Chapter 26

Considering Nutrient Management in Future Western Forestry

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ABSTRACT. During the past decade, the social environment for forest management in the western United States and Canada has been dynamic and often confusing. Amid this turbulence, some general trends can be seen that may affect nutrient status of forest soils and trees. Three categories of such trends are described: (1) social, economic, and political considerations; (2) changes in the objectives or practice of forest management; and (3) technological advances. Many of the trends suggest that fertilizer applications will be expanded to meet future demands for wood from western forests. Such applications must be finely targeted and closely monitored so that risks to other forest values are minimized and benefits are increased. The trends also indicate a need for improved communication and public education about the direct and indirect benefits of forest fertilization and measures taken to prevent fertilizer operations from impairing other forest resources and values.

Predicting future trends is always difficult, and it is particularly so at present in the area of natural resource management. The social environment for forestry in the western United States and Canada has been dynamic and often frustrating and confusing during much of the past decade. Turmoil and uncertainty are likely to increase as society comes to terms with diverse values and views of nature, and begins to recognize that forest land is a finite resource and must meet many needs.

Given this situation, we were uncomfortable with the "futuristic" nature of the topic assigned to us. After some discussion, we decided to minimize the long-range and predictive aspects of the assignment and concentrate on identifying and discussing some trends and other important issues likely to shape future nutrient management activities. These topics fall into three categories: (1) social, economic, and political trends; (2) changes in the objectives or practice of forest management; and (3) technological advances. Within each category, we will identify some of the major trends, describe the underlying factors, and suggest their implications for nutrient management.

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Social, Economic, and Political Trends

Several significant trends can be seen in the economic and political arenas. They primarily reflect recent and future changes in resource decisions and management practices, and are likely to have a substantial impact on use of fertilizers in forests of western North America. Because these trends are interrelated and the anticipated effects on nutrient management and fertilization are general, we will discuss each trend and the factors contributing to it individually and then suggest overall implications.

Increased Demand for Western Wood Products

Demand for western wood products will continue to grow. Within the United States, roundwood consumption has nearly doubled since 1950, and it will probably increase by another 30% in the next 50 years (Haynes 1990). About one-third of the U.S. national consumption is provided by forests in the Pacific Northwest (Haynes 1990). This trend is strengthened by the continued worldwide population growth as well as the development of a global economy. Likely to be of major significance in the future is energy and the role that woody biomass may play in domestic energy policies.

Human populations will continue to increase both domestically and worldwide. The current world population of 5.6 billion is expected to nearly double in the next 40 years, and the U.S. population may increase by

more than 20% (Marcin 1989). Throughout the world, prosperity is rising and international trade is expanding (Naisbitt and Aburdene 1990). Countries of the Pacific Rim are booming, in both economic and population growth, and will provide expanding markets for western forest products. Concerns about energy are likely to become more serious, and may further increase demands for wood for two reasons: (1) wood-based products generally require much less energy to produce than their plastic, aluminum, or steel counterparts (Boyd et al. 1976); and (2) the use of fuels derived from plantation-grown woody biomass instead of fossil fuels can substantially reduce carbon dioxide emissions (Wright et al. 1991).

Decreased Land Base for Producing Wood Products

The area of forest lands available for growing wood products is decreasing regionally, nationally, and internationally. In the Pacific Northwest, industrial and nonindustrial private forest land has declined by about 1.3 million hectares since 1952 (Haynes 1990). In addition, a large percentage of public forest land has been withdrawn from commercial wood production. Timber output from much of the remaining public land is likely to decrease because of greater emphasis on nontimber values.

This trend of decreasing commercial forest land is associated with population growth and the associated conversion of forest land to meet residential, commercial, and industrial needs. Withdrawals and harvest limitations on some remaining forest land are the result of changes in societal values and attitudes regarding forests, especially those on federal land.

Increased Value of Other Forest Resources and Amenities

Concern for environmental quality and forest sustainability will continue to grow, and society will place increasing value on forest resources other than timber. Evidence of this trend abounds in the news media and in popular literature. It is expressed most dramatically in the current conflict over harvest of old-growth timber in the Douglas-fir region, and is supported by a series of federal and state laws requiring that greater management consideration be given to nontimber resources. The formation of special committees or commissions to deal with this trend is becoming standard procedure in the state of Washington. In the last four years, we have seen the Timber/Fish/Wildlife (TFW) agreement, the Commission on Old-Growth Alternatives, and the Sustainable Forestry Roundtable. The overall consequences are that land area devoted primarily to timber production will be reduced and the methods used to grow timber crops will increasingly have to consider the effects on nontimber resources, on-site as well as off-site.

Increased Regulation and Public Involvement in Forest Practices

The trend of increased regulation and public involvement in forest practices is closely related to—in fact, results from—the increased valuation of nontimber resources. Recent federal and state laws mandating environmental assessments and impact statements have opened the way for litigation as well as more subtle and interactive methods for participation in agency decisions by the general public and by forest resource interest groups. Consequently, more regulations have been imposed—internally and externally. Other developments related to these trends are tendencies toward polarization among segments of society, suspicion of professional resource managers, and the emergence of a naturalistic dogma—a kind of "biofundamentalism"—that claims that "hands-off" management is inherently more desirable and more ethical than intensive technological methods. As a result, costs of forest management will increase, and chemical applications, including nutrient amendments, will be scrutinized more closely.

General Implications of Social, Economic, and Political Trends

Most of these trends suggest a need to enhance the productivity of the land base remaining in wood production. Fertilizer application has proven its potential to meet this need in many areas throughout the West, and it is one of the best and most cost-effective ways to increase growth of existing stands. Some industrial and state forest managers have fertilized extensively during the past two decades; other managers have made only limited use of this practice. Certainly there are additional opportunities to enhance forest fertility in many areas of the West. Indications are that expanded use of fertilizer will require quality control procedures to ensure that other resources are not adversely affected. Such trends suggest the need for improved communication and public education about direct and indirect benefits of forest fertilization and measures taken to prevent fertilizer operations from impairing other forest resources and values.

Trends in Forest Management

Several trends in the goals and practice of forest management have developed during the past decade. Some are likely to affect nutrient status of forest soils and use of fertilizers in western forests. Four of the more important trends will be described. Because their potential effects on forest fertilization are more specific than those for social, economic, and political trends, implications will be discussed with each trend.

Decreased Prescribed Burning

Fewer and fewer hectares are undergoing prescribed burning, and we expect this trend to continue. Initial reductions in burning were related to concerns over air quality and associated restrictions. But other considerations are involved as well. These include public opposition to "visual nuisances," an increase in utilization of young-growth stands, and assessments that suggest that burning is not needed for either silvicultural or fire-control purposes on many harvested sites.

The effects of decreased prescribed burning on nutrient status and the need for fertilization are mixed. We know that combustion of organic matter causes volatilization and convective ash losses of nutrients, especially nitrogen, phosphorus, and sulfur; and we know that exposure of mineral soil may increase loss of nutrients via erosion and leaching. Thus reduction in burning should help to conserve existing nutrient capital. But species changes will also occur; those present in the understory as advance reproduction will increase, and those dependent on mineral soil seedbeds will decrease. Moreover, on many western sites, prescribed fire releases nutrients immobilized in organic matter for plant growth.

To the extent that existing nutrient capital is conserved and becomes available for tree growth, the decrease in prescribed burning could reduce the frequency of—or dosages used in—fertilization of subsequent crops. Reduced use of slash burning, however, could increase the need for fertilization because such N_2-fixing species as *Ceanothus* and *Alnus* are less common on unburned sites and because decomposition of organic matter and release of nutrients may be too slow for rapid early growth of preferred tree species, especially those like Douglas-fir that are adapted to periodic fires. On some sites, fertilizer application at or shortly after seedling establishment may become a more important practice.

Increased Emphasis on Nontimber Resources

Increasing attention is being devoted to nontimber uses and values on commercial forest land. Although especially apparent on public lands, political pressures also affect management of industrial and other private lands. "Multiple-use" management has been part of the forestry philosophy for decades, yet efforts devoted to nontimber resource management have increased markedly. Recent concepts and practices proposed under the banners of New Forestry and New Perspectives are evidence of such change.

To the extent that modified forest practices result in conservation of nutrients and organic matter, the need for fertilizer may be reduced on some sites. If increasing biodiversity results in greater numbers of hardwood trees, deciduous shrubs, and herbs, the quality of organic matter and rates of nutrient cycling may increase, and thus decrease the need for fertilization. Application of fertilizer may also decrease in such stands because the percentage of noncommercial or less valuable species is sufficiently large that the growth response of comercial species to fertilization will be inadequate to justify the expense. Conversely, fertilizer application offers an opportunity to compensate—at least partly—for reductions in timber yields that may accompany greater allocation of site resources for nontimber purposes. Fertilization practices on such sites, however, must be finely targeted and closely monitored to reduce risk and increase benefits to nontimber values. Application of fertilizer to favor selected crop trees deserves greater consideration than we have given it in the past; individual-tree fertilization also is a means to accelerate development of structural diversity as deemed desirable for certain wildlife species. Moreover, it seems likely that careful fertilization can improve nontimber values, such as quantity and quality of forage, because forage plants are also commonly limited by infertile soil.

Increased Rotation Ages

Rotations longer than those anticipated in the past seem likely on public and perhaps on portions of private forests. On national forests, minimum rotation length is set by law to approximate the age at which mean annual increment culminates. Even longer rotations may be desirable for many nontimber objectives and other aspects of multipurpose forest management. On some private and industrial lands, political pressures to provide additional forest values may favor longer rotations. On the other hand, such pressures have led to greater uncertainties about future harvest restrictions, markets,

and tax structures; hence these uncertainties could result in accelerated harvest of existing stands and decreased investment to enhance the productivity of future stands.

Longer rotations will decrease nutrient losses associated with harvesting and site preparation (Johnson 1985). Although this suggests less need for fertilization, other aspects of longer rotations imply increased need; for example, fertilization can increase growth, which (1) reduces the time needed for production of economic and other values associated with larger trees, (2) increases yield, or (3) does both. Such benefits are particularly attractive when fertilizer applications are combined with stand density treatments. Moreover, in boreal and many temperate forests, longer rotations will extend the period during which nutrients accumulate in the forest floor. In such forests and on other nutrient-poor sites, this immobilization of nutrients, especially of nitrogen, is likely to result in reduced forest growth (Miller 1981). Fertilizer applications offer a solution to this consequence of extended rotations. Thus there are several counteracting effects of increased rotation age on fertilization programs, and the net balance of these influences probably will differ by site.

Increased Management of Hardwoods

Management of cottonwood, red alder, and other hardwoods has increased markedly in the past decade and will continue to do so. This trend is supported by economic and ecological factors. Recognition of the high economic value of fiber and solid wood products made from hardwood species has resulted in substantial investments in hardwood research and plantation establishment by several major forest products companies on the Pacific coast. A Hardwood Silviculture Cooperative was established at Oregon State University in 1987, primarily to develop guidelines for managing red alder. In 1989, the Washington State Legislature established a Hardwood Commission to help organize and expand the hardwood industry, and a similar group in Oregon convened a forum on sustaining the supply of hardwoods. The contribution of hardwoods to biodiversity, wildlife habitat, riparian values, and soil development is now recognized, and public forest managers are also beginning to plant hardwood species.

These recent developments are likely to increase the intensity and sophistication of nutrient management practices. Because alder is a rapid-growing, nitrogen-fixing species, its expanded use is likely to enhance levels of soil nitrogen and organic matter in many Pacific Northwest forest soils. Other less desirable changes may occur also, including acidification and decreases in the amount or availability of other nutrients. We therefore must develop cultural systems that consider conifers and alders and the long-term productivity of soils on which they grow. The accelerating establishment of clonal hybrid poplar plantations is a different situation. Such trees grow very rapidly, and they require large amounts of nitrogen and other nutrients. Except on the most fertile bottomland sites, fertilizer applications are likely to be a significant aspect of these short-rotation cultural systems.

Technological Considerations

Recent and anticipated advances in technology may influence future needs for nutrient applications, and they may affect methods used in fertilizer application programs. In the near future, however, such effects of technology seem somewhat less important than those associated with social, economic, and political trends or with changes in management practices.

Genetics

Opportunities to control and manipulate the genetic makeup of trees can have an impact on future nutrient management in several ways. If genetic programs concentrate primarily on growth, the use of improved genotypes is likely to place greater demands on native nutrient supplies, thus increasing the need for fertilizer applications. Closely related to this is the likelihood that an enhanced nutrient environment will be necessary for full expression of the improved growth capacity of the genotypes. On the other hand, existing evidence shows considerable variation within species in ability to acquire nutrients from native supplies as well as in the efficiency with which they are used to produce stemwood. Such differences in acquisition and utilization offer possibilities for reducing nutrient drain and the need for fertilizer applications. To date, however, little if any selection effort has been directed toward improvements in either nutrient acquisition or nutrient utilization.

Harvesting Equipment

Changes in harvesting technology are more likely than genetic manipulations to affect fertilizer needs in the near term, particularly on terrain where ground equipment can be used. Development of harvesting equipment that cuts, delimbs, and processes or merchandises trees at the stump rather than at landings or

other concentration sites is a boon for nutrient husbandry. Use of such equipment may result in on-site retention and uniform distribution of fine woody debris, such as foliage and small branches. These materials are rich in nutrients and are likely to enhance cycling rates as well as conserve nutrient supplies, thus reducing the need for nutrient amendments. On the other hand, if utilization becomes more intensive and fine materials are removed from the site, fertilizer applications may be needed to supplement natural inputs of nutrients.

Nutrient Diagnoses, Stand Simulation, and Information Systems

Technological advances could also increase the effectiveness of nutrient management programs and fertilizer applications. Some items to consider are diagnostic methods for assessing nutrient status, computer simulation modeling, information management systems, and fertilizer application methods. Agriculturists now have technology that not only identifies significant differences in nutrient status within small fields but uses such data to control and vary in-field distribution of applied nutrients via a fertilizer spreader equipped with a microprocessor (Abelson 1990). We are a long way from such sophistication in western forestry. In the near future, refinements in response prediction and stand-specific prescriptions are most likely to come from improved systems for information management coupled with better understanding of stand development obtained through growth and yield simulators.

In the distant future, we also may be able to improve diagnoses of nutrient status and thus further improve response predictions and fertilization prescriptions. During the past decade, researchers have tested several methods for characterizing tree and soil nutrient status, including nitrogen mineralization and various other analyses of soils and plant tissues. To date, none of these approaches have substantially improved our ability to predict response of Douglas-fir in western Oregon and Washington beyond predictions attained with more readily determined stand characteristics such as stand age, site index, and density. Reasons for this lack of progress are probably related more to the nature and level of effort and the inherent variation in conditions and growth in natural stands than to any mysterious obstacles. In this research, we have attempted, for example, to meet several objectives with the same experimental design, including development of estimates of per area responses, refinement of prescriptions for fertilizer dosages, and assessment of relations between some measure of nutrient status and tree growth. Although this has resulted in improved or more specific estimates of stand response by site index, age, and density, further refinements have been elusive and are likely to remain so unless we pursue the other questions specifically and with an appropriate level of effort.

The accelerating development of computer technology provides opportunities for major improvements in the management and transfer of information and technology related to forest nutrition. Individual data bases—both experimental and observational—can now be combined more easily and used in mathematical models and other decision-aiding tools, including expert systems. Such technology can incorporate assessments of effects of management practices on financial returns and other resources as well as on wood production. Geographic information systems (GIS) facilitate storage, retrieval, and application of such information as it relates to specific forest locations. Well-designed monitoring systems can be used to further improve the data base and existing models. Greater use of these tools is likely to enhance economic efficiency as well as social acceptability of forest fertilization and other cultural practices.

Final Comments

We have discussed several significant trends that we believe will shape future nutrient management programs in western forests. We have also shown the role forest fertilization could play as a nutrient management technique and how this may change. There are two additional items that merit emphasis. One is the need for a continued, strong commitment to increased broad-based forest nutrition research and greater use of interdisciplinary scientific teams in carrying out this research. The future use of fertilizer in forests and improvements in the effectiveness of such use will require us to examine nutrition and productivity questions and issues more broadly and more deeply. The second—and equally important—matter is the need to overcome the dogma and misinformation about resource issues that have become trends in themselves. Recently there has been a growing tendency of certain sectors of our society, including some resource professionals, to disparage tree planting, genetic improvement, and fertilizer application programs. Although these attacks may be unfounded and illogical, they must be answered. One way to deal with them is to develop educational programs for wide public dissemination. Such efforts should provide objective, responsible information on intensive forest practices, including the usefulness of fertilizers, in the management of all resources of western forests.

Literature Cited

Abelson, P.A. 1990. Dialog on the future of agriculture. Science 249:457.

Boyd, C.W., et al. 1976. Wood for structural and architectural purposes. J. Soc. Wood Sci. Tech. 8:1-72.

Haynes, R.W. 1990. An analysis of the timber situation in the United States: 1989-2040. USDA For. Serv. Gen. Tech. Rep. RM-199.

Johnson, D.W. 1985. Forest nutrient cycles as affected by climate, species composition, stand age, and intensive harvesting. International Energy Agency and ENFOR, Canadian Forestry Service Joint Report 1. 15 p.

Marcin, T.C. 1989. Demographic change and its impact on forest resource requirements. p. 30-37 *In* Proc. Society of American Foresters National Convention, Society of American Foresters, Bethesda, Maryland.

Miller, H.G. 1981. Forest fertilization: some guiding concepts. Forestry 54:157-167.

Naisbitt, J. and P. Aburdene. 1990. Megatrends 2000. William Morrow, New York. 384 p.

Wright, L.L., R.L. Graham, A.F. Turhollow, and B.C. English. 1992. Opportunities to mitigate carbon dioxide buildup using short-rotation woody crops. *In* Sampson, R.N. and D. Hair, eds. Forests and global warming. American Forestry Association, Washington, D.C. *In press.*