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# FERTILIZING COASTAL DOUGLAS-FIR FORESTS

A Guide for Nonindustrial Private Forest Landowners in Western Washington

by Donald P. Hanley, H.N. Chappell, and Ellen H. Nadelhoffer

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## Preface

### Forest Fertilization in Future Forestry Planning

*by S. P. Gessel and R. B. Walker*

The present controversy over forest land use resulting in the withdrawal of large areas from wood production has brought a new focus on the role of soil fertility in forest productivity. The limited areas that will be available for growth of our wood crops must produce more and on a sustained basis to meet our needs. This is especially true if the role of wood and wood products in the economy of the Northwest is going to continue its present importance. These concepts and trends are being recognized by a number of professional groups who are developing programs of enhanced and sustained land productivity for all aspects of forest use.

We do know that current and future forest productivity depends primarily on the health and vigor of the trees in a stand. A number of factors affect this health and vigor, but among the most important are those relating to tree nutrition. This fact has not always been recognized in forestry. A common belief for many years was that somehow nature supplied all essential elements for all trees, and the forest soil contributed very little. Ezra Meeker, an early agriculturist in the Puyallup Valley, made it more specific by observing that when a tree burned he could hold all the ashes in his hands. This, he said, proved that trees had very low requirements and, therefore, no problems. Of course he did not know that some of the essential elements, such as nitrogen, are lost in the burning process and don't remain in the ashes. Nor did he understand the importance of some of the necessary microelements.

Fortunately, we now have years of research results that clearly establish the role of essential elements in tree growth and forest productivity. We know that forest soil nutrient management is an important part of both current and continuous or sustained forest productivity. We also have abundant research results showing that forest fertilization is a biologically sound and economically effective way of improving productivity. From this same research we also know the tissue levels and growth characteristics of trees that indicate either deficient or adequate amounts of essential elements. These are detailed in a University of Washington College of Forest Resources Bulletin by Walker and Gessel (1991)*. The tissue levels can be estimated through color or growth characteristics, or determined exactly through chemical analysis. We also know something about the supply cycle of each essential element in our forest soil systems, and how this may be affected by our management practices. We know that nitrogen is likely to be the element that initially limits forest productivity in many of our Washington forest soils. From the research we also know many facts about the nitrogen cycle in forest soils, especially what cultural activities add or detract from the overall supply and how to increase nitrogen in both the short and long term. We also can detect deficiencies of other essential elements and supply these with relative ease to most forest areas.

The most obvious way to improve nitrogen or other essential elemental supplies in forest soils is through direct application of necessary elements, or forest fertilization. You can purchase the essential elements in a variety of forms, either individually or in combination. Forest managers have commonly applied nitrogen to many forest areas in the Northwest in the form of urea, either by air or hand. Other forms of nitrogen are available for fertilization programs, including processed sewage and other waste sludges, now called "biosolids." These materials have generally demonstrated very good effects on trees. Under present technology these biosolids are relatively high in cost unless the landowner is able to establish a cooperative program with the producer. A number of cooperative programs are in operation.

The remainder of the bulletin will cover the detailed questions that must be considered in any forest level fertilization program. The authors hope to develop interest in the potential and opportunities of fertilization for small landowners to consider. WSU Extension can provide more information.

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* Walker, Richard B., and Stanley P. Gessel. 1991. *Mineral Deficiencies of Coastal Northwest Conifers.* Institute of Forest Resources Contribution No. 70. University of Washington.

*Stanley P. Gessel and Richard B. Walker are professors emeritus of forestry and botany, respectively, at the University of Washington. (Author's note: Dr. Gessel died shortly before the first version of this bulletin went to press.)*

# Introduction

As a private landowner in the state of Washington, you presumably invested in your land for a variety of reasons. Conservation of wildlife habitat, wetland preservation, production of special forest products, income from the timber, personal enrichment, and recreation are a few of your potential management objectives. Increasing demand for timber and high stumpage prices are causing many private landowners to explore more seriously timber production as a financial option. Specifically, owners of second-growth coastal Douglas-fir forests might find forest fertilization an excellent way to increase timber production, thereby providing additional financial return. Proper use of fertilization, along with other cultural techniques such as thinning and pruning, can increase both the quality and quantity of wood grown in a normal rotation.

Forest fertilization, however, is more than just a “growth enhancing” technique. Well-nourished trees are crucial to the health of forest ecosystems. Forest fertilization can improve wildlife habitat and aid in conservation goals. Finally, timber production is not an “all or nothing” proposition. With proper planning, landowners can manage private forest lands for timber production and a variety of other objectives, including clean water, improved wildlife habitat, and recreational enjoyment.

Forest fertilization is a way of maintaining or enhancing nutrients normally available to healthy stands of trees. It is not a remedy for poor management practices that have caused erosion or other critical nutrient deficiencies. Rather, forest fertilization is a way of supplementing a normal forest’s “diet” with nutrients to enhance growth.

Coastal Douglas-fir stands in the Pacific Northwest usually are excellent candidates for fertilization. In fact, Pacific Northwest forest industry and agencies have long used forest fertilization to enhance the yield of second-growth coastal Douglas-fir. Forest fertilization is an integral part of the management regime planned for many Douglas-fir plantations established today. Among nonindustrial private forest land owners, however, forest fertilization remains a largely underutilized practice. This bulletin emphasizes fertilization in coastal Douglas-fir stands since many of those stands are likely to respond positively to the practice .

Recommendations differ for eastern Washington forest stands. Refer questions on eastern Washington stands to a WSU Extension agent.

## The Basic Biology of Forest Fertilization

To understand the fundamentals of forest fertilization, it is helpful to first understand how a tree functions.

Using water and nutrients obtained from its roots and carbon dioxide from the air, chloroplasts in tree needles take energy from the sun to create sugars and oxygen. The sugars produce food energy for the tree, which moves downward from the leaves to all living cells within the tree.

Phloem, or inner bark, transports the food (sugar solution) from tree needles to the roots and other tissues. Eventually, phloem becomes bark as the tree grows. Cambium is a thin layer of specialized cells that divide to produce new phloem to the outside of the tree and new sapwood to the inside.

Sapwood transports water from the roots to the needles. The less active interior cells in the trunk gradually die and become heartwood, which is composed of dead cells that store water and nutrients as well as provide support for the tree.

Roots absorb water and dissolved nutrients, such as nitrogen (N) and phosphorus (P). Roots also provide storage for sugar in the form of starch during tree dormancy.

Important concepts to understand in forest fertilization are nutrient availability and the processes involved in making nutrients available to plants. Nutrient availability is a term that describes how usable a nutrient is. For Pacific Northwest soils in western Washington, nitrogen is the most commonly deficient element. Considerable nitrogen is usually present in the soil organic matter, but it only becomes available to plants through decomposition and mineralization. Mineralization is a natural process that converts organic forms of elements to inorganic forms that trees can absorb through their roots.

In the Pacific Northwest, cool temperatures slow decomposition and mineralization. Often trees require more nitrogen during growth periods than is available in the soil. When this occurs, trees develop a deficient condition. Nitrogen deficiencies appear as a general yellowing of the needles. Continued deficiencies result in reduced growth and a greater susceptibility to disease and mortality from competition. Applying nitrogen fertilizer gives trees a "shot" of readily available nutrient.

## Before You Fertilize—Evaluate Your Stands

Before you fertilize, evaluate your forest in the following five categories: species, stocking, overall forest health, stand age, and nutrient availability.

### Species

Forest fertilization information provided here is for landowners growing Douglas-fir in coastal forests that were established either by planting or by natural regeneration. You can estimate at least a 70% chance of positive tree growth response to nitrogen fertilization.

Western hemlock, western redcedar, Sitka spruce, and the true firs (*Abies* spp.)

often grow in natural stands as associates of Douglas-fir. Less information is available on their fertilization responses compared with Douglas-fir. We do know that western hemlock growth responses have been inconsistent in regional field trials for reasons not wholly understood. No recommendations exist for fertilization treatments. Sitka spruce and true firs have been the subject of few fertilization trials. While spruce growth responses generally have been positive, inadequate information exists to develop a fertilization prescription.

### Stocking

An accurate inventory is an excellent place to start when you are contemplating fertilizing. Foresters call the inventory a *cruise*, and the process of inventorying *forest cruising*. Cruising helps you determine the kinds and amounts of wood growing on a piece of land. Today, most people rely on consulting foresters to cruise their land, but this should not prevent you from conducting your own inventory. For a concise description on how to cruise your own land, see PNW0031, *Measuring Trees*, available from WSU Extension.

## Forest Fertilization Research in Coastal Forests

Nutrition studies in coastal forests were initiated at the University of Washington about 1950, and began soon afterward in other organizations throughout the region. Early work demonstrated that nitrogen fertilization would increase Douglas-fir tree and stand growth. Promising results in early research projects and the initiation of operational fertilization programs in 1965 were major factors influencing the formation of regional research programs, including the Regional Forest Nutrition Research Project (RFNRP), which began in 1969 at the University of Washington.

Primary objectives of the programs and other projects in the region were to provide forest managers with information on growth and response to nitrogen fertilization of second-growth stands of Douglas-fir and western hemlock. Other objectives included comparison of fertilizer responses in thinned and unthinned stands, investigation of responses to alternative sources of nitrogen and other elements, fertilization influences on forest ecosystems, economic aspects of forest fertilization, and effects of fertilization on wood quality. The programs developed an extensive base of field installations.

In 1991, the RFNRP was integrated into the Stand Management Cooperative (SMC), forming a program providing information and developing techniques for planning and evaluating stand management strategies. The program, headquartered at the College of Forest Resources, University of Washington, is a long-term effort for addressing research goals that integrate forest nutrition, silviculture, wood quality, and modeling.

Information on the effects of a range of treatments and treatment combinations on tree growth, stand development, product quality, and product value will be synthesized for prediction of stand development under the full spectrum of silvicultural treatments. Results from the program will be used to support reliable biological and economic evaluations of stand management alternatives in coastal forests.

A well-stocked forest has an optimum number of trees per acre for ideal growth. Normal stocking rates, expressed as total square feet of basal area, vary depending on site quality. Ranges for high site (Site Class I) to low site (Site Class V) are 200 to 90 sq. ft./ acre for 40-year-old stands. Do not fertilize a forest where competition for sunlight has closed the canopy and trees are in a stagnated condition. Trees should have sufficient space around them for crown expansion. Without crown expansion, stem diameter growth is greatly reduced. Stands that have been properly thinned throughout their lifetimes are usually the best candidates for fertilization.

### Site Quality

Response to fertilization is greatest on those sites deficient in the nutrients applied, where other potentially limiting factors such as light and water are abundant. The basic problem in relating response solely to measures of site quality is that all the site factors influencing growth response to fertilization are not taken into account. Fertilizing Douglas-fir on poorer sites usually results in larger growth response. Medium and high quality sites also may respond well to fertilization. Research has shown that growth increases can occur over a wide range of site conditions; however, responses are more likely on the poorer sites.

### Forest Health

Evaluation of general stand health is also important. Fertilization is a method for maintaining and enhancing nutrient availability. You will get the best return on your money if you fertilize trees that are already healthy. Avoid stands that are heavily infected with root rots, especially laminated root rot *(Phellinus weirii)*, since trees with damaged roots normally will not respond to fertilization treatments.

### Stand Age

In general, expect maximum growth response in young stands since nutrient demand is highest at about the time of tree canopy closure. Fertilization at this stage of development provides an opportunity to achieve significant increases in growth rates and harvest of merchantable-size stems in subsequent commercial thinning. If growth is not captured by thinning the gains will be reduced considerably due to mortality over time. Fertilization of stands of mid-rotation ages (i.e., of commercial thinning size, 20–40 yrs) can result in additional merchantable volumes provided you thin trees to capture subsequent mortality.

Fertilization late in the rotation may be the most attractive alternative economically. Applications timed so that the response period immediately precedes final harvest give the most attractive financial investment for two main reasons. First, money invested in fertilization is held for the shortest period of time before returns are realized. Second, the volume gain occurs on larger, high value trees, and can be captured in the final harvest.

### Nutrient Availability

Use foliage and soil analyses to determine which stands may be limiting in either macro or micronutrients. Nitrogen is the most common growth-limiting nutrient in coastal Douglas-fir stands. Response to nitrogen fertilization has been demonstrated in an extensive set of field trials in the region. Other elements also may be deficient, but little information is available to specifically relate responses to fertilization. In some coastal Northwest stands, foliage analysis has identified phosphorus (P), sulfur (S), boron (B), and other micronutrients as potentially limiting growth. They may become more significant after nitrogen fertilization (a secondary deficiency). Consult with your local WSU Extension Forester or agricultural agent for foliar and soil analysis instructions and interpretations.

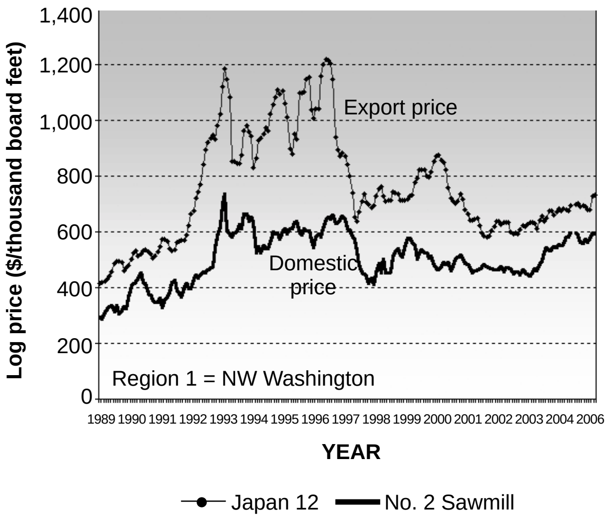


*Figure 1. Log export price premium for northwest Washington softwood logs. Sources: Log Lines Price Reporting Service, Mount Vernon, WA, http://www.logprices.com; and Jean Daniels, USDA Forest Service, Pacific Northwest Research Station.*

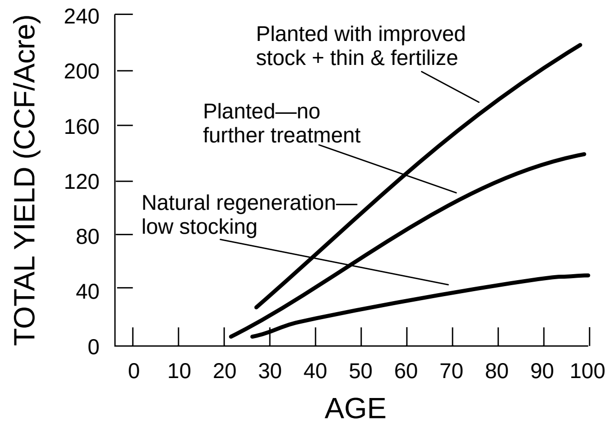


*Figure 2. Effects of management intensity on Douglas-fir yield for a single acre, site class III, cubic volumes in gross merchantable timber. Source: McMahon, J.P. 1992. The Place of Nutrition in Forest Management. In Proceedings from Forest Fertilization Symposium: Sustaining and Improving Nutrition and Growth of Western Forests. Chappell, H.N., G.F. Weetman, and R.E. Miller, eds. Institute of Forest Resources Contribution No. 73, University of Washington, Seattle.*

Forest soils information can provide a good basis for determining the need to fertilize if you suspect that elements other than nitrogen are limiting. You can obtain accurate soils information from the USDA Natural Resources Conservation Service (formerly SCS) located in most Washington counties.

# Benefits and Costs

While it is impossible to predict exactly what your timber will be worth at harvest time, an accurate cruise can provide you with a good estimate of its current market value. Extrapolate from there to your final harvest age or rotation. Volume yield estimates can be simulated though the use of a number of computer simulation programs. Bear in mind that the trend is for level stumpage prices from second-growth stands.

As figure 1 indicates, from 1989–2006 alone, log prices have leveled generally. As available timber supplies decrease on public lands in the Northwest, family forest landowners, who own roughly 25% of Washington's forested lands, will play a pivotal role in supplying timber and other forest products.

## Increased Yields

By fertilizing second-growth Douglas-fir stands with nitrogen, you may increase stand growth by about 20% for an 8- to 10-year period. Done in concert with other cultural techniques like thinning and pruning, the yield and value effect of fertilization can be even more marked, as shown by figure 2. It is important, however, to factor in losses from pests, disease, competition, and weather. An increase in *merchantable* stand volume can be translated into a similar increase in the money received at harvest, minus expenses. Once again, it is impossible to predict exactly what your timber will be worth at harvest time. Losses from natural mortality also have to be added to the mix of variables, as well as the costs of harvesting and extracting the trees. For example, in a 30-year-old stand on an average site, the fertilization effect should produce an additional 100 board feet per acre per year or about 1,100 board feet per acre for the 8- to 10-year response period.

### Fertilizer Costs

Fertilizer for large fertilization projects is typically delivered in rail car lots then trucked to heliports near the stands to be fertilized. For smaller projects of a stand or two, fertilizer may be purchased from agricultural supply stores. In Spring 2006, farm store price for urea (46-0-0) was about $ 350[1]/ton. The examples above result in fertilizer costs per acre of $76 for urea. *These costs do not include application and chemical delivery expenses that may increase the final cost by 30%–50%.* Fertilizer costs can vary, so you should consider the most cost-effective formulation.

When ordering bagged fertilizer from the supplier, consider how you will handle the bags. Fertilizer can be custom packed in 50 lb or 80 lb bags, so if you will be hand loading or transporting the fertilizer, consider the difficulty in moving heavy bags!

### Cooperative Ventures

The cost of fertilizing will vary according to location, parcel size, and application method. If your parcel is adjacent to land managed by a forest products company, you might be able to join in their fertilization operations. In the Northwest, virtually all industrial forestry firms use helicopters to distribute fertilizer. Landowners who are not able to cooperate with corporate neighbors may find it useful to form a partnership with other small landowners to improve economies of scale and minimize expenses.

### Cost Share Assistance

Cost share programs are available for nonindustrial private forest landowners who pursue intermediate silvicultural treatments such as thinning, pruning, and fertilization. Forest fertilization operations may be eligible for USDA cost-sharing funds. These funds typically reimburse landowners for 65%–75% of costs. Local offices of the USDA Farm Service Agency (formerly ASCS) or your state forestry agency, the Department of Natural Resources (DNR), can advise you regarding the eligibility and requirements in your area. To qualify for USDA cost-sharing funds, landowners must apply and receive written approval from the FSA before work begins.

## How To Fertilize Your Forest

In the following section, we will address five steps involved in fertilizing forest stands: 1) choosing a nitrogen fertilizer, 2) application rates, 3) application methods, 4) application timing, and 5) application frequency.

### Choosing a Nitrogen Fertilizer

Nitrogen (N) is the element most commonly used as a fertilizer for second-growth coastal Douglas-fir forests. As a forest fertilizer, nitrogen is usually applied as: urea $CO(NH_2)_2$. Urea is most commonly used in forestry, since the 46% nitrogen content makes it a more efficient vehicle.

Fertilizer labels indicate the percentage content of nitrogen as N, available phosphorus as $P_2O_5$, and total potassium as $K_2O$. Since urea does not contain P or K, its fertilizer grade is 46-0-0.

[1] Spot price courtesy of J.R. Simplot Grower Solutions (503-838-1861).

## Application Rates

The standard forest fertilization application rate in coastal forests is 200 pounds of nitrogen per acre. If you choose to use urea, this translates into 435 pounds of urea per acre. The formula to determine the amount to apply is

Pounds of fertilizer per acre to apply =

$$\frac{\text{pounds of N to apply per acre}}{\text{\% N content of fertilizer}}$$

***For example**, to apply 200 lb of elemental nitrogen per acre as urea (46% N, 46-0-0), use the formula:*

*200/0.46 = 435 lb*


## Application Methods

If your forest is large enough that only a helicopter operation is feasible, the more concentrated levels of nitrogen found in urea will translate into less air time and lower application cost per acre.

Fertilizer can be spread by hand from a bucket or cyclone spreader, provided that the size, location, and terrain of your forest allow you access to all sections for even distribution.

When distributed uniformly in the proper amounts, nitrogen fertilizer does not pose a threat to wildlife or livestock. However, you should strictly avoid having standing piles of nitrogen fertilizer on the ground (for example, as a result of a bag spill). At that level of concentration, nitrogen can be toxic to wildlife and domestic animals. Clean up spills immediately, especially into water, since nitrogen fertilizer is harmful to aquatic life.

## Application Timing

In the Pacific Northwest, apply nitrogen fertilizer in the rainy season, during late fall, winter, or early spring. Optimal conditions are cool, wet, windless weather with temperatures of 55°F or cooler. Never apply fertilizer in warm, dry, windy weather since volatilization can occur. In volatilization, fertilizer nitrogen is transformed into ammonia gas that dissipates into the atmosphere—not part of your investment strategy!

## Application Frequency

How often to apply nitrogen fertilizers largely depends on the age of your stands and the potential investment period. A single application 8 to 10 years before final harvest of mature stands of 50- to 60-year-old Douglas-fir will provide an attractive financial return. During the 8- to 10-year period, volume growth will increase about 20% on average sites. Effective fertilization regimes for younger stands may include several applications during the rotation. The interval between applications will vary according to growth rate, which is influenced by stocking levels and overall site quality. Generally, fertilization effects last 8 to 10 years. Plan intermediate harvests (thinning) to regulate stocking and capture the growth increases from fertilization.

## Forest Practices Act Compliance

*Forest fertilization is regulated by the Washington State Forest Practices Act.* The law requires hand application in riparian and wetland management zones unless the DNR has approved a site-specific plan for another method. Aerial application requirements are varied. In general, avoid application to water or wetlands. Buffers are required around all waters, residences, and adjacent agricultural land. While water nitrate levels after fertilization operations have never reached levels that are a concern for human health, concerns exist for fish eggs and fry and other aquatic life. Be scrupulously careful whenever you are dealing with fertilizers near running or open bodies of water. The size of required buffer zones varies according to the type of water on your property. For a Forest Practices Act application and clarification of the regulations, consult with a Forest Practices Forester with the Washington Department of Natural Resources (360-902-1400, http://www.dnr.wa.gov/forestpractices) prior to application.

## Final Notes—Seek Advice

Fertilization can be a powerful tool in managing forest land and increasing the timber yield of second growth Douglas-fir forests. When fertilization is used in conjunction with thinning and pruning, timber yield and value increase can be substantial. Accurate information is the foundation of good decisions. The more you know about your forest and growing trees for timber, the better. Before committing to a forest management plan that includes fertilization, it is wise to seek the advice of a professional consulting forester. Consultant foresters working in the state are listed on the Extension Forestry website: http://ext.nrs.wsu.edu.

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