based on criteria other than timber production such as providing recreation or wildlife habitat. Some government agencies, such as the USFS operate under even-flow and multiple-use mandates to insure a steady available volume of stumpage. This volume varies somewhat as biological estimates are changed, revised, or species composition changes but the long-run timber supply from public land can be viewed as a relatively steady flow.

Forest industry corporations seek to earn profits on their land ownership but may also seek to reduce the uncertainty of stumpage supply. Corporations may plant lands more economically suited for natural or custodial management because pulpmills require a certain supply of particular species types to avoid mill down-time. Survival of the firm is a higher priority than incurring short-term losses from lower forestry returns (Montgomery et al. 1975, Irland and Runyon 1984).

Conversions of the spruce-fir type to other species usually accompany industrial planting activities. As future conversion costs rise, however, industry may seek to maximize profits by maintaining natural stands of spruce-fir and by managing them more intensively.

The remaining group of landowners, non-industrial private ownerships, can be characterized by short ownership tenure, differing expectations, and many different management objectives. Stumpage supply from private lands, however, has been observed as price responsive (Row 1980). Producing stumpage is only one objective and many owners do not consider stumpage production a primary objective. Rather, recreation, wildlife, or another use may be the primary objective. The private ownership contribution to stumpage supply also depends on the inventory volume as a whole. When the total volume of stumpage is high (given the same objectives) landowners are more responsive to stumpage price changes than when the total volume is low (Row 1980). Thus, as the total volume of available stumpage decreases, the long-run private stumpage supply curve will shift left, implying higher costs (the stock effect).

b. **Land.** Land is another major factor that will affect the long-run supply of spruce-fir stumpage. Land use for timber production will be expanded or contracted in response to price movements. Land can increase stumpage supply as the quantity devoted to stumpage production increases, as the quality of the land used for stumpage production increases, or as productivity on current land used is enhanced. Trends indicate that over 50% of the commercial forest land in the Lake States will still be privately held in the year 2030 (USDA 1981). If private ownership of commercial forest land declines over time, then the long-run spruce-fir stumpage supply from this source will decrease. The quantity of industry-owned land is also projected to decrease and it is assumed that this will result in a corresponding decrease in the amount of industry owned spruce-fir stumpage. Publicly owned land is not projected to change significantly.

c. **Ecology.** In the absence of fire, stands of aspen and birch succeed to spruce and fir. Succession to the spruce-fir type increases the spruce-fir stumpage quantity available at given prices. Disturbances such as fire and spruce budworm outbreaks would also affect supply. The physical supply, diminished in the short run, may increase or decrease in the long run. Fire may maintain pioneer species such as aspen and birch if it occurs regularly. Outbreaks of spruce budworm, while decreasing spruce-fir volume in the short run, would contribute to greater long-run volume by allowing advance fir regeneration to successfully compete with tolerant hardwoods.

2. **Spruce-Fir Pulpwood Supply.** If spruce-fir stumpage volume decreases in the long run and the best spruce-fir sites are converted, harvesting costs for spruce-fir would rise. Less volume of spruce-fir would be produced on a given land unit so costs per unit would be higher. Transportation costs would be higher if more remote areas needed to be harvested. These increased costs of harvesting and transporting stumpage translate into a decrease in the quantity of spruce-fir pulpwood supplied at a given price because producers would substitute less costly species. Real price increases (adjusted for inflation) in labor or other costs will likewise decrease the amount of pulpwood supplied.

By lowering costs, technological changes may increase the available quantity of pulpwood. Greater efficiency means lower costs (Hatch et al. 1976). Better utilization through new harvesting methods, such as whole tree chipping, can yield higher returns to operators. Increased utilization is equivalent to either increasing the growth rate or decreasing mortality. New methods and better equipment have an effect similar to increasing the available supply at current prices.

A summary of the factors and their effects on the long-run spruce-fir supply is presented in Table 1.

B. **Long-Run Demand.** In the long run, new markets may develop which will alter demand for the spruce-fir resource. Although U.S. demand for pulpwood is projected to increase more than 90% by the year 2030 (James et al. 1982), demand for particular factors, such as fiber type, may change (Leuschner 1973). The high capital costs of constructing new mills may induce industries to expand at good locations. In turn, industries gear their mill needs to species which they believe plentiful enough to ensure no mill shutdowns. The vast hardwood resources of the Lake States have attracted industry (James et al. 1982, Adams 1975). Trends in the Lake States indicate that while the use of aspen and dense hardwood pulpwood has increased about 3.5% annually since World War II, the use of softwood pulpwood has decreased about 1% annually (Lothner 1974). Technology which allows greater use of hardwoods by Lake States mills has caused the

Table 1. Changes in long-run spruce-fir quantity supplied in response to various factors.

	Ownership		
Factor	Government	Forest Industry Corporation	Private
New markets	—	—	increase
Conversions to other species	small decrease	decrease	—
Anticipated owner objectives	—	decrease	unknown
Decrease in quantity of land	—	decrease	decrease
Rising costs	—	unknown	decrease
Technological improvements	small increase	small increase	small increase
Overall expectation	stable	decrease	unknown
% ownership of total spruce-fir in Lake States	30	10	60

softwood pulpwood demand to decrease. A related decrease in Lake States demand for spruce-fir pulpwood may be occurring now as hardwood fiber is substituted for softwood fiber.

However, the long-run improvement of several markets for spruce-fir is probable. Balsam fir and spruce are usable as dimension lumber in the Lake States (Sinclair et al. 1981). Other markets include recreation, wildlife, and exports. Each has the potential to increase long-run demand.

Exports may become more important as world demand increases. The reintroduction of moose into Michigan's Upper Peninsula will increase the need for the spruce-fir type, as it is a preferred food. Spruce-fir is important thermal cover for deer in some areas. Values for wildlife of the spruce-fir type have not been estimated at this time, although it is assumed that they are positive.

Recreationists often enjoy the remote, glaciated areas which the spruce-fir type occupies. The visual and olfactory aspects which the spruce-fir type adds to the recreational experience is also assumed to be positive, even though the actual value has not been estimated.

C. **Market Analysis.** Overall, the long-run supply may be stable. Much depends on private owners, who own the majority of the resource. Large scale conversions, which are not foreseen, could alter this conclusion. New markets figure prominently in changes in demand and supply. Although the quantity desired at current prices has been decreasing new markets are developing and current markets are expanding. Thus, demand for Lake States spruce-fir will soon become stronger. The current surplus of spruce-fir will not likely recur in the future; a demand shift for spruce-fir stumpage may bring the market to equilibrium.

COMPARATIVE STATIC MODEL

The Comparative Static Model examines the supply and demand for spruce-fir after the effects of spruce budworm outbreaks. It is an extension of the Static Economic Model developed in the previous section. Periodic spruce budworm outbreaks cause extensive mortality in mature spruce-fir and create favorable open conditions for balsam fir regeneration. A very stable pattern of fir replacing fir in the absence of fire is usually maintained.

Specific damage varies among budworm-infested stands by stand age, density, size, and location (Witter et al. 1984). Tree mortality is caused by heavy defoliation over time. After losing 75% or more foliage, or after about five years of repeated severe defoliation, trees do not generally recover (Witter et al. 1984). Old, overstocked stands which are less vigorous usually die after three to five years of defoliation, while young vigorous stands can survive five or more years. Mortality in mature fir stands usually ranges from 70 to 100%, while mortality in immature stands varies from 30 to 70% (MacLean 1980). Spruce budworm outbreaks are usually so widespread that they can quickly decrease a region's timber supply by a large volume.

Mortality does not always occur but growth loss and injury often appear. After three years of severe defoliation, the terminal leader is killed. If the tree recovers, its value may be significantly reduced by buried dead terminals. Top-kill can decrease tree height by 0.3–3.66 m and is more severe in trees in lower crown classes (Witter et al. 1984). Increment loss in diameter growth can range from 50 to 90% during an outbreak (Munro et al. 1979). Growth loss alters both stem diameter and height from that normally expected and is often accompanied by a change in quality.

Susceptibility to invasion by secondary insects and diseases is also increased as balsam fir and spruce are stressed. Bark beetles are attracted to dead and dying trees and invasion by heartwood fungi is likely if top-kill occurs to a diameter of 7 cm or greater.

A positive aspect of the mortality caused in certain stands is the natural thinning effect which allows the surviving trees to put on rapid growth after release. The number of surviving trees is dependent on the length of time over which severe defoliation has occurred, tree species and vigor, and location of the tree or stand within the forest. Negative impact, such as mortality, growth loss, and increase in disease susceptibility, are usually greater than positive effects in the form of growth gains from the natural thinning effect. Long and short-run effects are discussed separately.

I. Short-Run Analysis

Spruce budworm outbreaks cause two shifts in the short-term stumpage supply curve. The first shift occurs as landowners realize that salvage must take place immediately or the resource will be lost. For many, the reservation price falls. This causes the supply curve to shift from S to S′ (Fig. 6). During an outbreak, a large property may yield more dead and moribund wood than can be sold, suggesting that even though owners might be willing to drop stumpage prices, the quantity mills will buy would not necessarily respond. If stumpage prices are relatively fixed, as hypothesized in the Static Model, the "over-supply" or surplus of spruce-fir stumpage which owners wish to sell will increase. Thus, in the Comparative Static Model, the Static Model surplus in supply of $\overline{Q_aQ_b}$ increases to $\overline{Q_aQ_c}$.

If prices of spruce-fir move downward in response to the outbreak, the quantity which owners desire to sell will fall. If prices fall to P_1 from P_e (Fig. 6), the quantity owners will wish to salvage will decrease to Q_d. Even though the available quantity has decreased, it remains in excess of the amount mills can process. At this price, the total revenue received by stumpage owners will decrease. The darkened rectangle represents the additional revenue owners will earn by lowering price and increasing quantity sold. The lined rectangle represents the lost revenue which would have been received without the lower price. Clearly, the revenue lost exceeds the revenue gained to stumpage owners.

The second shift in the short-run stumpage supply curve is caused by timber mortality resulting from spruce budworm outbreaks. As the available physical volume of spruce-fir decreases, the supply curve shifts to S″. However, due to the large surplus volume of all pulpwood species in the short run, it is unlikely that even this shift will absorb all the available spruce-fir pulpwood. The surplus after the leftward shift will diminish to $(\overline{Q_eQ_d})$ assuming that price remains at P_1. This is reasonable since stumpage demand is derived from pulpwood demand. Even after this shift, a surplus of spruce-fir material will remain, equal to $\overline{Q_eQ_f}$.

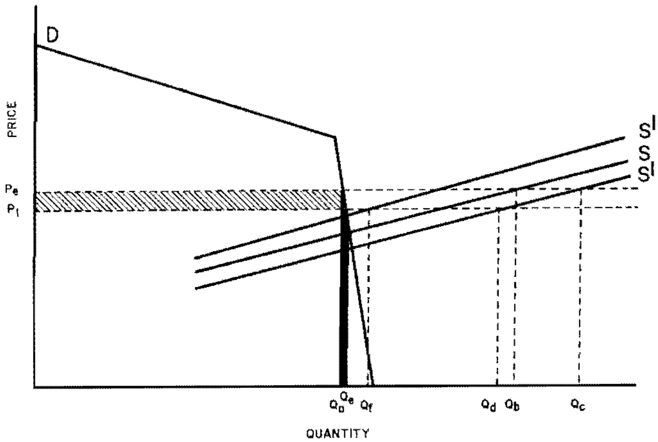

Fig. 6. Short-run effects of spruce budworm outbreaks on short-run stumpage supply.

Pulpwood production also changes as a result of the spruce-fir stumpage supply shifts. The quantity of spruce-fir harvested may increase slightly as a result of the immediate increase in stumpage availability. As the spruce-fir price falls, producers will substitute spruce and fir for other species. Trends in pulpwood production support this. Balsam fir pulpwood production increased by 6.3% between 1969 and 1978 in the Lake States. This is attributed to salvage harvests (Blyth and Smith 1981).

Producers may harvest more than they can sell. There are reports of pulpwood "sitting in the yard" waiting for a buyer in some areas. Thus, a surplus of spruce-fir pulpwood, like that of stumpage, also exists at the current market price (Fig. 7). As the stumpage supply shifted to S′, pulpwood supply also shifted and the surplus was created. Later, stumpage costs may rise and supply may shift to S″, so pulpwood buyers would substitute other species and pulpwood supply would shift back to S. The shift in spruce-fir stumpage supply to S″ indicates a decrease in quantity at prevailing prices. This would not result in a decline in the pulpwood supply per se but only in an adjustment of the species mix.

In summary, spruce budworm outbreaks in the Lake States probably create revenue losses to stumpage owners and produce a temporary "excess supply" situation in the pulpwood market. Demand is not influenced by spruce budworm outbreaks, although the price level may drop in response to the greater availability of salvage volume.

II. Long-Run Analysis

Spruce budworm outbreaks may decrease the quantities of spruce and fir in the market over the long run. The available quantity will decrease if spruce-fir stands are converted to other species. However, if spruce-fir stands are maintained and managed more intensively, the long-run supply curve for spruce-fir would shift, indicating greater quantities of the resource available. Subsequent price changes depend on both supply and demand shifts. If the current trend favoring hardwoods over softwoods continues in the future, then spruce-fir demand will be dampened and the price and quantity demanded of spruce-fir will be falling. National trends indicate an increasing pulpwood demand, so it is likely that the Lake States softwood pulpwood market will strengthen along with the hardwood market. In addition to the vast hardwood resources in the Lake States, the spruce-fir resource is also a "vast fiber source" and may prove the most cost-effective species to grow and regenerate on many Lake States sites.

Therefore, two scenarios are envisioned. The first is the anticipated increase in demand

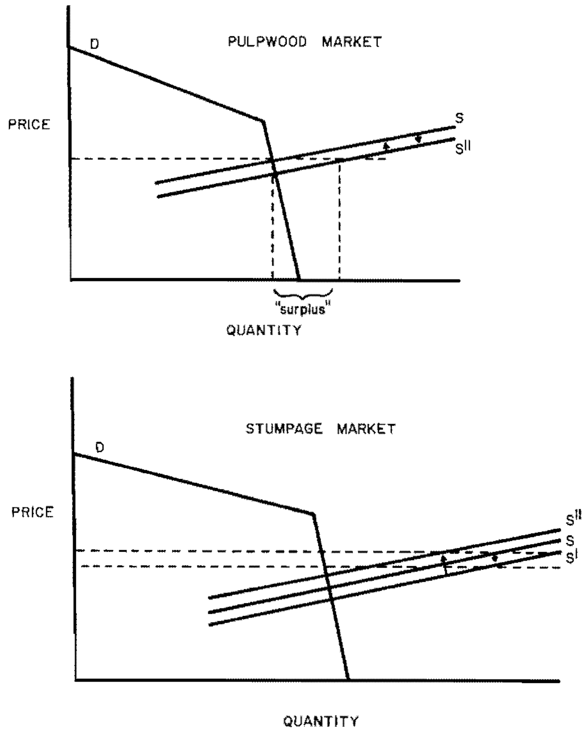

Fig. 7. Dynamics of the short-run spruce-fir market.

for the spruce-fir resource with no corresponding change in forest management techniques. The demand shift would dampen any tendency for a downward shift of spruce-fir prices, and even raise prices if strong enough without proper management procedures. However, spruce budworm outbreaks might still eliminate vast areas of the resource. If resultant mortality were high, prices might rise as the market quantity available decreased. The second scenario involves the implementation of management practices designed to minimize the risk of timber losses due to spruce budworm outbreaks along with an increase in demand for spruce-fir. This scenario would make the greatest volume of stumpage available. The first and second scenarios may be similar if the market is strong enough to induce the harvest of all mature and over-mature spruce-fir stands and maintain a rotation age of 40 years or less for spruce-fir, which would decrease the risk of future outbreaks.

Thus, the long-run effects of the spruce budworm on the Lake States market are dependent on the development of stronger markets and management strategies. Demand is expected to become stronger as a result of new and expanding markets while supply will be a function of management decisions. Spruce budworm outbreaks may weaken the shift of demand because industries may not have confidence in spruce and fir as a continuous fiber source. Supply of spruce-fir will be partly determined by the management activities used to prevent or suppress spruce budworm outbreaks. Under proper management, corporate confidence in spruce-fir fiber may be justified.

CONCLUSION

Outbreaks of the spruce budworm affect the Lake States spruce-fir supply in the short run. In the very short run, the shift in spruce-fir supply caused by salvage intensifies an "oversupply" situation. Short-run prices should fall as owners compete to sell stumpage which must be sold within 1–5 years or be lost. Spruce budworm outbreaks occur over a large area and the present outbreak in the Lake States yielded more dead wood than could be salvaged. In mature and overmature fir stands mortality can range from 70 to 100%, causing the cost of not salvaging to approach the value available from current sale, a now or nothing prospect. This means that owners may be willing to sell stumpage at any price which exceeds the costs incurred in producing it. In fact, some owners may be willing to sell stumpage for less than the costs of producing it in order to clear their land of dead trees. It is believed that the price level would eventually fall as buyers respond to salvage quantities.

As short-run supply shifts right and quantity demanded remains unchanged, an increase in spruce-fir harvests and a decrease in real prices is expected. Empirical evidence showing increased balsam fir harvests (Blyth and Smith 1981, 1982) and decreasing real prices for balsam fir (Lothner et al. 1982) supports this relation.

After salvage opportunities are exhausted in the short run (assuming that price levels do not change) the quantity owners wish to sell at the given price level will fall. Prices will not rise because other species can be substituted.

Stumpage owners are the losers in the short run. Lowered salvage prices and inventory reductions through mortality, growth loss, and quality declines decrease the revenue which these owners receive. In the Lake States, the cost of direct suppression (insecticides) for the purpose of reducing spruce budworm losses probably exceeds the value of these losses. But in certain localities, market conditions may be such that insecticide treatments may be financially justifiable (Marty 1982, Irland 1977). In Marquette County, Michigan, for instance, the Department of Natural Resources is examining the feasibility of spraying spruce-fir stands so that these stands are ready for harvest in 1986–1987.

The long run effects of spruce budworm outbreaks depend on the development and expansion of new markets in the Lake States. If demand strengthens as a result of these markets, rising prices could induce more intensive management of the spruce-fir resource, in which case supply might also shift. The greater the demand shift, the more prices will rise. With shorter rotations and fewer overmature stands of balsam fir, a more continuous supply of stumpage would be expected (Montgomery et al. 1982). This fact may encourage new corporate entrants and further shift demand. Without the development of new markets, no price incentives will exist to manage the resource. Thus, losses due to spruce budworm outbreaks would continue into the future.

Clearly, the long-run effects of spruce budworm outbreaks depend on the management of the spruce-fir resource. As markets develop, price incentives will instigate management techniques that will reduce losses and increase yields on spruce-fir sites. The benefits of the spruce-fir resource are many; it regenerates naturally, has good pulping qualities, grows well on a variety of sites, and provides good wildlife habitat. The direct cost of not managing the resource to reduce losses from spruce budworm outbreaks is the loss of a substantial volurme of stumpage. Thus, the long-run volume loss caused by spruce budworm outbreaks depends on management practices. The value of these losses, in turn, depend on the emergence of new markets.

Long-run shifts in demand can be facilitated by attracting new industry to the area, developing new markets for the spruce-fir resource, and demonstrating that the spruce-fir resource can provide a continuous fiber source in the future. A continuous, increasing long-run supply will be encouraged by rising prices. Further research is needed on new markets for the spruce-fir resource. Land management techniques have been developed which will minimize losses from spruce budworm outbreaks (Montgomery et al. 1982, 1983), now the price incentives are necessary to warrant their use.

ACKNOWLEDGMENTS

We greatly appreciate reviews of this paper by Mike Albers, Minnesota Department of Natural Resources, Grand Rapids, MN; James Blyth and Robert Ford, U.S. Forest Service, St. Paul, MN; Bob Heyd, Michigan Department of Natural Resources, Marquette, MI; Lloyd Irland, Maine State Planning Office, Augusta, ME; Robert Marty, Michigan State University, E. Lansing, MI; and Jerry Thiede, Michigan Department of Natural Resources, Lansing, MI. We also acknowledge suggestions and professional assistance from Dick Anderson, U.S. Forest Service, Iron River, MI; Bob Booker, U.S. Forest Service, Rapid River, MI; Dave Bromley, U.S. Forest Service, Sault Ste. Marie, MI; Jim Evers, U.S. Forest Service, St. Ignace, MI; Emery Feero, Mead Corporation, Escanaba, MI; Michael Lanasa, U.S. Forest Service, Escanaba, MI; Ann Lynch and Bill Magrath, The University of Michigan, Ann Arbor, MI; George H. Lyon, U.S. Forest Service, Manistique, MI; Jim Meunier, Jim Sommerville, Marion True, and Ed Vinoski, U.S. Forest Service, Ironwood, MI; and Dave Reiter, U.S. Forest Service, Bessemer, MI. We are grateful to Nancy Witter for drawing the illustrations and Betty Manoulian for typing the manuscript.

Work leading to this publication was funded by a USDA Forest Service sponsored program entitled Canada-United States Spruce Budworms Program, by McIntire-Stennis funds, and by The University of Michigan.

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