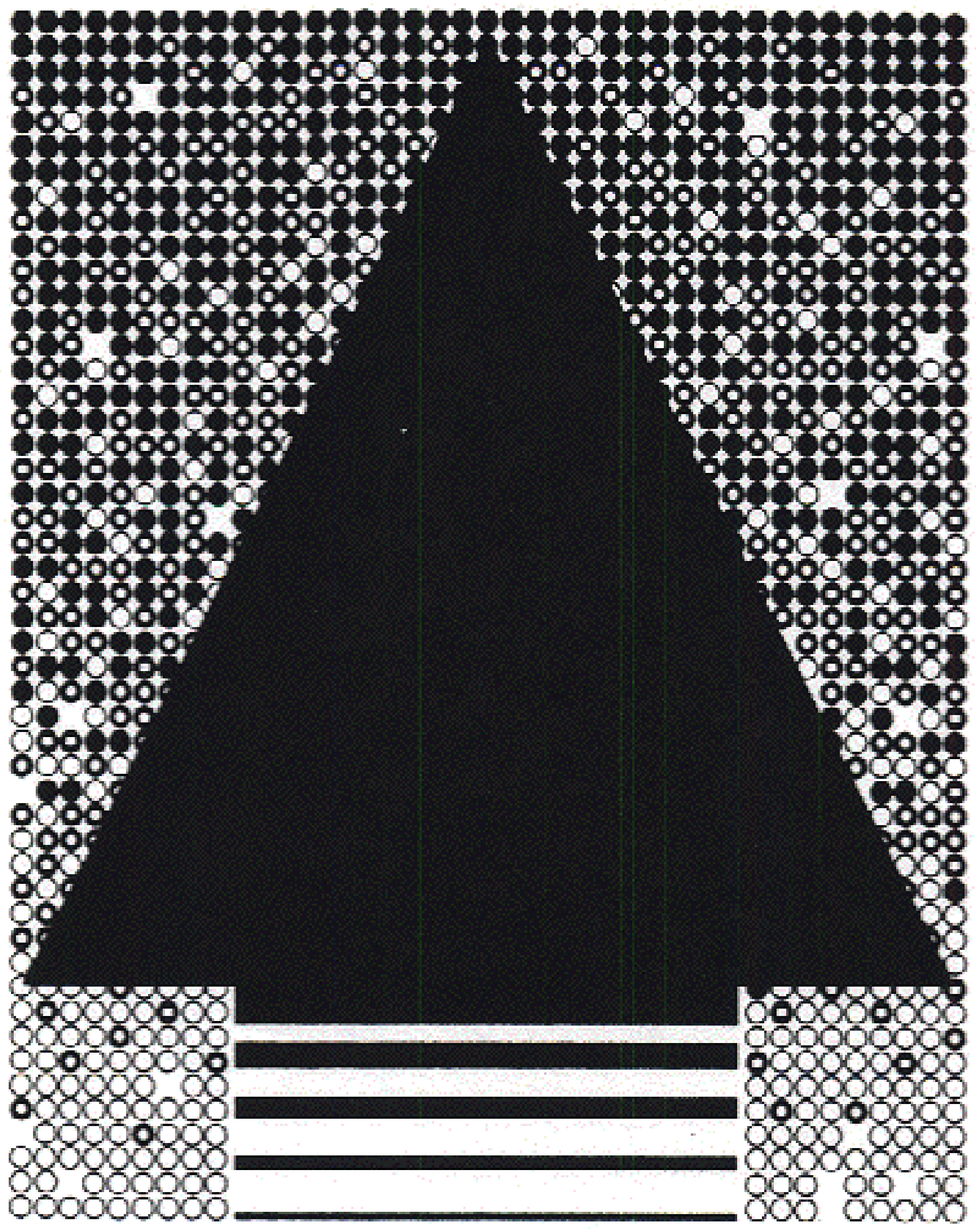

CONCLUDING REMARKS

G. F. WEETMAN

The contributors to the symposium from which this volume originated addressed many important questions dealing with the role of fertilization in relation to the nutritional needs of western forests. At this point it seems appropriate to also reflect on what questions were not raised. In doing so, we may find that certain areas of emphasis or omission come to light and some conclusions of interest suggest themselves.

Ecological Aspects

The energy balance question was not considered: since fossil fuel is used to make nitrogen fertilizer, is it a good idea to put it on trees? The answer is yes, because a net gain in energy is obtained through increased photosynthesis. A related question is whether nitrogen fertilizers should be used to grow trees when children are starving in many parts of the world because of protein shortages. That older moral issue was not raised this time.

Repeated reference was made to the need for better understanding of long-term fertility aspects and consequences. The evidence presented suggests that fertilization can offset fertility losses due to careless land use and nutrient export, but nitrogen effects are temporary. Little was said concerning public attitudes about commercial forest fertilization. It does not seem to be a major problem if common sense is used in application and prescription, and guidelines are followed.

We still have a lot of unknowns when it comes to the environmental impact of forest fertilization, but the effects do not seem to be fearsome or of a serious chronic nature.

Operational Aspects

Fertilization has become a standard operating procedure over a huge area of forest in the world. It is an established practice and we know how to do it in a cost-effective way. No real concerns were expressed about equipment, technique, or fertilizer used; these are not constraining. The technology is impressive, but good on-site organization and management are needed.

Market Forces

A sustained demand for large-size quality conifer timber is continuing as predicted, and the Pacific Northwest is about the best place in the world to grow it. Fertilization strongly influences piece size. The combined effects of accelerated operability, lower harvesting costs, and the extra wood produced by the "allowable cut effect" create very powerful reasons for fertilization. Stumpage values have risen faster than fertilizer costs, making even stand-level, as well as forest-level, economic assessments of fertilization favorable.

Science and Research

Wide-scale testing has been used to develop response predictions. Such empirical efforts have been very successful, but only for Douglas-fir. The managers have good data to use; empiricism has triumphed (and so has regression). Science has failed to identify the reasons for uptake and response in a quantifiable way that can be used to predict response over a variety of sites, soils, and species. The authors in this volume present the struggles of scientists to use many approaches to tackle the problem. Fundamentally, we lack understanding of the tree-nutrient uptake process in forest ecosystems. We seem to be missing something important and fundamental at the root level.

The complexity of predicting and understanding issues points to the development of expert systems for diagnosis and prescription, such as are now used in medicine and other fields. Several papers show the huge potential there is to improve productivity by more optimum nutrition. Growth rates may be doubled and tripled on many sites when the nutritional constraint is removed. The challenge is to document these results.

Whole Symposium

The symposium was not organized by managers because of any crisis or real problem in fertilization. It was organized by scientists and academics to bring us up to date. In this regard, it has been excellent. It is unfortunate to see that so few Canadian foresters and silviculturists were able to attend. Bureaucratic barriers, "not invented here" attitudes, and restricted staff travel across borders are a hindrance to progress. Forest fertilization is a specialized area of forestry with great potential returns, but expertise and rigor are needed and staff attendance at conferences such as this one should be mandatory.

To the organizers and University of Washington staff, my appreciation for a job well done.

ROBERT F. POWERS

My summary remarks are divided into three main categories: progress made since the 1979 conference at Alderbrook Inn, problems that were recognized then but continue to be unresolved, and emerging issues and challenges for the next decade.

Progress Since Alderbrook

Fertilization has proved its potential in the Douglas-fir region. That it is a viable and effective silvicultural tool is now beyond question. This conclusion is supported by eight points from this conference.

1. We now have a good appreciation of the long-term effects of initial applications of nitrogen on coast Douglas-fir growth. Response can be expected to last from five to ten years, or longer.

2. As shown in the Cahill and Briggs chapter, we may have moved beyond the fear that fertilization produces weak wood. Weak wood is principally "juvenile wood" formed when the live crown is near that point on the tree bole. If the crown has migrated beyond that point, fertilization should not alter wood quality much beyond what is normally produced at that bole section.

3. Thanks to the diligence of the RFNRP cooperative, we now have a good sense of the effectiveness of repeated applications of nitrogen. High rates of growth can be sustained through timely refertilization.

4. Nitrogen fertilization has passed beyond the exploratory phase and has become another option in the planning process. As shown in the chapters by Diggle and Daoust, protocols are in place in some sectors for incorporating fertilization in the operational planning process.

5. We now realize that stocking must be considered in making a fertilization prescription. Fertilizing grossly overstocked, weakened stands is a poor use of time and money. Light and moisture are finite resources. In dense stands, crowns and roots need room for expansion if nitrogen fertilizers are to reach the targeted trees. Unless light and moisture are adequate, fertilization is a poor investment. Apparently, the Law of the Minimum and the Principle of Limiting Factors apply to the Pacific Northwest, as elsewhere. Somewhere, de Saussure, Liebig, and Mitscherlich must be smiling.

6. Preliminary systems for monitoring certain environmental effects of fertilization have emerged since Alderbrook. As Bisson et al. point out, this centers on hydrologic aspects of fertilization, and some states have developed quality standards for monitoring.

7. Mika et al. and Powers show that fertilization research has progressed to species other than Douglas-fir. Not surprising, other species need, and respond to, nitrogen.

8. Research is now identifying deficiencies of other nutrients that were masked by a primary deficiency of nitrogen, or that may preclude or limit response to nitrogen fertilization. Again, the Principle of Limiting Factors is alive and well in the Pacific Northwest.

Continuing, Unresolved Problems

There has been a vexing lack of progress in at least four important areas of nutrition research.

1. The problem of diagnosing where deficiencies exist is still with us. Despite a decade of work, the old standbys of soil and foliar analysis have not solved the problem. What seems to work in one instance seems to fail in another. Much of the problem may be traced simply to variations in methods of collection or analysis. But even if this is the root cause, the fact remains that chemical analyses are terribly expensive for operational applications. And too few laboratories can be depended on to produce consistently sound results. We need more practicable ways of screening stands for probable fertilization response. Small-plot screening trials are one approach, but they take time and magnify the usual problems of operational "falldown."

2. With some exceptions, there has been scarce progress in learning how nitrogen fertilization interacts with other silvicultural options. This gap is particularly pronounced in the Douglas-fir region. Although we have improved our understanding of fertilization x thinning interactions, much remains to be learned about interactions with nontree vegetation, genetics, wildlife values, forest insects and diseases, and environmental stresses. Work in the Douglas-fir region has been single dimensional and too application focused to address broader questions.

3. We haven't gone far in blending fertilization response into yield projection systems. Although a fertilization option has been spliced into existing forecasting models like DFSIM, this is simply a "piggyback" approach that serves as a stopgap until true fertilization projection models are developed for managed stands.

4. Related to this is the slow progress we've made in developing forecasting models that are useful to managers who must deal with landscapes broader than simply the stand. Turner and Knott outline a hierarchical soil classifica-

tion system for New South Wales that scales precision to the level of management resolution, and offer choices in resolution that vary from stands to states. Jacobson describes a method used by forest industry in the South that ranks management units for fertilization priority. Here in the Northwest we still think at levels of stand response. A hierarchical system would provide managers with the flexibility needed to plan at larger landscape levels.

Emerging Issues and Challenges

In the next decade, many issues will surface that now are glimpsed only dimly, if at all. How does one embark on work that addresses tomorrow's problems? Let me make six recommendations.

1. Fertilization will always be an expensive silvicultural option, and we must do more to preclude the need for it. This means making a commitment to understand the long-term implications of existing management practices—particularly those involving timber harvest and site preparation. In my mind there is no doubt that these operations have the potential for triggering immense changes in inherent site productivity. Too much of our attention is paid to simple inorganic nutrition. We need a far more fundamental understanding of how management-induced changes in site organic matter and soil porosity affect long-term site productivity through their impacts on energy substrates, soil biotic activity, and stress resistance.

2. The poster presented by Wickman et al. shows how fertilization could be used to offset the damaging effects of defoliation from spruce budworm. New thrusts that explore the role of nutrition in combating insect and disease problems through biochemical pathways should be undertaken and supported. There is a growing need to find the means to favor forest health.

3. We need a better understanding of the cycles of biological availability of applied nutrients and how they are affected by the environment. Some nutrients are immobilized readily and seemingly "lost." Others remain in a biological cycle of plant availability. By having a more fundamental understanding of how such basic site factors as temperature and moisture govern biological activity and nutrient availability—and how these factors are influenced by forest manipulation—we may have the means for developing more comprehensive and flexible models of nutrient cycling.

4. Coordinated work should be started on where fertilization fits in favoring multiple, nontraditional forest values, such as browse production to benefit both large and small forest animals. Work would not be confined to terrestrial ecosystems, but should consider aquatic values also.

5. The biological limits of growth for a species are unknown. What is the growth potential for a species if it is freed of constraints that can be modified by management? Some research should be shifted to innovative fertilization treatments starting from stand establishment onward. Fertilization should be crossed with other controls of constraining factors, such as competition, pests, and plant genetics. Other treatments might involve soil heating and site irrigation to simulate the effects of climate shifts. Regardless of practicality, there must be administrative tolerance and support for innovative and high risk kinds of research that may not have an obvious link to application. Freedom for some individuals to follow unconventional lines of inquiry can lead to leaps in our understanding of how ecosystems function and respond to environmental change, and what we might fashion through management.

6. Finally, we need to develop models to deal with the uncertain future described by DeBell et al. Such uncertainty encompasses changes in supplies, markets, land use, and climate. Perhaps our best bet for the moment is to develop flexible "expert systems" based on scientific facts and professional judgment. These will give managers a range of alternatives for dealing with uncertainty, and should tide us over until the future is better known and until new, innovative research offers better guidelines.

In conclusion, we've made sizable progress since Alderbrook. I believe that the force behind our progress traces to one man. Physically, he doesn't look like a giant, but Stanley P. Gessel surely must be one because we have stood on his shoulders for decades. Because of his vision and perseverance, we are now able to view our science from a higher, broader plane. We all owe Dr. Gessel a tremendous debt, for he has given solid footing to the platform that supports our science today.

While I'm encouraged by our progress, I'm disappointed by our failure to tackle broader aspects of nutrition and site productivity. But the future brims with promise because we are an amazing people joined by a sense of land stewardship. We have the potential to adjust technologically to almost any future if we have the foresight and the will to support good science and prompt application.