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Constructive Use of Herbicides In Forest Resource Management

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ABSTRACT—Herbicide-based methods have come into use as partial or full substitutes for tools long used in timber stand establishment and management. Some are effective and economical, offering a way to improve resource productivity. Yet their environmental impacts are being questioned in much greater detail than were the practices they replace. This article describes some of the practices and examines some of the questions regarding the relative impacts of some analogous chemical and nonchemical methods. The choice of methods is considered as an active process that takes into account both the advantages and disadvantages of each option in management and social contexts.

The status of all the principal resource values in commercial forests—timber, forage, wildlife, water and recreation—is more or less dependent upon the condition of the dominant forest cover: the tree layer. Because timber is the main producer of revenue on commercial forest land, silvicultural practices have traditionally been directed toward increasing the value growth of wood products. Herbicides are being used in an increasing number of such practices. Are such uses consistent with the constructive management of all forest resources? This question must have a positive answer if foresters are to continue the use of herbicides. If indeed the answer *is* positive, perhaps more intensive use is in order. If negative, we need to reduce or eliminate the inconsistencies or cease their use.

Analyzing Impacts on Ecosystems

To evaluate the impact of a specific method, we must first evaluate the effect of achieving its goal. Its impact can then be interpreted independently of the degree of success. This perspective allows us to select the approach with minimum disturbance in relation to a specific set of management objectives.

Virtually all silvicultural practices, wildlife habitat management techniques, and watershed management schemes involve removal of certain over-story components. The general purpose is to reduce the demand on site resources by certain species or cover types. Selective removal provides for selective recovery of remaining vegetation and focuses site resources in support of desirable species, with perhaps changes in water or wildlife yield. The very consideration that primary production can be focused in support of objectives principally by selective *de*vegetation implies that forest manipulation is generally *de*structive at the detail level, although *con*structive in the long run.

The ability of the desired cover to respond to liberated resources is conditioned by the effects of the practice on both residual vegetation and the site. Disturbing an ecosystem tends to set forest development off on a new trajectory. Ideally, we choose a management target and select a method that will aim the system in that direction. Usually, we have several choices of trajectory that will reach the same target, in response to different methods of implementation. The differences between impacts of chemical and nonchemical methods, then, are measured by differences in behavior of ecosystems while headed toward the same long-term objectives.

Effects in Eastern Multiple-Use Forest

Let us consider the management objectives for which there is a choice of chemical and nonchemical methods. In many forest types of eastern United States, production of high quality timber, whitetail deer, and clean water is an important set of objectives. The large percentage of low-value species and cull hardwoods compromises timber production while not generally affecting deer and water adversely. Many stands have a desirable component that can be released by removal of low-value species with an end result consistent with all objectives. Release may be done by felling (including harvesting), girdling, injection with growth-regulator herbicides or organic arsen-

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Figure 1. Selective application of 2,4,5-T by helicopter favors development of conifers in Pacific Northwest brush (Figure 1A at left) and of conifers in low-grade northern hardwoods (Figure 1B above), at low cost and with no site disturbance. The abundant regrowth of ground cover is excellent deer habitat.

icals, or by basal spraying. Aerial spraying and mist blowing with 2,4,5-T and other herbicides have also been done with considerable success in forests of certain compositions here and elsewhere (*Figure 1*). If all these practices may be used effectively for timber management, their impact on multiple use may be evaluated in terms of intermediate effects on water yield and wildlife habitat. Presumably the long-term effects on water and wildlife will be determined by the ultimate composition of the overstory.

The existing evidence suggests that removal of some trees consistently increases ground forage and improves whitetail deer habitat. Methods that stimulate sprouting tend to enhance habitat even further, as sprouts contribute to browse which is already stimulated by understory release. The phenoxy herbicides and organic arsenicals have been demonstrated effective in promoting sprouting when applied at certain times of the year and suppressing sprouts at others.

Phenoxy herbicides can stimulate the development of browse in both broadcast and individual shrub applications (*9, 11*), and increases of browse may be achieved without exposing the deer to toxic quantities of herbicide (*19, 21*). Similarly, recent studies suggest that organic arsenicals can be used safely (*22*). Although the specific factors of safety are beyond the scope of this paper, they have been summarized in detail elsewhere (*21, 22*).

The toxic hazards of herbicide use, which must be regarded as speculative at this stage, must be compared with the problems of physical changes of wildlife habitat associated with mechanized methods. Wildlife habitat that has been treated with herbicides is usually accessible, and gains in browse may be fully used. In contrast, browse development in an area strewn with heavy slash is only partially accessible; browse or planted seedlings, therefore, may grow out of reach by the time deer can move around.[1] To be sure, winter felling can furnish browse from tops as well as stump sprouts. Because herbicides are generally not mobile in forest soils (*21*), the toxic hazard of both types of practice on watersheds is probably negligible. Under various circumstances, both procedures probably should retain a place in management.

Effects in Brushfield Reclamation

The timber-dominant management goal is often the motivation for converting derelict brush-hardwood stands to productive coniferous forests. Areas to be converted may be prepared in several ways. Scarification by bulldozers, crusher-chopper techniques, spraying with herbicides, injection, burning, or combinations of these are all in general use. The option of *no* treatment is not consistent with the management objectives related to timber, because it usually rules out success in regeneration of timber species.

Complete conversion of forest cover constitutes a major disruption to an ecosystem, followed by secondary succession (*Figure 2A*). The degree of physical impact has an important bearing on ecosystem structure.

Total removal of standing vegetation by bulldozer or like equipment has several effects; it: (1) eliminates all site protection, (2) removes all cover for animals, (3) removes or bunches much nutrient capital, (4)

[1] *Newton, M. Unpublished data recorded on the Hamer Lake Cooperative Project, Oregon State University, School of Forestry and Starker Forests, Corvallis, Ore. 1975.*

Figure 2. The aerial application 2,4,5-T is a minimum-disturbance method of preparing sites in the Pacific Northwest (Figure 2B at right). Machine scarification has visible results and lower planting costs, but risks soil damage and siltation as well as destroying existing stocking (Figure 2A above).

maximizes microclimatic extremes, and (5) creates a new beginning for undesirable as well as desirable species, native or introduced, so that selective treatments may later be needed to reach production objectives. Under some circumstances, heavy equipment can be used with minimal soil disturbance with much less total impact (*6*).

Fire achieves many of the same vegetation management effects as a bulldozer. Unique to fire is the stimulation of seeds of certain species uncommon without fire and the short-term release of nutrients, with some losses of nitrogen through volatilization. Unlike scarification, fire does not knock down or disrupt standing trees not consumed and leaves a less extreme microenvironment for seedlings and better cover and habitat conditions for certain animals, especially birds. Smoke poses temporary problems of air quality in some circumstances.

Herbicides seldom are prescribed to kill all vegetation and do not physically disrupt soil. Herbicide selectivity determines which species are favored at the expense of those controlled (*Figures 1A, 2B, 3*). Because spray treatment has no physical impact, wildlife habitat is modified largely with regard to changes in ratio of favored food species. The unique feature of herbicides—biological activity—may have a residual effect on vegetation that may last for a few days to a year, depending on persistence of the herbicide and availability to plants. At rates used, they are not known generally to have direct effects on wildlife other than through habitat modification (*1*).

Combinations of treatment types offer means of obtaining success with minimum adverse effects. Spraying and crushing of brush permits minimum intensity of machine operation. Spraying and burning eliminates machine operation and destroys herbicide residues; dry fuel also burns with less smoke and for shorter duration. In the various regions and forest types, an infinite variety of combinations is available to the forest manager; herbicides figure prominently in many of them.

In summary, of the various techniques used in brushfield reclamation, impact of herbicides is probably least, followed by fire and then scarification. But herbicides alone may also have the lowest expectation of success *because* of their selectivity and low impact.

Effects on Water Conservation

Transpiration control through vegetation management is a concept that has been pursued in both reforestation and watershed management. The short-term effects of vegetation control on water conservation are well documented (*13, 23*). Long-term effects relate to the changes in dominant vegetation type that occur as a result of vegetation control and to the duration of the physical effects resulting from the use of such treatments.

When vegetation control is pursued in the quest for regeneration of timber stands, control is achieved either by soil tillage or by direct application of herbicides to plantations.

Tillage destabilizes soil and prepares a seed bed for invading pioneer species that tend to shorten the time that moisture is conserved. Herbicide practices—for example those involving the use of atrazine—give some residual control of vegetation and maintain a plant mulch without disturbing the soil. In the context of reforestation, these practices are usually targeted on

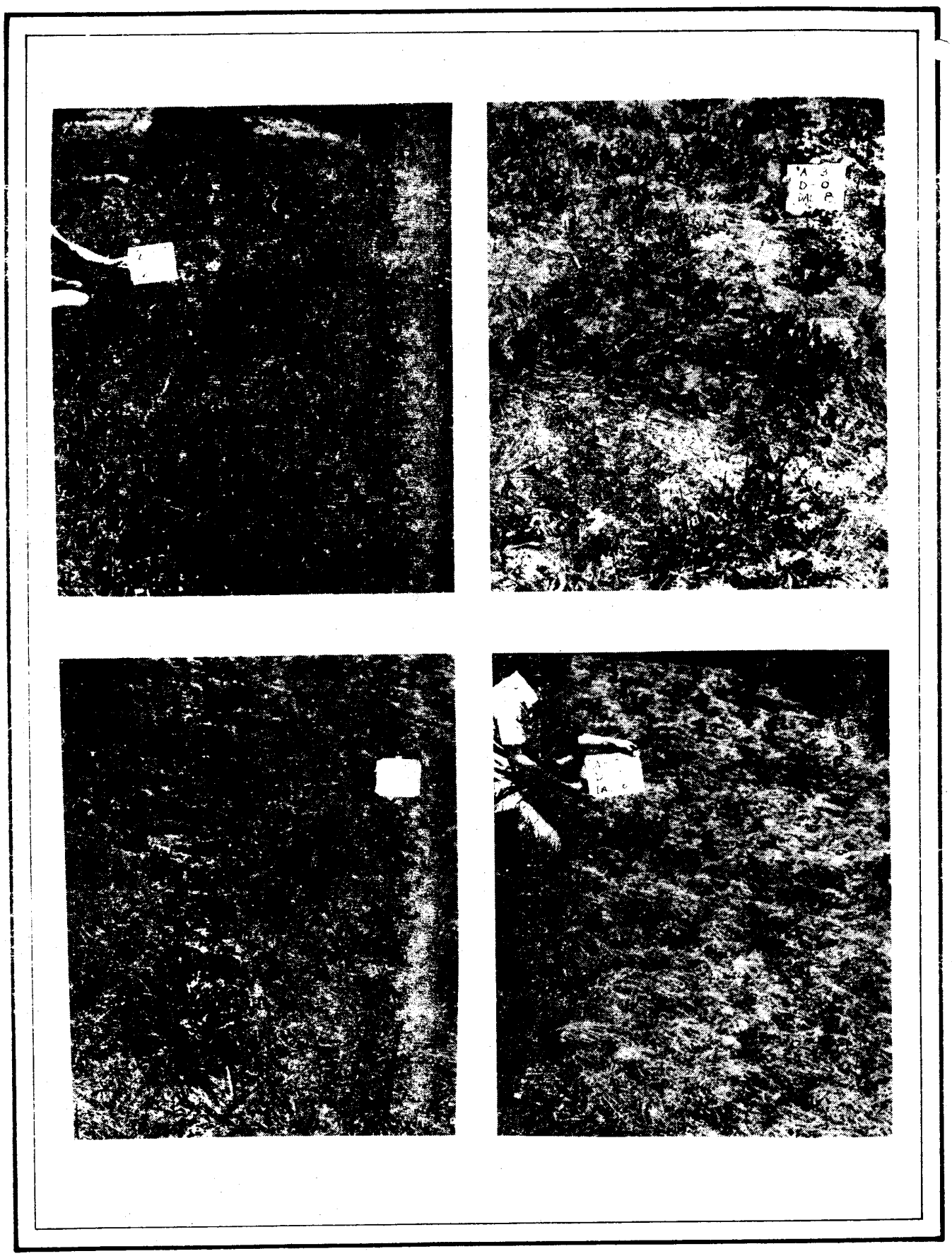

Figure 3. Combination of herbicides can be used to grow Douglas-fir (Figure 3D lower right), highly palatable perennial grasses and Douglas-fir (Figure 3C lower left), highly desirable gopher food and Douglas-fir (Figure 3B upper right), or non-use of herbicides can cause plantation failure (Figure 3A upper left) in old fields of the Pacific Northwest. (Atrazine, dalapon, and 2,4-D were used.)

herbaceous vegetation, primarily grasses (*Figure 3*). Direct effects of such weed control are usually restricted to the first year or two of the life of a stand; the principal, long-term result is replacing herbs with forest. Wildlife habitat recovers the first year (*2*).

The same practices pursued in quest of increased water yields—although tactically similar—are aimed toward a vegetation structure that consumes a minimum amount of water without destabilizing soils. Achieving this goal entails practices that will simultaneously promote the development of a shallow rooting cover at the expense of a deeper rooted cover. The herbicides 2,4-D and 2,4,5-T have been used to some effect to achieve this goal (*16*), and a good deal of data suggest this may be achieved with no toxic hazard or danger in use of water from treated steep watersheds (*20*). There is no known way to achieve the same type of vegetation-related conservation with traditional mechanical methods in the steep terrain of the water-deficient Southwest without serious effects on soil, hence water quality. Even in those areas where soils permit machines and fire, their effects are often temporary because of re-encroachment of the woody cover.

The same general principles may be used to evaluate the impact of a change from grass to forest for timber production or from woody plants to grass for watershed management. In pursuit of both management objectives, a minimum impact practice is apparently desirable from a practical standpoint of minimizing later problems. Herbicides may well replace much mechanized equipment for the specific reason that they minimize surface disturbance in pursuit of both goals.

Potential New Practices

Control of bark beetles and root rots in young stands.—Precommercial thinning is receiving much attention in the coniferous forests of the West and elsewhere. Done primarily to enhance individual tree growth, thinning also allows temporary increased development of ground cover and game habitat. Thinning is normally done with power saws, but injection of herbicides has been in use for this purpose since about 1966.

In stands of late-precommercial size, recent data indicate that chemical thinning may achieve the same long-term objectives with less adverse effects, and at lower cost (*25*). Adverse effects reduced include the minimizing of root rot entry (*10*), reduction of sunscald, snowbreak, and windthrow on residual trees plus reduction of slash[2], and restriction of bark beetle development (*17*).

Most chemical thinning is now done with injections of monosodium methanearsonate (MSMA). It has been tested on numerous species with consistent effectiveness (*18*). Potential hazards of the use of this compound in the forest have been examined in detail (*22*). On balance, herbicides apparently may substitute for saws in stands more than 30 feet tall to minimize biological impact of thinning operations. The combination of chemical and season must be selected with care, however, because the wrong choice of herbicide or season of application can negate these gains (*10, 17*).

Reduction of harvest impact.—Reduction of the impacts of harvesting in western United States is receiving much attention, and the environmental impact of clearcutting has been debated at considerable length. This and other harvesting practices have been criticized for disturbance to streams, soils, microenvironments of regeneration, and smoke management. Measures to reduce impact have included clean yarding for smoke abatement, balloon or helicopter yarding for minimizing soil disturbance, and grass seeding for soil stabilization.

All these measures have some shortcomings in that they increase certain impacts while reducing others. Clean yarding maximizes soil surface disturbance and loss of nutrient capital, while minimizing the need for burning. Balloon yarding leaves a maximum of slash and brush in furtherance of minimum soil disturbance

Figure 4. A Douglas-fir tree 15 months after treatment with MSMA, for pre-harvest drying, remains free of the Douglas-fir beetle. Weight loss and ease of debarking were economically important. (Photo by H.A. Holt)

[2]*D.G. Malmberg, Research Forester, Crown Zellerbach Corporation, Seaside, Oregon. Unpublished observations from thinning studies in western hemlock.*

and erosion hazard, but the residue can increase the difficulty of planting and may increase later need for brush control. Grass seeding is a well established practice for protecting disturbed soil from erosion, but grass also tends to create an adverse environment for regeneration on droughty sites. In terms of forest development, practices that stabilize brush or grass cover in effect prolong the impact of deforestation.

Herbicides offer opportunities for reducing the impact of harvesting. Several specific problems may be reduced or eliminated by the application of herbicides without perceptible compensating harm. Killing trees with MSMA before harvesting them, for example, drys, partially debarks, and defoliates trees of many species. This practice reduces fine fuel in slash and minimizes the volume of bark and nutrient capital removed from the site (*7*). It also presents an opportunity to reduce the suitability of cut stumps for root rot colonization (*10*). Where unutilized slash offers habitat for bark beetle buildup, some findings suggest that prior treatment with organic arsenicals reduces hazard (*17*) (*Figure 4*). Chemically induced separation of bark from wood in roundwood during chipping also has been reported (*12*), with some prospect that preharvest treatment may simplify use of low-grade wood residues. The lower cost of harvesting dry timber and lower cost of handling and processing pre-treated logs without increased degrade or breakage are incentives for pursuing this practice.

Insect control by habitat management.—Insect control is seldom considered in reference to herbicides; the subject deserves much closer attention. Herbicides have the potential of managing habitat with considerable selectivity. This concept alone gives immense power to control habitats of specific organisms, but there is a mysterious hesitancy for insect control agencies to investigate it. Specifically, the organic arsenical herbicides have been used with experimental success to control bark beetles in western conifers (*4, 5, 17*) under a wide variety of conditions. Considering that expensive saturation treatments with a persistent chlorinated hydrocarbon, lindane, is the principal method in use, and that most beetle attacks are combatted with salvage operations, the opportunities appear good for development of this technique. At least one herbicide, cacodylic acid, is registered for this use.

Defoliators have been the cause of massive outbreaks in many forest types. Some, for example, the Douglas-fir tussock moth and the spruce budworm, are specific in their habitat requirements. The usefulness of herbicides for their control depends on the nature of host specificity and the available range of effects from herbicides. These insects are dependent upon newly emerged foliage in their first and second instars of development. This may offer an opportunity to use growth regulators to delay bud emergence. Herbicides with this ability are known to exist and to have growth regulating properties at levels that do not kill the host. Foliage desiccants may also be used at rates that dry new foliage without total defoliation of conifers. Either property of a herbicide would permit it to be used to starve the target insect with no residual effects.

Herbicide specialists do not ordinarily value these properties for vegetation management, and tests that produce these subtle effects are often abandoned. Although use for modification of insect habitat is possible, no herbicides are presently registered for this use. Indeed, the idea of deliberate defoliation to avoid accidental damage by an insect has been more likely to evoke incredulity than serious consideration in forest pest management.

Figure 5. Leaving dead culls standing provides perches and habitat for hole-nesting birds, while minimizing physical impact of stand improvement. This Vermont beech injected with cacodylic acid.

Management of wildlife friends and foes.—The dependence of wildlife on habitat offers opportunities for population management by habitat control. Wildlife populations are characteristically very resilient. It is generally reasonable to state that in the presence of a parent population, a particular habitat will support a certain population structure. Direct pressure on this population (hunting, poisoning) will tend to cause decrease in numbers followed by an increase in reproduction; removal of the pressure will quickly result in the return to equilibrium with habitat. If this generalization is correct, it would appear that direct control measures would produce temporary benefits at best. Habitat for some species can be improved by selective use of herbicides (*9*) (*Figure 5*) or impoverished by the same chemicals used in a different way (*8*). Suppression of desirable habitat species caused a marked reduction in the use of reforestation areas by deer and certain small mammals during the period of herbicide effect on vegetation (*2, 3*). The same practices did not affect other mammals measurably. Habitat requirements were apparently quite specific and manageable.

Mice, gophers, rabbits, mountain beaver, and deer all have contributed in various ways to the difficulty of establishing plantations. Each species thrives under a

certain range of environmental conditions; these conditions are dominated by vegetation. The selection of herbicides with no known toxic effects as used in relation to wildlife offers a substantial opportunity for management of food and cover. Habitat can be controlled without affecting the ability of the wildlife species to repopulate an area once regeneration is out of reach. There is at least one example of vegetation management in use today in which herbicides are being recommended in plantations of the Pacific Northwest for the specific purpose of controlling gophers *(24)*.

Integrated management to minimize pest problems.—Vegetation management can be directed toward solving several problems simultaneously. Some problems which are not directly soluble by vegetation management alone may be approached through the broader range of options that vegetation management presents. To illustrate, many brushfields in the moist region of the Pacific Northwest sustain extremely high densities of deer population. When mechanical removal of the brush eliminates cover, openings are created in which forage species are abundant and trees accessible. The movement of deer from peripheral areas into these openings may actually concentrate the animals in plantations. The situation is so severe in some cases as to prevent the successful establishment of Douglas-fir without elaborate methods of protecting individual seedlings; the failure to remove the brush may preclude the option of growing Douglas-fir, regardless of the state of the animal herd.

Some studies with western hemlock suggest that hemlock is not only less palatable to wildlife than Douglas-fir, but will also tolerate the residual brush left after the application of selective herbicides *(15)*. Planting the more tolerant hemlock compensates for deficiencies in light engendered by lack of physical removal of brush, and the low intensity of deer pressure in the treated brush permits the hemlock to develop without caging *(Figure 6)*. Considering that hemlock growth rates can be comparable to those of Douglas-fir and that costs of planting and partial chemical control tend to be substantially lower than costs of scarification or total chemical control, this approach has some merit.

Herbicides can be used to apply highly specific pressure to ecosystems. They can also effect considerable damage when the pressure point is missed or the herbicide is precribed incorrectly for the right diagnosis. Although this is true for any tool, herbicides are politically visible today and errors can be more than biologically disastrous. If used according to label directions, these problems are unlikely. There certainly is a need for more developmental studies that will support registration for the more sophisticated uses.

The Outlook for Herbicide Practices

This outline has presented some examples of herbicide use where the alternatives are expensive, unsuccessful, injurious to soil, or biologically undesirable. Yet herbicides are under attack constantly—in mass media, by regulatory agencies, and in the courts; it is not unreasonable that they do not receive more general usage. Furthermore, development of herbicide uses in forestry has lagged for several important reasons.

Unquestionably, one of the principal reasons is that undergraduate programs in forest management simply do not prepare new graduates to handle herbicide technology. Moreover, young professionals are sel-

Figure 6. Use of low-palatability species for planting in good animal habitat minimizes the need for site preparation methods that remove all cover.

dom taught quantitative ecology in the functionally mechanistic sense required for sound herbicide prescription. This is a correctable shortcoming. (I have developed an outline of formal instruction, available on request.)

Another restriction in development has been the legal responsibility on agricultural chemical companies. The herbicides used in forestry are not generally manufactured by a single company with proprietary rights. Regulations at both federal and state levels hold manufacturers responsible for obtaining data on efficacy, residues, toxicity, selectivity, and hazards of use. The expense of obtaining such data for each registration precludes development for a small market, especially when shared with other manufacturers. There is no ready remedy for the unwillingness of the chemical industry to invest in forestry development. Companies are not willing to give up patent options for the sake of having government agencies pay the developmental costs, and "lowest-bid" purchase of chemicals by the forest industries and government agencies does not stimulate investment. As long as the herbicides used in agriculture make up a large percentage of forestry usage, this picture is unlikely to change. Yet with a 300 million-acre marketplace there is obviously a very large opportunity in the woods somewhere.

The other principal limit on development has been the political climate relating to pesticides, in general, and the unfortunate analogies that have been made in reference to military use of herbicides. Foresters have been hesitant to promote practices receiving unfavorable mention in the press, and chemical manufacturers are understandably hesitant to invest in development that could be jeopardized by political pressure on regulatory agencies, whether such a danger is real or imaginary.

There is a hopeful emergence of the *rule of reason (26)* in decisions regarding herbicide use in which rational interpretation of solid evidence provides the basis for decisions. It is becoming increasingly apparent that the hazards of non-use must include the effects of production techniques that are more violent, and often more destructive to ecosystems. Critical shortages of raw materials in various resource areas are stimulating an awareness that forest products must be grown deliberately. The option of nonmanagement is no longer with us. As the details of toxicity and environmental damage come under increasingly close scrutiny, the transient impact of herbicides is becoming increasingly well documented in relation to physically disturbing alternatives. Moreover, there is an increasing body of information on which dubious foresters and regulatory agencies can now depend in their quest for supportive data. Finally, the court challenges and controversies appearing in the news media about uses of herbicides have made such words as 2,4-D and 2,4,5-T almost household terms. Even though much of the printed matter regarding these herbicides is of questionable accuracy, it serves to acquaint practitioners with some of the issues that must be resolved before the use of such chemicals can be recommended without reservation.

In conclusion, an immense amount of work is needed to put the nation's timberlands in good condition. Many practices are involved. Given an option of several practices, it is clearly unprofessional to choose methods which are more destructive than lower cost practices which may achieve the same management results. None is a panacea; all must destroy something in order to achieve the management objectives. But professional responsibilities require that foresters proceed. In so doing, they can select least-disturbance techniques and defend their decisions on a factual and objective basis. ■

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