Experience with Nitrogen Fertilization in Northern Idaho

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ABSTRACT. Nitrogen fertilization has been considered economically viable in parts of the Intermountain region for nearly two decades. Potlatch Corporation embarked on an operational fertilization program in the 1970s, treating over 8,000 hectares of mature timber until the early 1980s. Potlatch and the Intermountain Forest Tree Nutrition Cooperative (IFTNC) continued research on nitrogen fertilization, the results of which provided the basis for resurrecting the practice on private forest lands as economic conditions improved. Potlatch currently treats 1,600 to 2,000 hectares annually with urea nitrogen, utilizing stand-level guidelines to identify conditions likely to meet specified growth response requirements. Operational fertilization is closely monitored to ensure application quality, and long-term monitoring plots are used to assess improvement in stand growth and to determine if these investments achieve expected returns. More research is needed to improve stand selection criteria used by forest managers and, more important, to identify other possible nutrient deficiencies that require mitigation. A better understanding of basic forest nutrition is needed to properly address natural and management-related nutrient deficiencies.

Nitrogen fertilization is an important and economically viable silvicultural tool. The following topics will be addressed relative to the experience of Potlatch Corporation with operational fertilization in northern Idaho: importance of fertilization to Potlatch, justification of the program, stand selection, monitoring, and additional information needs.

Potlatch Corporation manages approximately 253,000 hectares of productive timberland. Forest soils typical of this region vary in origin and include granitic, basalt, and quartzite parent materials, most of which are covered with a layer of volcanic ash deposited following the eruption of Mount Mazama. This "ash cap" contributes significantly to the productive capacity of northern Idaho soils. Terrain in this area is generally semimountainous, with elevations ranging from 450 m to over 1,500 m. The combination of productive soil and rainfall (>100 cm/yr) results in an average grand fir (*Abies grandis*) 50-year base site index in excess of 27 m.

Forest stands in this region are composed primarily of grand fir and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) with varying amounts of western redcedar (*Thuja plicata*), western larch (*Larix occidentalis*), and Engelmann spruce (*Picea engelmannii*). In some parts of the ownership, lodgepole pine (*Pinus contorta*) or ponderosa pine (*P. ponderosa*) predominates. Over 80% of our ownership is classified in the cedar or hemlock vegetation series (Daubenmire and Daubenmire 1968). Western white pine (*P. monticola*) currently represents only a small component in mature stands due to extensive blister rust (*Cronartium ribicola*) mortality and past harvesting practices.

Harvesting history may be best characterized as having been a selection system: "The logger selected the best tree and cut it." This practice created considerable species diversity in the region, with a predominance of lower quality growing stock remaining on many hectares.

Suitable site quality and stand conditions have contributed to a relatively long history of fertilization activity. The practice initially received serious consideration during the 1970s, since many companies west of the Cascades had undertaken extensive nitrogen fertilization programs. Operational fertilizer applications began in the mid-1970s and were largely justified on the basis of experiments conducted outside northern Idaho.

Long-term fertilizer response information for Intermountain species was limited, but empirical trials

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had been established and preliminary (two to four year response) results appeared promising. By the early 1980s investment capital was becoming limited, and Potlatch, as well as most private forest management organizations, curtailed most silvicultural investments. The predominant thinking was that these investments were postponable. Potlatch halted operational fertilization in 1980 after having treated over 8,000 hectares with urea at a rate of 224 kg N/ha.

Through the 1980s, Potlatch and the Intermountain Forest Tree Nutrition Cooperative (IFTNC) continued research efforts to improve the basic understanding about nutritional deficiencies in the region and to quantify potential nitrogen fertilizer response through field experimentation. By 1989, Potlatch had gathered and evaluated considerable nitrogen response data for northern Idaho grand fir and Douglas-fir stand types, bolstering confidence in continued use of this practice. Data collected and analyzed during this period also identified other possible nutrient deficiencies and influenced a change in research emphasis from nitrogen response to the much broader aspects of overall forest nutrient management (IFTNC 1991). Beginning in the fall of 1989, Potlatch again undertook an operational nitrogen fertilization program which currently averages between 1,600 and 2,000 hectares per year.

The importance of fertilization stems from attractive economic returns as well as a growing concern over future timber availability and supply in the region. The uncertainty surrounding timber availability from public lands throughout the Pacific Northwest has heightened the impetus to achieve and maintain maximum production from managed forests. Fertilizer investments in stands that are within 10 to 25 years of harvest have been the most economically attractive for the following reasons:

1. Relatively short-term investment
2. Relatively low investment cost ($150/ha)
3. Efficient treatment for large blocks of land
4. Empirical trials indicating adequate return over a wide range of conditions
5. Minimal environmental concern resulting from treatment

Demonstrating that investment in nitrogen fertilization remains a sound business decision has played a key role in retaining the practice. Two important economic issues were addressed in this process. First, a clear understanding was needed of how much extra value would have to be obtained from this treatment to achieve a specified minimum return on investment. Second, it was important to have a way of estimating the probability of consistently achieving an acceptable response at the stand level under operational conditions.

The first question can be addressed without having fertilizer response data and is simply guided by basic economic assumptions, treatment cost, cost of capital, and investment period. The second, however, requires information about the expected magnitude and duration of response over a range of stand and site conditions.

Response estimates applicable to specific stand and site characteristics, as opposed to regional averages, are important to the resolution of the second question. Having the ability to characterize responding and nonresponding stand conditions increases the probability of achieving treatment objectives at the stand level. Regional response estimates mask variation in response observed over the range in stand conditions actually tested.

For example, one approach is to characterize stand conditions most likely to respond to treatment using common stand and site variables (Table 1). Variation in response by stocking level and site conditions allows identification of the highest response conditions and provides the basis for developing a supportable stand-based fertilizer program.

A clear definition of response is also necessary to complete the stand evaluation process. Most often, fertilizer response is defined solely in terms of the quantity of additional wood volume likely to result from treatment. Considering response in terms of harvesting and processing costs can identify additional benefits from treatment. The value associated with having larger individual trees is often overlooked. It is generally accepted that average tree size influences handling and processing costs. We have observed that relatively small changes in average tree diameter within a stand can have a measurable impact on total harvesting costs. Using fertilization to move a stand from a mean diameter of 38 cm to 41 cm results in a measurable reduction in pieces

Table 1—Northern Idaho predicted four-year gross volume response (m^3/ha), grand fir vegetation series.

Initial Basal Area (m^2/ha)	Site Index (m) 15-18	19-21	22-24	25-27	28-30
18-23	13.7	18.9	19.8	18.1	13.7
24-34	14.3	18.0	18.8	17.1	12.7
35-46	11.7	15.3	16.3	14.5	10.1
47+	16.6	20.2	21.2	19.4	15.0

Data from Intermountain Forest Tree Nutrition Cooperative, 1988.

per thousand board feet (MBF). Carrying this further, for our operations, a reduction of only two pieces per thousand board feet of volume in a mature stand averaging 40 cm in diameter can reduce harvesting cost by as much as $10/MBF. In a stand having a volume of 50 MBF/ha, harvesting costs might be reduced by as much as $500/ha. It becomes apparent that, depending on stand size characteristics, harvesting cost reductions alone may exceed the investment in fertilizer. Combining these cost savings with the value of the additional wood produced by the nitrogen treatment enables a more accurate estimate of returns.

This type of analysis serves only to quantify potential gains and does not specifically identify stands that would benefit from treatment. A more difficult task facing forest managers is matching stand and site conditions that have demonstrated an acceptable economic response in research trials with actual ownership conditions. Typically, stand selection guidelines for fertilization are based on empirical trials which characterize candidate stands by inventory attributes such as site index, vegetation series, parent material, stems per hectare, or basal area per hectare. Applying research results to field situations can be difficult, however, due to the inherent variability in stand structure and site quality within relatively small areas. Forest inventories are often inadequate when attempting to characterize stands in enough detail for silvicultural treatment evaluation, because forest inventories are often developed solely to provide estimates of standing volumes for harvesting purposes. Many forest inventory systems are being modified to accommodate a need for more detailed information, which is necessary in the planning and implementation of successful silvicultural programs, including forest fertilization.

Regarding our operational experiences with forest fertilization and recommendations for successful implementation, a major contributor to achievement of silvicultural objectives is the caliber of contractor employed to apply the fertilizer. Using the "low bid" approach as the sole means of assessing contractor suitability is not recommended. Administrative costs associated with poor contractor performance can be excessive and are not generally included in the evaluation of treatment cost. Additionally, severe contract penalties, though they may appear to provide protection, are generally not a timely solution to ensuring a quality fertilizer application. With aerial fertilizer applications in particular, we have found that a successful contract depends primarily on the quality of the contractor.

There are several important essentials in implementing a fertilizer contract successfully:

1. The contractor must use efficient, well-maintained support equipment. We have found this to be important from both administrative and environmental standpoints.
2. The fertilizer application must be monitored to ensure acceptable distribution and application rate throughout the project. Problems should be communicated immediately to the pilot.
3. Good heliports are necessary. For example, don't require a pilot to fly uphill or along a stream course when departing a heliport. This introduces unnecessary safety and environmental risks. Provide heliports with good access, preferably along well-maintained roads.
4. Continuous communication with the support crew and the pilot must be maintained. Work with them to identify and correct problems on a daily basis.
5. Clear boundary designations and exclusions (i.e., active stream courses) need to be provided. Allow the pilot to assist in determining the most appropriate pattern to fly an area.

Control of the distribution and the application rate is critical to achieving economic objectives. For this reason, application monitoring has been an important component of our program. Unlike other silvicultural treatments that produce visible structural changes in the forest, nitrogen granules dissolve and disappear within a relatively short period, leaving no immediate visual changes. Studies conducted in the 1970s (Mahendrappa 1976; Olson 1979) confirmed suspicions that several factors contribute to poor quality applications, any of which can result in a significant "operational falldown" in response. Operational falldown is the difference in response between the level observed under controlled trials and that realized under operational field conditions. Factors contributing to falldown are generally either biological or application related. Biological factors are a function of differences in forest structure and composition compared with areas actually tested for response. This type of falldown can be minimized, but not eliminated, through adherence to stand selection guidelines based on field trial results. Application-related factors contributing to falldown over which we have direct control include: (1) product granule or prill size, which can affect crown penetration and swath width; (2) flight pattern, which affects the probability of achieving uniform coverage; and (3) rate of product applied per pass.

Our field monitoring of the application is two-phased: equipment calibration prior to contract start-up, and in-field monitoring during the application. Calibration is accomplished using a systematic grid of fertilizer traps located in an open area or meadow. Circular 0.2 m^2 traps are placed perpendicular to a designated flight line. Successive passes are made over the grid, simulating an operational application. Fertilizer collected in these traps is weighed to determine swath width and rate applied. An effective swath width, the zone where 80% or more of the target rate is applied, is typically 35-40 m, using forestry grade urea. Abnormal distribution patterns within the swath are easily detected using this approach. Adjustments to air speed and application equipment can be made before operational application begins.

But preapplication calibration alone will not ensure uniform application over the treatment area. During application, field monitoring is conducted using the same collection traps. One person systematically places traps in the treatment area and tallies weights as the fertilizer is applied. Unacceptable application rates within a designated area, including skips, are noted and communicated to the pilot periodically each day. Our goal has been to recognize problems as they occur and adjust the operation, as needed, on a daily basis. Invoking contract penalties is usually not very successful in getting quality applications. We have found that field monitoring activities require only one person, keeping contract administration costs quite low.

Longer-term response monitoring is accomplished through installation of permanent one-fifth acre plots in selected stands that have been operationally fertilized. Specific stand and tree measurements (species, crown ratio, height, diameter) are made at five-year intervals until the stand is harvested. This type of monitoring has not replaced empirical trials established throughout our operating area, where we continue to monitor treatment response under more controlled conditions.

Environmental monitoring associated with all forest management activities is an area of growing concern. During the 1970s, water quality issues related to forest fertilization were addressed in several studies. Results supported the premise that nitrogen applied as urea was fairly stable in acidic soils, especially those soils with deep organic layers, typical of most forest conditions in this region. The consensus was that unless urea is applied directly to a stream course, adverse impacts to stream quality were minimal. To prevent direct application of urea fertilizer to streams, active water courses are identified and buffered by a 30 m untreated strip. Each area is pinpointed on aerial photos and reviewed with the pilot prior to fertilizer applications. In-stream monitoring was conducted in the 1970s but is not currently undertaken, as buffers provided adequate stream protection.

Potential adverse range and wildlife impacts have been considered in northern Idaho. Of special interest has been the protection of cattle, because Idaho is an open range state. Concentrations of urea in and around landings pose the greatest threat to both cattle and wildlife. The equipment used by prospective contractors in handling fertilizer at the heliports and railheads is considered before awarding a contract. An efficient fertilizer-handling system that controls spillage is an important criterion our foresters consider in selecting contractors. Well-designed and maintained equipment generally translates into efficient handling of fertilizer, thus minimizing environmental concerns.

In closing, I would like to mention informational needs that would help forest managers make more informed and responsible decisions regarding management activities that affect the nutritional status of our forests.

Nitrogen fertilization is not the sole remedy for nutrient imbalances in our operating area, even though nitrogen has generally proved to be a growth-limiting factor. In recent years we have recognized the need to more thoroughly investigate the general area of forest nutrition and broaden research efforts to include evaluation of other possible nutrient deficiencies, both natural and man-caused. In this regard, there is a growing body of information, derived in large part from agricultural research, that supports the premise that there is a correlation between nutrition and the incidence of disease. Studies are currently under way in the region to determine if there is a relationship between the potassium level and the rate of root rot infection (IFTNC, unpublished). Given this possibility, we should consider revising our traditional view regarding the benefit of forest fertilization beyond that of simply adding growth. Clearly, potential gains in forest productivity that might be realized by reducing disease-related mortality are enormous. In northern Idaho and Montana alone, approximately 30% of total annual mortality has been associated with root disease (Byler 1982).

We still lack a basic understanding of forest nutrient demand and supply in relation to growth, disease, and long-term productivity. This is especially necessary at the stand level if we are to make better nutrient management prescriptions. We see this more and more as we attempt to address, often unsuccessfully, the myriad environmental and resource issues now being laid at our doorstep.

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