Chapter 22

A Coastal Landowner's Approach to Forest Fertilization

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ABSTRACT. Champion International Corporation has fertilized over 23,000 hectares of forest land on the West Coast since the early 1970s. Fertilization must compete with all of Champion's other capital investment opportunities and is generally not given high priority. Stands to be fertilized are primarily selected based on comparative financial analyses of profitability. Key variables affecting priority are stand age, site index, stand density, and species composition. In addition to financial screening, Champion has tried using foliar and soil analyses and a paired-tree growth response technique for selecting stands for fertilization. During fertilization operations, done by helicopter, no systematic method is used to monitor fertilizer distribution. Some response monitoring has been done using paired-tree methods. Fertilization contracts are granted through competitive bidding, and contractors handle all aspects of the operation, including purchase of the fertilizer.

Stumpage prices in the Pacific Northwest showed strong gains from 1985 to 1990 (see Figure 1). While some of those gains have been lost in the current recession, the very low stumpage prices seen in the last recession in the early 1980s are unlikely to return. Northwest public timber supplies are shrinking, and private resources are at a low point due to past harvesting levels. Timber demand should be fairly strong through the mid-1990s. As a result, stumpage prices are forecast to continue rising over the long term in the Northwest (Veltkamp et al. 1990), and owners of timber will be the beneficiaries. With the future of privately owned timber looking so bright, it is not surprising that fertilization and other silvicultural treatments that enhance growth are attractive investments for industrial forest landowners. Fertilization has the potential of generating the highest incremental internal rate of return (IRR) of any forest management investment opportunity, because nitrogen fertilization normally results in a substantial growth response in Douglas-fir and it can be used later in the rotation than any other commonly employed silvicultural activity, such as precommercial thinning.

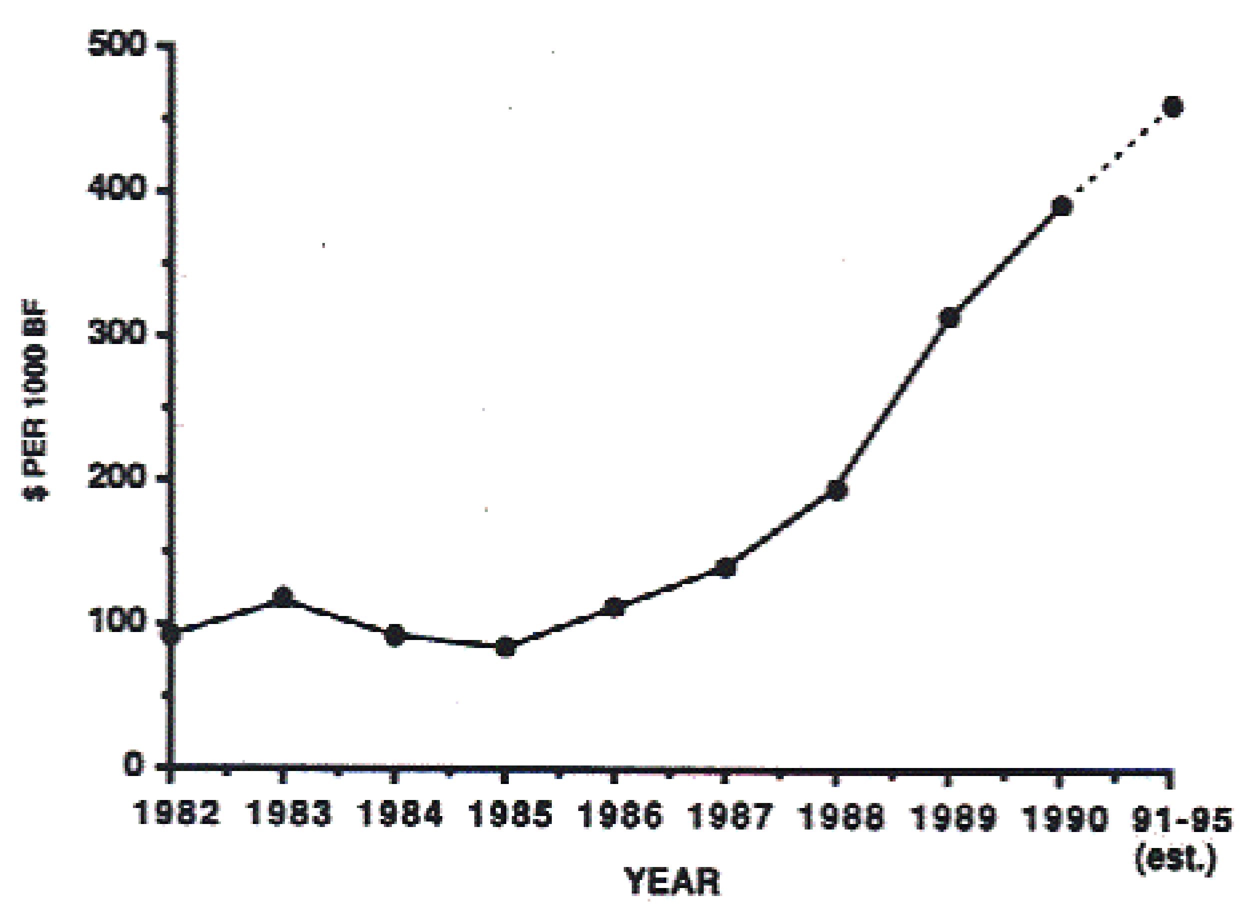

Figure 1. Average West Coast stumpage bid prices (all species). Source: USDA Forest Service, Region 6.

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While the practice of fertilization is generally viewed as a beneficial treatment for industrial forest lands, it is far from an exact science. There are numerous operational concerns. On the research side, despite many years of excellent forest nutrition research by the Regional Forest Nutrition Research Project (RFNRP) at the University of Washington and the Pacific Northwest Forest and Range Experiment Station (USDA Forest Service), there are a number of fertilization response relationships that need more study. However, the many operational concerns and unanswered biological questions have not prevented the forest products industry from carrying out large fertilization programs on the West Coast. Indeed, based on a 1986 survey on past and future fertilization programs of large West Coast forest landowners (members of the RFNRP), these forest landowners in western Oregon and Washington fertilized over 1.3 million hectares from the early 1960s to 1990

(Chappell and Opalach 1986). This survey covered about 80% of the commercial forest land on the coast. The small private class of forest land was the only category largely not included in this survey, and few of those owners fertilize their lands.

Champion International Corporation has fertilized over 23,000 hectares of forest land on the West Coast since 1972, and thus its foresters are experienced in conducting operational fertilization projects. Based on Champion's experience the following issues will be discussed in this chapter: (1) financial decisions, (2) monitoring programs, (3) operations and contracting, and (4) information needs for further improvements.

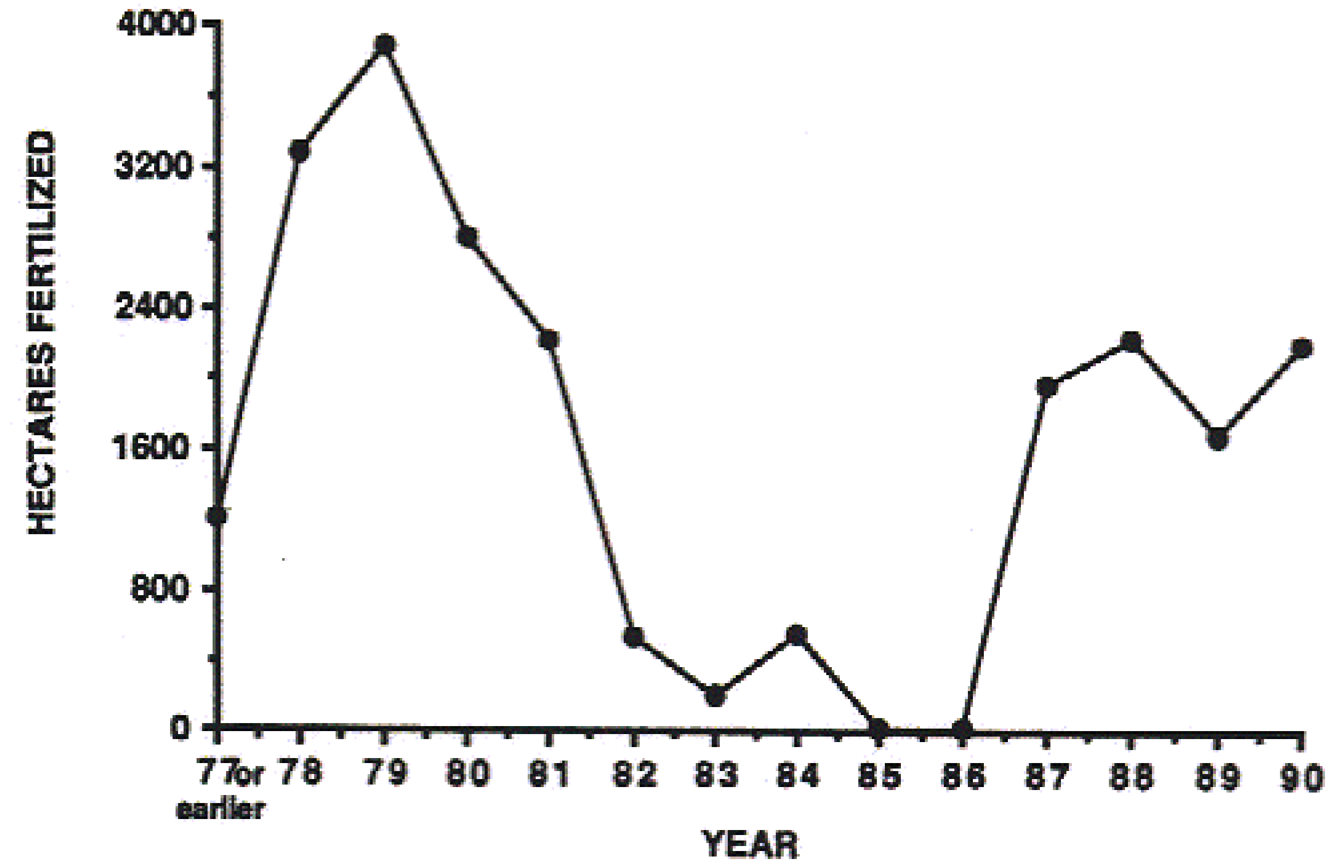

Figure 2. Champion's West Coast fertilization history.

Financial Decisions

Capital Availability

The amount of capital available for a corporation to invest in any given year depends on a large number of external and internal factors. Interest rates charged on borrowed money and the investment level of competitors are among the external influences. Internally, some of the influences are the rates of predicted return on possible investments, level of dividends paid to stockholders (tied closely to net income levels), and level of debt already incurred. Within corporations, capital availability is *always* limited. Fertilization must compete not only with other silvicultural options such as precommercial thinning but also with nonsilvicultural investments such as new manufacturing equipment. Although fertilization appears to offer the potential for generating high incremental rates of return, it is not given priority over other silvicultural options for a variety of reasons. Regeneration and plantation maintenance are given higher priority in capital allocation for legal reasons and because Champion views itself as a long-term land manager (a philosophy that obviously requires ownership of well-stocked lands). Some land managers are concerned because Douglas-fir stands do not always respond to nitrogen fertilization (to be discussed in detail later). Thus fertilization seems somewhat risky to many foresters, and because of that most foresters would rather spend limited capital dollars on precommercial thinning. Champion does not overtly use fertilization in an allowable-cut effect rationalization for increased harvest levels (this might be a reason to give fertilization a higher priority than some other treatments in allocating capital). As can be seen from the following discussion, the allocation of capital within Champion for fertilization is not a simple process. The actual amount of capital allocated to fertilization in any given year involves numerous economic and strategic considerations. It is safe to say that fertilization is not generally given a high priority for investment capital in Champion and that only in those years where capital is plentiful will fertilization be funded.

The level of capital allocated to fertilization on Champion land on the West Coast has varied significantly over the past 18 years since the first operational fertilization was done. Figure 2 shows historic fertilization levels by Champion on the West Coast. The recession of the early 1980s had a major impact on Champion's fertilization program, as did the 1984 merger with St. Regis Corporation. Champion took on an additional $1 billion of debt in 1985 to merge with St. Regis. This certainly affected Champion's ability to take on additional investments, no matter how attractive.

Guidelines for Selecting Candidate Stands

Aside from the capital availability decision, which is made by corporate-level managers, the most important fertilization investment decision is choosing which stands to fertilize. Since there are usually more seemingly acceptable areas to fertilize than there is available capital, a prioritization process is carried out. The primary rationale used by Champion in prioritizing stands is simply choosing those stands for which the greatest financial returns are expected. A number of approaches have been used within Champion to give field foresters guidance on which stands are the most financially attractive for fertilization. Prior to 1984, foresters generally used RFNRP-developed fertilization priorities (RFNRP 1976, 1979). These priorities showed that older, preferably thinned stands of Douglas-fir (*Pseudotsuga menziesii*), sites II through IV, were the best fertilization investments. In 1984, Madsen (1984) developed a set of internal guidelines for fertilization priorities which again relied heavily on RFNRP data but also incorporated stand density relationships similar to those discussed by Strand and DeBell (1981). Incorporating stand density criteria into the stand selection process lowers the priority of stands that are in either an overstocked or an understocked condition. Not surprisingly, this analysis showed that the highest priority stands for fertilization are older, thinned Douglas-fir stands (mid to high site index) followed by older mid-site, unthinned Douglas-fir stands with not over 120% or under 60% normal basal area (Chambers 1980).

In 1987, the process of selecting which stands to fertilize was refined further at Champion by initiating a program in which an incremental IRR calculation was made for each stand proposed for fertilization. Such calculations had been made in the past, of course, but in 1987 a process was established whereby all stands proposed for fertilization were screened by this calculation. In this process the winners are picked, and the funding for fertilization is allocated accordingly. Thus some districts receive more capital for fertilization than they expect and some receive less. While this may slight some district's expectations, the process is objective and hard to criticize.

While fertilization is financially very attractive when analyzed using broad regional response data, not all Douglas-fir stands respond to nitrogen fertilization. Miller and others (1988) found that of 111 study sites in Oregon, 70% showed significant response of Douglas-fir to nitrogen fertilization. Response data from a broader range—British Columbia to southern Oregon—show an even lower response, around 60% (Miller et al. 1986). There are several reasons why a stand might not respond to nitrogen fertilization, including: (1) other limiting nutritional deficiencies (van den Driessche 1981; Turner et al. 1979); (2) other limiting growth factors, such as light or moisture (Strand and DeBell 1981); (3) high mineralization rates of available nitrogen (Shumway and Atkinson 1978); (4) urea effects on mycorrhizal populations due to increased pH (Lavender and Walker 1981); and (5) high forest floor carbon-nitrogen ratios on the site (Miller et al. 1989; Edmonds and Hsiang 1987). Champion has experimented with methods to increase the reliability of fertilization response, including foliar and soil analyses and a paired-tree growth response technique. In addition, Champion has made a thorough examination of local RFNRP installation results and either contracted for or installed additional units in areas not covered by the RFNRP on the West Coast.

In 1981, Champion conducted a trial study of pretesting stands by foliar analysis, performed on systematically sampled trees from 16 different stands on Champion's Roseburg District. The within-stand variability of percentage total nitrogen found in this study was relatively low, thus agreeing with other such studies (Heilman and Gessel 1963; Lavender 1970). However, none of these stands could be termed deficient using a criterion of 1.2% total nitrogen on current foliage (van den Driessche 1979). Only 6 of the 16 stands had a lower than 1.4% total nitrogen average level. Based on RFNRP response data for the general area, this proportion of nitrogen-deficient stands seemed low. The cost of sampling on this "operational" test amounted to approximately 4% of the cost of the fertilization; thus the costs of this technique appeared to be acceptable. Because the foliar N levels did not seem to correspond with expected levels of nitrogen-deficient stands in the Roseburg area, and sampling procedures require a significant amount of administrative time for a practice that may or may not be funded in any given year, foliar analysis screening has never become operational within Champion.

Soil analysis has been used less frequently than foliar analysis in prioritizing stands for fertilization within Champion. No formal study was ever established to test soils operationally. However, some broad soil type differences are used to prioritize stands for fertilization in a few areas where soils differ significantly (e.g., the glacial outwash soils on some of our western Washington lands).

In the early 1980s it became clear that what many Champion foresters wanted was a prefertilization screening technique that included response of the trees themselves, not some index of nutritional deficiency. Thus Champion began studying the use of paired-tree growth response. The first trials of this technique began on the Lebanon District in 1983. There has been a low level effort to install paired-tree transects since that time. A description of the sampling technique used by Champion was reported in 1987 (Milner and Berns 1987). In brief, the technique can be used as either a stand screening method or a way to monitor operational fertilization response. The technique simply compares pairs of trees in which one tree of each pair is fertilized and the other is not. The fertilized tree may be in an adjacent operationally fertilized stand or it may be a nearby tree that is fertilized by hand (when the technique is used to screen for fertilization response potential). Table 1 shows the criteria and standards Champion has used to pair trees. If the technique is used for operational monitoring of response, areas used for pair selection are carefully chosen prior to fertilization to ensure that the sites are

Table 1—Tree pairing standards used in Champion's paired-tree technique.

Tree Measurement	Trees Must Be Within:
Crown ratio	±10%
Diameter at breast height	±2.5 cm
Past 5-year radial growth	±0.25 cm
Site index	±3 meters
Competitive status	±2 m^2 basal area (larger trees)

similar in slope, aspect, age, and site index. The pairs generally come from dominant or codominant crown classes, although some intermediates have been paired as well. The data from ten paired-tree transects on the Lebanon District were analyzed recently. Some showed a significant response to fertilization and some did not. The overall level of response was very close to RFNRP average levels (i.e., an 18% increase in basal area growth). Those data showed that in order to detect a 15% response level at the 0.10 probability level, approximately 12-14 pairs must be established. This number of pairs can be established by a forester in two days or less. Once the installations are made, remeasurements take very little time. Only tree diameters are remeasured. Reliable results appear to be available two growing seasons after fertilization. This technique has not been analyzed for its suitability as an operational screening process. The cost would most likely exceed that of foliar sampling; however, land managers would have much greater confidence in the results.

Another source of response data, available to all members of the Stand Management Cooperative, is the RFNRP installation summary material. While RFNRP installations were not designed to be used for testing significant response potential for the stands where they are located (Turnbull and Peterson 1976), they can provide data that indicate regional trends. This has been done for RFNRP installations on or around Champion lands in Oregon and Washington. These regionalized results have, for example, revealed that a lower percentage of RFNRP installations in the Mapleton (Oregon) area showed a significant response to fertilization.

Since Champion's Klickitat District (between Mount Adams and the Columbia River, just east of the Cascade divide) lies outside the RFNRP westside area of coverage, Champion recently helped fund a cooperative effort for the installation of six fertilization response study sites in this area. These were established by crews from the Inland Forest Nutrition Research Cooperative at the University of Idaho. The information will be used, like the RFNRP summaries, to show generally how stands in a narrow geographic area respond to fertilization. Similarly, Champion installed five fertilization study sites on company lands in interior northern California, since that area is also outside RFNRP coverage.

Financial Decisions Summary

Where is Champion now as far as stand selection for fertilization is concerned? Many of the older stands have been fertilized. Indeed, many of the stands fertilized earlier have already been harvested. Younger stands are now being fertilized. Some stands are being treated for the second time. Capital availability for fertilization remains a problem (e.g., it is likely that no acreage will be fertilized in 1991). Foresters would like to start using the paired-tree method to screen fertilization candidates in areas where they are uncertain of seeing significant response, such as high sites or areas where past fertilization has shown little obvious response on increment core samples. However, with limited staffing it is unlikely that many paired-tree installations will be set up in the near future.

Monitoring Programs

Treatment Monitoring

Treatment monitoring is perhaps one of the most difficult aspects of operational fertilization. The primary concerns about treatment monitoring are obtaining an even distribution of fertilizer and staying within the treatment boundaries. To increase the uniformity of distribution, Champion service contracts call for a double coverage of the unit, with the helicopter using perpendicular flight paths. If cross flying is unsafe, the second flight per line is to be in an opposite direction to the first if possible. In addition, Champion fertilization contracts allow for sampling the ground distribution of granules or prills to check uniformity of coverage. The specification used in the Champion contract states that if an area of one-fourth swath width or more has less than 50% of the desired fertilizer, the deficient area must be reflown at the contractor's expense. In practice this is done only if an obvious problem is seen by the Champion forester(s) supervising the operation.

Marking the stand boundaries of fertilization units so they can be seen from the air can be extremely important. Obviously, fertilizing a second-growth stand surrounded by clearcuts offers the easiest delineation of stand boundaries. Of course, this is seldom done. In areas where cutting lines or natural landmarks are not adequate to guide the pilot, some type of marker must be hung in trees for unit boundary reference. The standard one-inch flagging, regardless of color, does not work well for marking. Large white garbage bags seem to work well, although there are certainly many other good boundary marking methods (helium filled balloons, "hula-hoops" with bright flagging attached and placed in the tops of trees, etc.). Champion uses a variety of all of these methods depending on the situation and the preference of the local land managers.

Environmental Monitoring

The main step taken during fertilization operations to minimize environmental impacts is to avoid direct application of fertilizer in open waters and active streams. In Oregon no fixed buffer is required by Oregon forest practices rules while fertilizing adjacent to active streams or open waters. The Washington forest practices rules require a 25 foot buffer (7.6 m) left between the fertilized unit and adjacent streams or wetlands. Many of the stream buffers in western Oregon and Washington contain little Douglas-fir, and in any case harvesting is very restricted in stream buffers. Thus there is no temptation or any economic incentive to get urea near streams in either state. All Champion fertilization units are flown with the helicopter pilot prior to treatment to point out not only unit boundaries but also stream buffers. Stream buffers are not marked or flagged. The preoperation flight with the applicator pilot is sufficient for ensuring that the buffers are observed. Champion contracts require that all necessary precautions be taken by the contractor to avoid direct application of fertilizer to streams or wetlands. In addition, the contractor is responsible for all damage claims made against Champion in cases where application is made outside agreed upon areas. Champion has not monitored water quality in fertilized watersheds to check for accelerated nitrate levels. Buffers are checked occasionally for the presence of urea prills.

Response Monitoring

As was previously mentioned, Champion has a modest response monitoring program established. Monitoring comes from paired-tree transects established in fertilized and adjacent unfertilized stands, as outlined above. The objective of this program is primarily to build confidence in Champion's fertilization program. Most foresters feel this is an important program, but there is a healthy skepticism among foresters about achieving a response. Foresters will take an increment core from a fertilized tree, see little or no increase in radial growth rate, and assume no response has occurred. Often, however, response is much more subtle than a simple increment core can detect. By comparing pairs of very similar trees—one fertilized and one unfertilized—a much more objective appraisal is made. Obviously, this approach is not without problems. Only a fairly small geographic area can be covered with a paired-tree method. To go to larger areas would be too expensive. Foresters generally trust the RFNRP results; however, they are concerned about that 30-40% of their land that will not respond (Miller et al. 1986, 1988). The average RFNRP response levels Champion uses in its economic analyses include the nonresponding installations, of course. If these nonresponding areas can be reduced, higher levels of response and greater profitability from fertilization can be achieved. In one case, a favorable analysis of many paired-tree installations on a Champion district resulted in that district significantly increasing its level of fertilization in a year when there was extra capital for fertilization.

Operations and Contracting

All of Champion's operational fertilization is done by helicopter. Since Champion owns no helicopters, operational fertilization is contracted out by competitive bidding to one of the many contractors in the Northwest who offer this service. District stands to be treated are usually grouped with stands of other districts for bidding purposes. The contract Champion generally uses in fertilization operations specifies: (1) materials to be provided (Champion requires the contractor to supply the fertilizer and transport it to the landings); (2) equipment to be supplied (helicopters, transport trucks, a scaling system for accurate weighing, etc.); (3) personnel to be supplied (properly licensed pilots and a ground crew); (4) Champion's obligations (unit maps, photos, and personnel to accompany the pilot on reconnaissance flights, etc.); (5) assistance in marking the unit (the contractor will supply a helicopter and personnel to assist in marking); (6) heliports and roads to be used (these are selected by mutual agreement); (7) the date work will begin, completion date, and average production standards; (8) fertilizer application criteria (average daily production rate, even distribution requirement, units to be flown twice with half the fertilizer to ensure even distribution, precautions to be taken to keep fertilizer out of streams and open water); (9) testing and inspection (allows for Champion to inspect application coverage, following distribution criteria mentioned in the previous section); (10) responsibilities of the contractor for damage claims against Champion; and (11) insurance requirements (covering personal injury, property damage, aircraft liability, and chemical liability). There are other contract provisions, but they are not relevant to this discussion. Many of the application specifics are left up to the contractor. For example, swath width obviously depends on the type of helicopter, application equipment, and urea prill size utilized. Double coverage of the unit using perpendicular flight paths is required in the contract; however, it is not always safe to do it this way. Thus parallel overlapping flight paths are often used.

For the job itself, Champion usually assigns two foresters. But this is not always possible. Ideally one forester is in the unit to be fertilized monitoring coverage, and the other is on the landing monitoring the number and size of loads, coordinating moves to other landings, monitoring weather conditions, and flying the unit prior to the start of the operation to point out boundaries and the waters or streams to avoid.

Information Needs

A considerable body of information is available on the fertilization of conifers on the West Coast. The RFNRP and a few PNW Experiment Station scientists truly have made fertilization a silvicultural choice on the West Coast. Without this base of knowledge it is highly unlikely that anywhere near the 1.3 million hectares of fertilization completed to date on the coast would have occurred. Despite this productive history of research, there are still a number information gaps. The following areas appear to need further attention: (1) stand density impacts on response levels; (2) updating of the fertilization response functions in various growth models (e.g., SPS and DFSIM); (3) long-term productivity issues surrounding the practice of intensive forest management; (4) diagnostic studies (including paired-tree growth response methods); (5) tree shape changes due to fertilizer effects on crown characteristics; and (6) noble and Pacific silver fir response to urea and ammonium nitrate.

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