INCREASED WOOD-FIBER PRODUCTION: TECHNOLOGY, ECONOMICS, AND ECOLOGY

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Forest tree improvement is a form of technological change, and it should be viewed as such. The economic objective of technological change is to increase productivity per dollar invested. This is accomplished through selection and breeding for increased growth rates or reduced losses to insects and disease. Programs which yield improved planting stock make forest investments more profitable by reducing initial costs. The empirical evidence to date (e.g., Davis 1967, Lundgren and King 1965) indicates that investments in forest tree improvement can and do pay off, sometimes rather well.

Along with economic objectives, other goals may be achieved through tree improvement. The improvement of ornamentals, particularly in terms of resistance to pests and the rigors of urban environments, leads to increased amenity values. Even this sort of goal may have economic overtures, however, because of social costs for tree removal and changes in property values associated with tree losses.

ECONOMIC ANALYSIS

The analysis of economic benefits and costs follows a well established procedure (Marty *et al.* 1966). The changes in cash flows attributable to a tree improvement program must be estimated, then discounted to the present. A comparison with the investment cost will establish if the program is viable — i.e., benefits at least equal to costs. A comparison with other alternatives will establish the relative priority of tree improvement investments. More sophisticated analyses will consider alternative silvicultural packages of fertilization, weed control, tree improvement, and so forth to search out the optimal combination and intensity of practices.

Uncertainty can be incorporated into such analyses. It is possible, using data such as Lester and Burr (1965) published to design selection and breeding systems that virtually guarantee success. If the costs of such a program are not justified, then incremental analyses can suggest at what point the increase in benefits from reduced uncertainty in a tree improvement program just balances costs. Although operationally useful, a yet broader integration of uncertainty may be of greater long-term use when contemplating a technological change such as a tree improvement program.

TECHNOLOGICAL CHANGE

Our perception of technological change has changed rapidly. A McIntire-Stennis project was established at the University of Wisconsin in 1966 titled "The Causes and Effects of Technological Change in the Forest Industries" (Bentley 1970). The economic viewpoint focused on the role of technological change in the growth and development of national economies. Definition and measurement dominated many research discussions. Unemployment was the dominant social issue, aside from an occasional prophet of environmental doom. All this has been changed by the rapid growth of environmental awareness. Technology no longer is viewed as predominantly beneficial, and many bad side-effects — externalities or costs that are incident on society as a whole — are commonly identified. Many scholarly and popular treatments of these issues, such as Toffler's *Future Shock* (Toffler 1971), have appeared in recent months. The rate of change, scale of impacts, and often unexpected biological and social side-effects give hysterical cries of "ecocide" some credence.

Technological change is the logical outcome of rationalizing man's productive activities. Industrialization, notes Boulding (1964), began with the "turnip."

When agricultural man began to develop crop cultures and plant and animal breeds, and to evolve patterns of rational husbandry, he laid the foundations for industrial man. Later, the harness of energy (mainly coal) provided the major breakthrough for the rational systems of industrial production in the modern world. Forestry has been a part of this phenomenon. For example, changes in mill technology from pitsaw to the modern, all-electric gangsaw are illustrative of the general industrialization of developed nations.

Silviculture has been slower to move beyond primitive stages. The general environment was not conducive to change because excess natural raw material, especially in North America, generated low unit values for wood fiber. Long rotations have precluded the rational research and development that took place with hybrids and other rapid advances. A further difficulty faced by the tree improvement people is that breeding for higher wood production is not as easily accomplished as breeding for higher grain production.

We can expect increased interest in intensive silvicultural systems as wood fiber becomes more scarce, causing unit values and the cost of scarce inputs, especially land, to rise. I think there will be a premium on space for timber growing as primary use because of increased demand for recreation lands. As general and specific knowledge increases, more complex systems can be developed at lower costs.

One view on intensive silvicultural systems with which I am familiar was developed by Gordon and Bentley (1970) at the 1969 Wisconsin Forestry Colloquium. Following through their points, we first can note three principles of rational silviculture:

1. Yield is determined by quantity and distribution of photosynthate, and yield is increased by manipulation of these factors.

2. Yield increases require investments, and, other things being equal, the shorter the rotation, the better.

3. Flexibility is always desirable.

In a similar vein, four principles of rational applied research were proposed:

1. Applied research is planned today to yield information in the future. Therefore, the problems that research is designed to solve must be problems of the future.

2. The future is uncertain. Therefore, applied research must be oriented toward producing results with built-in flexibility (breadth of applicability).

3. Applied research must be coupled in real time to productive systems, to provide useful feedback from practice to research. More simply said, research must be goal-oriented, and the goal must be a production goal (e.g., profits).

4. In this technological age, the productive system must be predicted at least in part upon the capabilities of applied research to aid it.

These principles were combined into the following conclusions:

1. Short rotations are necessary to reduce capital carrying costs, allow research results to lead to rapid results in the field, and provide frequent opportunity for change in land use.

2. Intensive care of dense stands will enable rapid vegetative coverage of the site, and maximum photosynthetic activity with fertilization, pest control, breeding, mechanical planting, harvesting, etc. to avoid biological or technological bottlenecks.

Achievement of this type of system, we concluded, will require a research team approach with a systems viewpoint. As almost an afterthought, perhaps prompted by our declaration of a systems view, we have the following paragraph of warning:

Another point should be made regarding a systems approach to more rational silviculture. Agriculture has not done a very able job in recognizing the adverse effects of its rationality. Some of these, such as site deterioration through intensive fertilization, watering, and cultivation, directly affect the producer. Other effects, particularly those associated with monocultures (hard pesticides, for example), may have greater social costs than private costs. A true systems viewpoint will perceive and incorporate these difficulties as well as the more pleasant and profitable advantages of modern plant culture.

FOREST MANAGEMENT

These ideas, together with a definition of the forest management process, lead to an important conclusion. The processes of management are:

1. *Perception.* — The problem-finding step — being aware that a problem exists and what it is.

2. *Planning.* — Specification of the problem for analytical purposes, information gathering and analysis, evaluation and decision — the problem-solving step.

3. *Implementation.* — On-the-ground activities to carry out planned decisions — the *administrative* step.

4. *Feedback.* — An ongoing step that relates all other steps. It is especially important if new perceptions of problems are to be an improvement over previous problem conceptions. Feedback is a dynamic activity, and it is antithetical to an equilibrium view of the world economically or ecologically.

Most researchers specialize in the analytical component of problem solving. There has been a conflict between analytical problem-solvers and land managers for some time (Macon 1967). Planners think problems are solved by evaluation and decision; implementers recognize that nothing is changed until activities are accomplished. Feedback mechanisms often are bad — fire control is the only forest activity with a highly developed feedback learning mechanism — and effective learning devices should be built into all planning-implementation systems. It is in problem perception, however, that we are the weakest. Perhaps it would be better to describe this weakness as the most incomplete step in forest management.

PROBLEM PERCEPTION

If our understanding of problems is weak, too often we solve the wrong problem, then implement the wrong solution, and follow up with a weak feedback mechanism that does not identify our basic mistakes in perception. We need a broader viewpoint than industrial rationality to resolve this difficulty. The principles that Ferkness (1969) recently outlined provide the basis for going beyond industrial man to a philosophy of "Technological Man" — really "Ecological Man." These points are really an ecological viewpoint composed of three interrelated ideas:

1. *Naturalism.* — Man and his management of the forest resource as an integral part of nature — emphasis on natural, not physical complexity.

2. *Holism.* — The systems viewpoint (as contrasted with systems analysis) that all components of a system are interrelated and only have meaning in context of each other.

3. *Internal self-determinism.* — Focus on internal creation of the system — the forest ecosystem with man included — rather than external, usual unexplained forces creating the system.

With this broader perspective of "Ecological Man," we can construct silvicultural systems, including needed tree improvement programs, which are *ecologically* and *economically* sound. To take a few problem areas, we must be concerned with:

1. *Genetic changes,* especially a narrowing of gene pool. How might such changes affect ability to resist much more rapid population processes in pathogens and insects?

2. *Ecology of artificial monocultures,* including effects of fertilizer, pesticides in nutrient and biochemical cycles.

3. *Is the intensive forest flexible,* as we suggest, in terms of real human wants, or is the more "natural" forest sounder?

Answering such questions might lead us to conclude that medium intensity management may in fact be superior for agriculture and silviculture. Such systems would have fewer negative externalities — i.e., pesticides, mineral leaching — and would have more positive externalities — e.g., amenities, ecological diversity.

Consideration of such issues does not mean capitulation to the current environmental evangelism — especially voices that reflect naive or erroneous understanding of forest ecology and economics. It will contribute to the development of sounder strategies for maintaining or improving all qualitative aspects of our life. A broad perspective, while yielding more complex problem concepts, will lead us to attack and solve the real problems. A narrower view of forest production will defeat current timber production efforts because of uncertainty about what facts and opinions we will face in the future. Economics and ecology are, in fact, quite compatible — the discounted value of an ecological disaster, even if it is in the distant future, still is a high present cost to contemplate when designing a rational, but narrowly conceived silvicultural system.

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