RP 517

Developing harvesting systems for the future: linking strategies, biology, and design

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Abstract

Development of harvesting systems in the United States has proceeded in relative isolation from long-term strategic planning for forest management and consideration of biological requirements of future timber crops. The time has come to change that approach to one that takes a long-term view of harvesting-system development, integrating economics and biology as variables. This approach, already successful in agriculture, will permit designers, biologists, and managers in forestry to develop a broader range of future options and increase their chances of achieving some semblance of optimality. The long time period between forest-tree crops adds even more urgency to developing solutions now. Institutional models for such integrated, cooperative efforts can be found elsewhere in the world and should be initiated in the United States.

In this article we describe an approach to harvesting-systems design which incorporates both strategic goals of forest management and fundamental biological requirements of the species managed. Although this is a common approach to systems design in agriculture, it has not been attempted in forestry.

We believe that harvesting-systems development should be viewed in the context of the overall timber-production system (Fig. 1), in which changing one subsystem or component produces changes in others. Further, we believe that time is a major factor influencing the approach to harvesting-system design in the context of this timber-production system. If the system is viewed over long time periods, decisionmakers can consider a wider range of options for adjusting each subsystem and have a better chance of achieving some semblance of optimality. Factors normally viewed as constants may be treated instead as variables for the purpose of strategic planning.

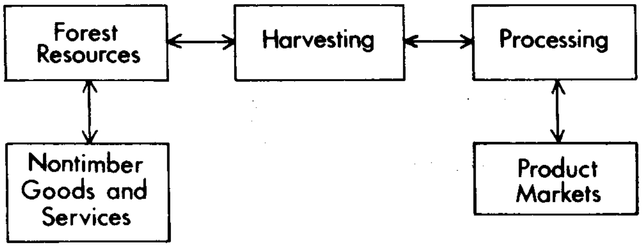

Figure 1. — Conceptual structure of the timber-production system.

The history of harvesting-systems development in the United States has proceeded in a fashion almost diametrically opposed to these views. Harvesting has been isolated from the other components of the timber-production system; emphasis has been on the immediate rather than the long term. There are two basic reasons why:

1) Development of harvesting systems has not been adequately supported by research. Boyd, Carson, and Jorgensen[1] noted that only about 70 scientist years were devoted annually to harvesting-systems research in the United States — a number that has

[1]Boyd, C. W., W. W. Carson, and J. E. Jorgensen. 1977. Harvesting the resource — are we prepared? J. Forestry 75(7):401-403.

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Forest Prod. J. 32(6):35-38.

not changed appreciably since 1977. On the basis of annual roundwood harvested, the United States has only one-sixth the number of harvesting researchers as Sweden and only one-fifth that of the Soviet Union.

2) In addition to being small, the harvesting research and development effort has been poorly coordinated, even regionally. The industry is highly fragmented; its many small, independent contractors lack a consensus about need or the target systems on which harvesting research should focus. This, in turn, has resulted in research on short-term problems, primarily removal of products currently available in our forests. Gains in productivity have been relatively small, without major technological breakthroughs in the harvesting and handling of raw materials. But most importantly, our horizons have been limited to the present rather than extended to development of systems for the forests of the future.

How have our present systems evolved, in the absence of organized research and development?

1) By trial and error, often by the loggers using the systems. Frequently lauded as the only practical way to develop harvesting systems, this approach is costly and time-consuming. Although occasionally spawning good ideas, trial and error usually produces designs that meet unique rather than general needs.
2) By development in small job shops, often in response to the needs expressed by a logger client. At this level, some engineering design often is incorporated into the development process. Again, some good ideas come from small shops but frequently are not fully exploited because of limitations in size of production line, investment capital, and engineering staff.
3) By major equipment manufacturers in the United States. Their contributions have generally been small in relation to their potential, in part because the harvesting-system market is small compared to these manufacturers' major markets, the construction and agriculture industries. Further, the lack of consensus about specific needs within the harvesting industry has created a climate of healthy skepticism among manufacturers; they are quick to point out examples of significant investment in prototypes built to specification which had only limited demand. They served in other words, as large-scale versions of job shops but with considerably more overhead. In many cases, manufacturers have become buyers, not developers, of technology, or have confined development to harvesting attachments for machines principally produced for construction or agriculture.

We recognize that this is a classic chicken and egg problem — harvesting-system capabilities influence strategic management and biological decisions, and vice versa. But, it is time to take another approach to harvesting-systems design, one that incorporates the broader strategic goals of forest management.

Strategic planning and design

Planning harvesting systems that adequately reflect strategic management and biological goals requires the designer to think at the strategic level and to be a part of the strategic planning process. Factors normally viewed as fixed must be construed instead as variable. For example, the size and quality of timber stands to be harvested are relatively fixed in the short term but may be considered variable over long time periods. Likewise, the biological parameters (e.g., genetic traits or forest ecosystem composition) affecting growth and yield become variables in the long term. Similarly, key economic and financial factors such as interest rates and cash-flow requirements may tightly constrain short-term thinking but are variables at the strategic level. Strategic thinking should produce a strategic plan — the development of broad objectives, goals, constraints, and alternatives that provide an overall, purposeful set of directions for an organization in light of its resources and opportunities.

An example of the way in which strategic planning can influence harvesting-system design can be drawn from the issue of precommercial spacing and thinning in the Pacific Northwest. Precommercial thinning, based on a classical relationship between forest growth and stocking (Fig. 2), is an investment that redistributes subsequent growth onto fewer, higher quality stems. As stocking is increased beyond point B, growth is either distributed on more stems, each of which is reduced in value, or on more basal area, which may produce more value if the number of stems is reduced. Precommercial thinning in a stand where growth is increasing rapidly with stocking (up to point A) results in short-term costs of reduced stand volume to redistribute growth on even fewer stems. The payoff is twofold (Fig. 3). First, subsequent commercial harvesting costs are reduced because fewer, larger pieces remain for cutting. Second, product values may increase because larger pieces are processed.

An example of an important strategic decision is assessing the discount rate against the costs incurred in precommercial thinning. A high discount rate will nullify the net increase in value from precommercial spacing, making it a less attractive investment. Thus, selecting a high discount rate leads to a strategy for managing stands that will contain many small stems (point C and beyond in Fig. 2). Part of that strategy must

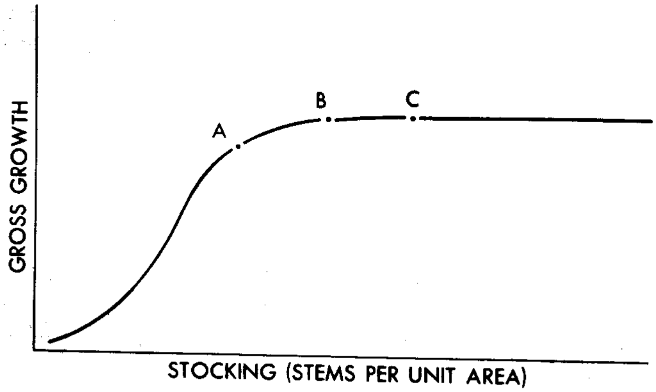

Figure 2. — General relationship between forest growth and stocking.

include development of equipment appropriate for harvesting timber of the size and spacing anticipated.

The strategy to invest in commercial thinning requires the same kind of careful analysis as that for precommercial thinning. The major difference is that the material removed from the stand has value. Again, the strategic decision to include thinning as a management tool leads to consideration of several important harvesting-system criteria. Removal may cause damage to remaining stems or soil unless prevented by design. Terrain may also impose design constraints, particularly in the Pacific Northwest where slopes greater than 35 percent are common.

At the strategic level, planning for tomorrow's forests requires consideration of a wide range of alternatives that will directly or indirectly provide basic criteria for the harvesting-equipment designer. Consider these three possible strategies for managing stands of young Douglas-fir in the Pacific Northwest:

A: Plant available nursery stock, precommercially space, then harvest small trees.

B: Plant available nursery stock, precommercially space, thin, then harvest large trees.

C: Breed genetically superior seedlings, plant, precommercially space, fertilize, then harvest small- to medium-sized trees on a short rotation.

All three strategies include precommercial spacing which, together with the specified discount rate and return on investment, will determine for the designer the type of precommercial spacing system needed and its cost allowance. Strategy B requires thinning in a stand with spacing established by earlier precommercial spacing; this will provide some design information on maneuvering room in stands mechanically thinned or on obstacles likely to be encountered in a skyline thinning operation. The size of tree harvested varies with each strategy. In addition, trees grown under Strategy C are likely to be much more uniform in size and straightness, with fiber properties that reflect rapid juvenile growth.

In summary, then, strategic planning permits managers to influence factors which are at least partly controllable in the long term and which may substantially define design specifications for harvesting equipment. Successful designs will not just shift harvesting costs along the curve in Figure 3 — they will alter its shape, accentuating the difference between log value and harvesting cost even more.

Biological engineering

Not long ago, the subject of genetic engineering was a topic relegated to science fiction literature. Today, it is widely discussed and debated. Industry, government, and universities are now jointly engaged in a wide range of sophisticated genetic research projects that have major implications for tomorrow's forests. However, seldom discussed are the opportunities this rapidly advancing science affords for jointly designing forest crop, harvesting system, and ultimate product.

Most silvicultural activities depend directly or indirectly on the removal of trees or other stand components,[2] yet harvesting and silvicultural research has traditionally been done separately. Reasons for the separation vary from ignorance to the deliberate focus of limited resources on narrow objectives. Although harvesting researchers have tended to take biological and silvicultural characteristics as given, silviculturists have tended to perceive harvesting systems as unresponsive to silvicultural requirements. This situation has been aggravated in North America, where naturally occurring, unmanaged stands have been the focus of harvesting attention and, too often, constraining models for silviculturists. However, as plantations of trees bred and managed for specific products replace natural stands, the opportunity arises for combining silvicultural and harvesting research in a synergistic way. Currently, where silviculture and harvesting are jointly addressed, silvicultural considerations precede those of harvesting, as exemplified by the often-heard dictum (at least in the Northwest) that it is the harvesting systems which must adapt to smallwood conditions and not the reverse. If this linear thinking persists, we will have missed our chance to jointly design tree growing and harvesting systems.

The research approach we have in mind considers harvesting and silviculture simultaneously. Such research is futuristic in that it looks forward at least one rotation, which is the minimum time frame for genetic tree-improvement programs. Thus, the most logical starting point for joint design is genetics. Increasingly, tree-improvement programs are focusing on ideotypes, or ideal stand participants for a specific production goal. Ideotypes provide useful targets for tree breeders and are now beginning to be developed with a fairly specific silvicultural regime in mind. Although harvesting methods and constraints usually are considered only cursorily, if at all, it is precisely at this stage that targets for diameter, limbiness, wood and stand density, crown shape, and even bole center-of-gravity are set, either explicitly or implicitly. Joint silviculture-harvesting research should carefully evaluate the interaction

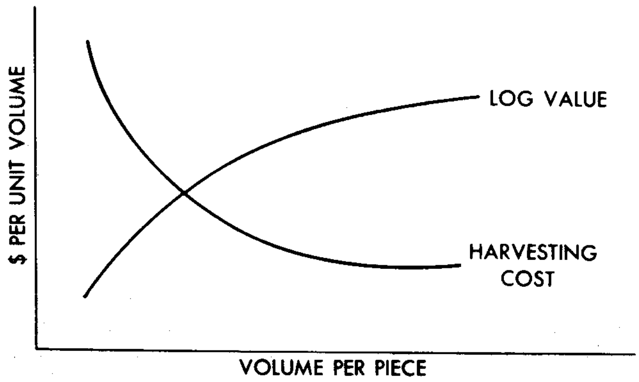

Figure 3. — General effect of volume per piece on harvesting cost and log value.

[2]Smith, D. M. 1976. The scientific basis for timber harvesting. Presented at a joint meeting of the Washington Academy of Sciences and the American Society of Foresters, Washington section, Arlington, Va., November 18, 1976.

among biological ideotypes, alternative harvesting systems, and end-product characteristics, all in terms of biological, engineering, and economic efficiency and effectiveness. Once tradeoffs are identified, adjustments can be made before seed orchards have been established or harvesting machinery design set.

The precedent for jointly designing crop, management practice, and harvesting systems to achieve an optimal combination is well established in agriculture. Varieties of tomatoes, developed especially for machine harvesting, have been bred to be durable and to ripen at a fairly uniform rate. Varieties of pineapple have been selected for cylindrical shape to minimize waste and increase efficiency in packing. Methods to control ripening also have been developed so that harvesting can be accurately timed and scheduled.

Examples closer to forestry are fruit trees and machines to harvest them, including selection of dwarf varieties and development of pruning systems to allow over-the-row harvesters. Pruning, in turn, has been accompanied by methods to control sprouting. Because trees are shaken or swayed by harvesters, root stocks had to be developed which could withstand motion and not uproot.

Efforts to incorporate machine design into long-term strategic plans for forestry are underway in Sweden, Canada, and New Zealand through cooperative research ventures which include industry, government, and universities. We need to begin a similar effort, tailored to our situation, in the United States.

There is ample evidence that geneticists, horticulturists, and engineers can work together to develop machine-crop combinations that improve productivity. We feel that the same principle can and should be applied in forestry. The major difference between agriculture and forestry in these examples is the long time period required to genetically alter forest-tree crops and develop machinery for their harvest. Although this makes the forestry problem more difficult, it further emphasizes the need for developing solutions. Managers in forestry deal with long-term problems in every aspect of their jobs: projections for growth and yield and decisions about product type and land-use allocation. It is time to include machine design as a component of the strategic plan. The goal should be development of options for the future so that managers can later select those that are economical. In the process, we may shorten the time involved for growing trees profitably and contribute to making forestry a more stable enterprise.

Summary

The key to developing rational designs for the harvesting systems of tomorrow lies in recognizing that these systems are part of, not separate from, the overall timber-production system. Designers must become part of a strategic planning process that considers long-term financial and biological options at the same time harvesting-system criteria are developed. Both forest managers and consumers will benefit from the gains in productivity.