EVALUATING SHORT-AND LONG-TERM EFFECTS OF HERBICIDES ON NON-TARGET FOREST AND RANGE BIOTA

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Herbicides are one of the most ecologically powerful, environmentally gentle tools available to the manager of forests and rangelands in the United States. These chemical tools are used to accomplish a wide variety of management objectives through alteration of density and composition of vegetative communities. Their power suggests that they can be used as substitutes for more destructive practices. This same power, however, dictates the need for thoroughness in the search for harmful effects, both through research and observation of practice.

An adequate biological evaluation of the environmental impact of herbicides in forests and rangelands requires consideration of both short-and long-term effects which are mediated, either directly through toxic impact or indirectly through microsite or habitat modification. The environmental statements required by NEPA are the vehicle with which such evaluations are made on federally managed properties. Environmental statements for vegetation management programs using chemicals have markedly improved as professionals have gained experience with the environmental statement process. However, we find overwhelming attention has been given to consideration of direct toxic impact on non-target animals with little evaluation of the only profound ecological impact of herbicide use: i.e., the alteration of the composition, density, and developmental trajectory of the vegetation. It is apparent that primary producers, and the modification thereof, have a determining role in the lines of all other biota. This paper presents an approach based on that principle for use in the preparation of environmental statements and management plans.

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LAND MANAGEMENT SYSTEMS AND THE ROLE OF HERBICIDES

Forest and rangeland management objectives nearly always revolve around vegetation. Management of vegetation is basic to timber or grass production and wildlife, recreation, or water considerations. Each growing site has some potential for the production of vegetation biomass. Modern land management objectives frequently involve capturing (or recapturing) as much of the site potential as possible in a desirable form of vegetation. The knowledge that ecosystems will respond in certain ways to treatment is basic to the use of these tools to effect certain changes. The ecological basis for vegetation management can be examined by considering the relative biomass trajectories for four major types of vegetation on the grassland ranges and forest tree communities in the United States during the last several hundred years (Figure 1).

Many ranges now dominated by shrubs were largely occupied by grass at the time of European man's entry on the landscape. The tree, shrub, and forb components of the communities were present but less prominent. Ancient man undoubtedly influenced the biomass distribution among these four components to some degree, but his activities were neither intensive nor extensive. Modern man, on the other hand, has gone through a period of resource exploitation in which selective foraging has resulted in a strong shift away from grass and forbs towards unpalatable trees and shrubs.

The recent application of management techniques using selective herbicides has caused a marked shift in allocation of site resources back to grass. Herbicide-sensitive trees and shrubs (the dominant parts of the target systems) are substantially reduced in biomass and the resulting void is soon filled by seeded grasses and forbs and later by native grasses or species adapted to the grazing regime. This practice is almost a reverse of the grazing effect. In the face of selective removal pressure, the resistant species, whether removed by herbicides or animals, become more abundant. Because of their inferior competitive position, under pressure, the sensitive species subsequently have difficulty returning to sites occupied by resistant species without additional disturbance. Therefore, chronic harvesting pressure must be complemented by a weeding program of comparable intensity for maintenance of the harvested species.

Range managers use both weeding and control of harvesting (i.e., vegetation management) to stabilize primary production in preferred species. Such a procedure influences the carrying capacity of the ecosystem for non-target species and cattle. The same set of principles appears to hold in forests as well as rangelands.

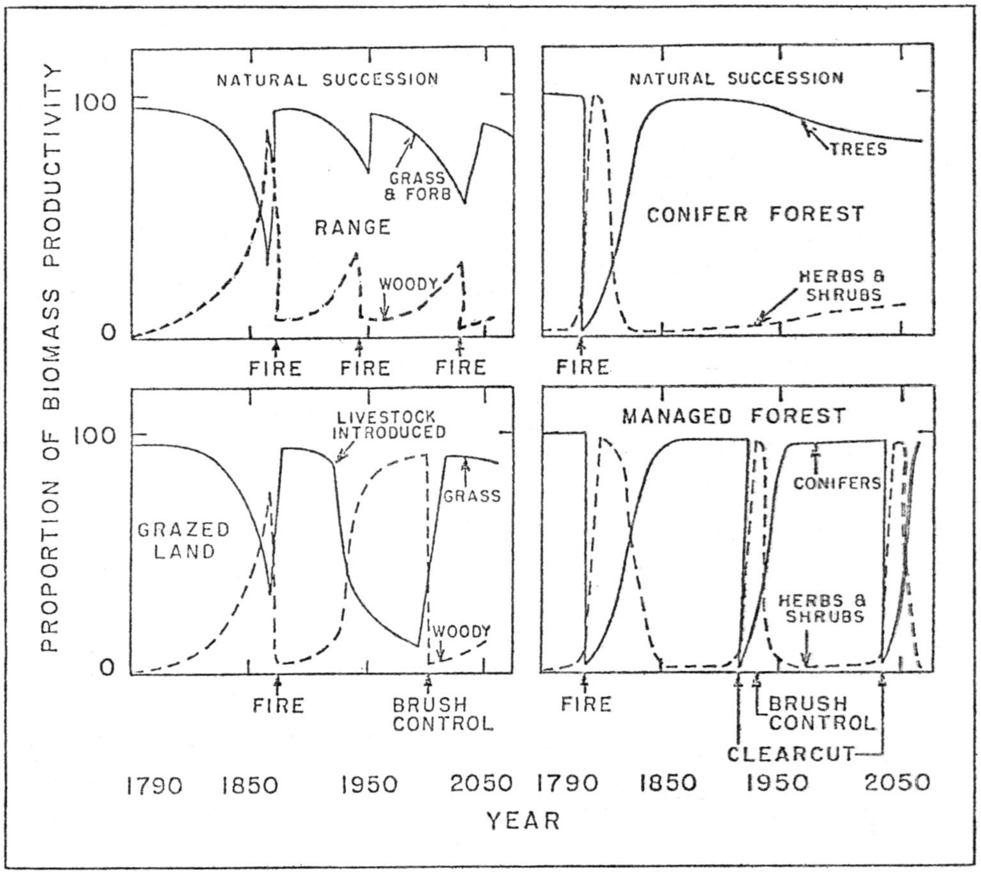

Figure 1. Generalized biomass trajectories for two major types of vegetation in their natural state of periodic disturbance (fire) and under moderate intensity management.

MANAGEMENT TECHNIQUES INVOLVING HERBICIDES

Herbicides are used for a variety of specified purposes in both forest and range management. Range applications nearly always involve reduction in the density of shrubs and trees to favor forbs and grasses. This may be type conversion where forbs and grasses are essentially no longer a major part of the present community. In this case seeding or planting operations are also conducted to provide growing stock of desirable species to occupy the site vacated by trees and shrubs. "Release" treatments are used when grasses and forbs are part of the stand but their growth is restricted by deficiencies of light, water, nutrients, and growing space caused by tree and shrub species. In this case, the application of selective chemicals may be augmented by seeding or some other cultural practice to ensure occupation of voids by desirable species.

Type conversion and grass release are by far the most extensive patterns of range herbicide use. Contiguous rangeland applications may vary in size from only a few hectares to several square kilometers.

Applications may be made by ground equipment but more frequently by fixed wing aircraft or helicopters. The size of the sprayed unit is important to non-target biota, and the degree of importance is related to species mobility.

Herbicides are used in forestry for purposes which are analogous to those in range management. Reforestation or type conversion, for example, involves a reduction in shrub, grass, or weed tree biomass to permit establishment of desired forest tree species. Fire frequently is used as an adjunct tool. Seeding or planting insures occupation of the site by desirable species. "Release" spraying is used when various weeds (trees, shrubs, forbs, or grasses) prevent established desirable tree species from achieving site dominance because of excessive competition for site resources. In this kind of application, selective herbicide action (achieved through the use of a particular chemical, rate, or season of application) is used to depress the competitors and accelerate the growth of a desirable species.

Reforestation, type conversion, and release treatments account for the vast majority of herbicide applications in forestry. However, the thinning of overstocked stands and cull tree removal with chemicals are increasing in importance as the intensity of forest management increases.

Herbicide application for type conversion, reforestation, and tree release are most frequently accomplished with aircraft, although ground application equipment is used in some locations when vegetation and terrain permit. Contiguous treatment areas are on the average smaller than in rangelands, but there may be a large number of the treated units varying in size from 1 to more than 100 hectares. Larger blocks of land are seldom treated; and the mosaic of treated and untreated sites offers considerable diversity and escape opportunity for wildlife, including species of limited mobility.

Herbicides are used on forest and rangelands for several purposes unrelated to specific land management objectives. These include the control of vegetation on powerline, railroad, and other rights-of-way and phreatophyte control in riparian zones. These are intensive applications but are more limited in scope.

The use of herbicides for modification of wildlife habitat is also a viable management technique for both habitat improvement and for control of damage to forest regeneration. Herbicides are not widely used for these specific purposes at present, but these uses are likely to increase. A great deal of big game habitat improvement results as an incidental benefit from other vegetation management practices involving herbicides.

RELATIONSHIP BETWEEN CHEMICAL BEHAVIOR AND DIRECT EFFECTS ON NON-TARGET SPECIES

Short-and long-term effects of chemicals are dependent on exposure of organisms to a biologically significant dose of herbicide. The initial distribution, movement, persistence, and fate of a herbicide in a particular environment are of paramount importance in determining the probability of organism exposure. Chemical behavior is the result of an interaction between the properties of the chemical and the properties of the environment. This interaction is guided by physical laws to produce the particular pattern of herbicide behavior observed in nature (Figure 2).

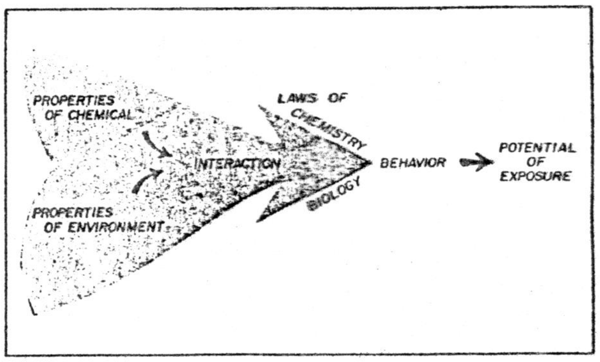

Figure 2. Chemical behavior in the environment determines organism exposure.

Herbicides are, for the most part, short-lived in the environment. Therefore, their direct toxic impacts are largely restricted to the occurrence of an acute lethal dose. Their indirect effects, however, can be long-lasting because they can alter short-term composition and long-term trajectory of the succession of the plant community. Chemical behavior in the environment, while clearly important in determining direct toxic impacts, should also be interpreted in terms of its specificity for certain plants when we analyze effects on vegetation and associated animal community structure.

ANALYSIS OF SHORT-TERM CHEMICAL EFFECTS - DIRECT TOXICITY

The time span in our definition of "short-term" is arbitrary. We have selected the year of application or the duration of biologically significant herbicide residues, whichever is longer. With the possible exception of picloram, short-term effects will be restricted to the year of application; most will be a matter of days or weeks. None of the herbicides used in rangelands or forests have been shown to accumulate substantially in animal tissues. The short-term of persistence eliminates chronic intoxication as a possible effect.

A direct toxic effect of an herbicide requires organism exposure to a significant dose. Toxicity to a given organism is an inherent chemical property. Organism response to exposure is produced by a combination of magnitude and duration of exposure with absolute toxicity.

The nature of the dose-response relationship varies with both the chemical and the organism. The pattern of dosage and potential responses of forest pesticides has been summarized by Newton and Norgren (1977). Variation within species (Figure 3) is indicative of the range of dosages producing some effect on a species. Exposure has no effect on the population up to a threshold level, then effects become progressively greater until nearly all organisms have responded. The data for <u>acute</u> toxicity usually shows a deviation from the normal distribution. There is typically a "no-effect" level and a "100-percent" response level (these extremes would be absent if the effects followed the normal distribution). It is <u>only</u> between these extremes that a herbicide has an effect on a given population. When comparing among populations, however, an array of population effects may be used to examine the differences in sensitivity among different classes of organisms.

The dose-response relationships for a herbicide to several organism groups, are compared in field and laboratory exposures in Figure 4. These examples show that broadleaf higher plants are consistently the most sensitive organisms to the herbicide 2,4-D, and that low sensitivity and low exposure both contribute to the safety of animals. This is the basis for its use for selective control of vegetation, and is the basis for using water quality criteria for protection of aquatic organisms. Most pesticides are registered for use to control only the organisms which are highly sensitive. Thus, a selective chemical effect is achieved through the

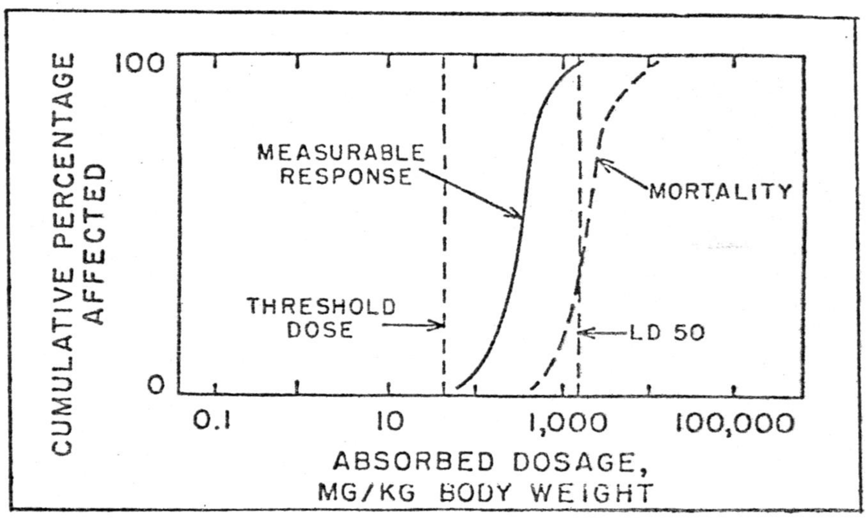

Figure 3. Typical dosage - response curve for an animal population fed a toxic substance. Note that dosage is based on units of toxicant per unit of body weight. Threshold (no effect level) is the dosage below which organisms detoxify chemical as fast as it is absorbed. These curves are transformed normal distributions. In laboratory tests, slopes of curves vary among species (Muirhead-Thomson 1971).

economic as well as biological screening process.

The probability for toxic impacts on non-target organisms is significant where dose-response curves for target and non-target organisms overlap to a significant degree. The herbicides used in forest and range management are not known to produce direct acute or chronic effects on organisms other than higher plants when used at registered rates of application.

EFFECTS OF HERBICIDES ON ANIMALS

Figure 4 illustrates a large margin between the dosage of herbicide required for maximum effect on higher plants and the level required for threshold response in animals of all kinds. Norris (1971) and House et al. (1967) have summarized a substantial amount of data on herbicide residues and persistence in vegetation, soil, and water, and (Newton and Norgren 1977) have summarized the impacts of such residues on a variety of species in the forestry context. In general these authors indicate that for a 2-kg/ha application, initial herbicide residue levels would (1) generally be less than 100 ppm in vegetation, (2) be less than 3 ppm in the surface 2.5 cm of soil and (3) be less than 0.05 ppm in streams, unless extensive direct application is made to surface water. These initial residue levels will vary somewhat with conditions of application and vegetation composition and density. Their quantities produce effects on sensitive plant species but not animals exposed to the same applications.

Animal exposure occurs dermally during and immediately after application. Dermal toxicity of herbicides is typically low enough to be of academic importance, as attested by research data and years of actuarial data for spraymen daily exposed to the concentrates. Oral ingestion, however, may be significant. Given the maximum level of 100 ppm of herbicide in treated herbage, in 1 day, an animal consuming 5 percent of its weight per day ingests a maximum of 5 mg/kg/day for each kg/ha applied, assuming all of its feed has a maximum concentration of herbicide. Animals appear to take in less than the maximum, however. Newton and Norris (1968) reported intake of atrazine[2/] and 2,4,5-T by deer amounting to about 1 percent of the theoretical maximum, or less. Furthermore, deterioration of both the herbicide and the treated vegetation limits exposure to a relatively short period, and herbicides usually pass through the digestive system with little or no retention

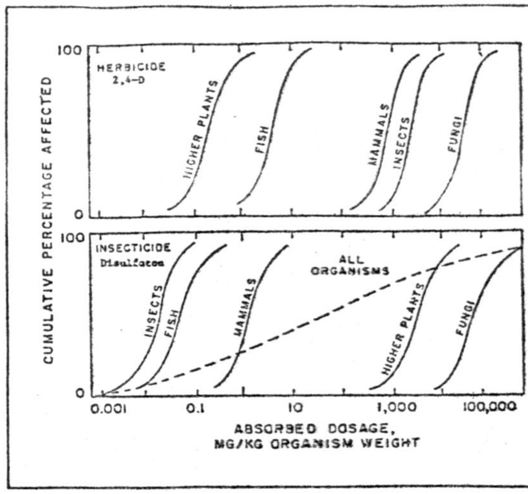

Figure 4. Typical dosage-response spectra for an insecticide and a herbicide for five classes of organisms. Mid-points for each group are estimates; those affected only in the range of 500 mg/kg or greater are not as precisely defined as those in the more sensitive groups.

or accumulation. More recently, Newton and Snyder (1978) have produced detailed evidence of negligible residues of the TCDD contaminant of 2,4,5-T in forest wildlife.

Herbicide movement and persistence are difficult to generalize in reference to precise levels of exposure to consumer and aquatic organisms. Norris (1971) and House et al. (1967) again offer reasonable summaries for persistence characteristics in vegetation and water. In vegetation, herbicide half-lives vary from 1 to 30 days. The half-life in stream water varies from less than 0.5 to 24 hours, when herbicide input is restricted to the time of application. Rapid herbicide

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[2/]This publication reports research involving pesticides. It does not contain recommendations for their use nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended.

dilution with downstream movement tends to protect aquatic organisms, and the recurrence of contamination by movement of soil water is unlikely (Norris and Moore 1971). Kearney et al. (1969) and Harris (1968) report in detail on the mobility and persistence of herbicides in soil, Figure 5.

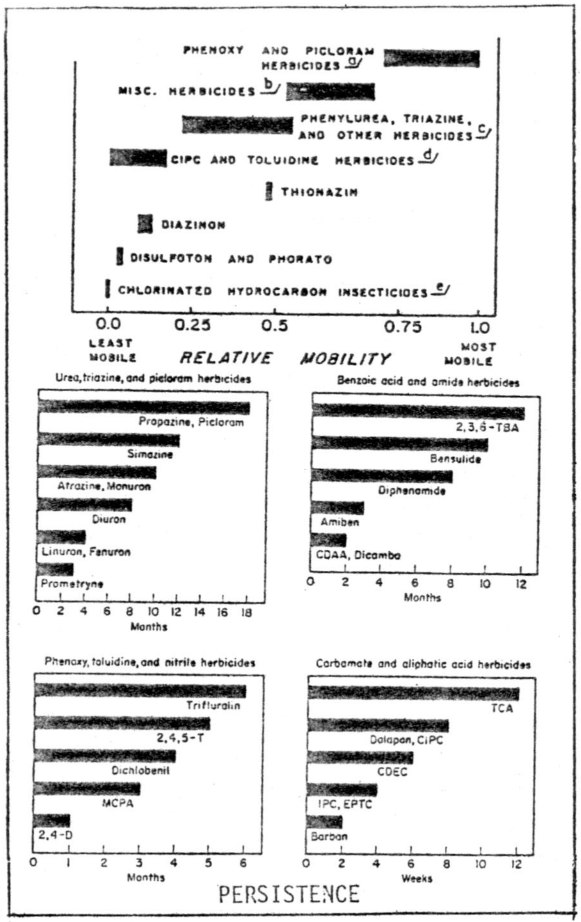

Figure 5. Generalized mobility and persistence characteristics of herbicides in soil (Harris 1968 and Kearney et al. 1969).

The data on residue and persistence characteristics of a herbicide in a specific environment can be used to determine both the magnitude and duration of non-target organism exposure. Exposure data can then be evaluated in terms of established dose-response relationships for the chemical and the specific organism or a closely related species for which test data are available. If the magnitude and duration of exposure are less than the threshold response level, direct toxic effects are precluded. This kind of an analysis consistently shows that those herbicides and patterns of use registered by the Environmental Protection Agency for use on forest and rangelands will not normally result in direct toxic effects on non-target animals. Strong evidence indicates that there is a large margin of safety in this regard even in the event of accident or other mishap.

EFFECTS OF HERBICIDES ON PLANTS

Herbicides are the pesticides to which plants are most sensitive. It is the intent of forest weed control to initiate a change of vegetation type, and the herbicide practices in use today are generally very effective.

For practical purposes, the herbicides in use in forest management may be grouped according to the spectrum of species they control. Table 1 lists the herbicides presently registered for forestry use and gives the principal group of plants affected, the important resistant species (commercial and non-commercial), and the persistence of biologically active residues in the forest environment.

The array of effects of herbicides listed in Table 1 suggests that most forest sites carry considerable vegetation that will survive virtually any herbicide applied at registered rates, even though plants are "sensitive." The target species are usually not killed completely by such applications, but are injured so as to decrease their competitive ability. The principal immediate effect of applying a herbicide may be expressed in terms of the model illustrated in Figure 6, which diagrams a forest ecosystem in terms of its principal structural components. Referring back to Table 1, it is possible to visualize at what point a forest ecosystem is affected directly by the herbicide and for how long the direct effect influences ecosystem function.

There are specific effects worthy of mention within each part of an ecosystem. These differ with the specific nature of the herbicide, the problem for which it is used, and the distribution of the herbicide in the forest. Triazines, glyphosate, dalapon, and occasionally pronamide or amitrole are used for herb control in reforestation areas where moisture is limiting to survival of conifers. The rates of use generally preclude the survival of large amounts of grass. These herbicides are broadcast in ecosystems in which seedling trees are to be planted. During a brief interval following application, there is a substantial reduction in primary production, a decrease in demand on water and nutrients, and a considerable decrease in

Table 1. Herbicides Registered for Use in Forest Management, Duration of Direct Effect, Sensitive Groups of Species and Resistant Groups of Species.

	Months of Activity in Plants	Soil Half-life Months	Target and Sensitive Spp.	Resistant Species Commercial	Resistant Species Non-Commercial
Amitrole	1/2 - 6	1/2 - 1	Shrubs, herbs	Coastal conifer	Hardwoods, shrubs
Asulam	12	1/2 - 1	Bracken only	All conifers, hardwoods	All woody
Atrazine	3	1 - 4	Annuals, Deciduous	Most woody	Woody, ferns
Ammonium ethyl carbamoyl phosphonate	24	<1	Shrubs, hardwoods	Conifers	Herbs, evergreen woody
Arsenicals,1/ organic	3	1 - 6	Conifers, hardwoods	Few	Few woody, many herbs
Dalapon	1	1/4 - 1	Grasses	Trees	Trees, shrubs, forbs
Dicamba	3 - 12	2 - 12	Shrubs, hardwoods	Few	Some shrubs, ferns
Dinoseb	1/4	<1/2	All green vegetation	None	None
Glyphosate	24	<1/2	Most herbs, deciduous woody plants	Conifers	Evergreen woody, dormant herbs
Picloram	3 - 24	2 - 12	Trees, shrubs	None	Few woody ever-green shrubs, grasses, ferns
Pronamide	2 - 4	3 - 6	Grasses	All woody	All woody, forbs
Silvex 2/	3 - 6	1 - 2	Shrubs, trees	Conifers	Some trees, shrubs, grasses, ferns
Simazine	3 - 6	4 - 8	Grasses, forbs	Trees	Trees shrubs, ferns some herbs
2,4-D	1/2 - 1	1/4 - 1/2	Some shrubs, forbs	Conifers	Hardwoods, shrubs grasses, ferns
2,4,5-T 2/	3 - 6	3/4 - 1 1/2	Shrubs, hardwoods	Conifers	Some hardwoods, ferns, grass

1/Applied by injection only; effect limited to treated stem.

2/Registered uses of Silvex and 2,4,5-T on forest land were suspended by EPA on March 1, 1979.

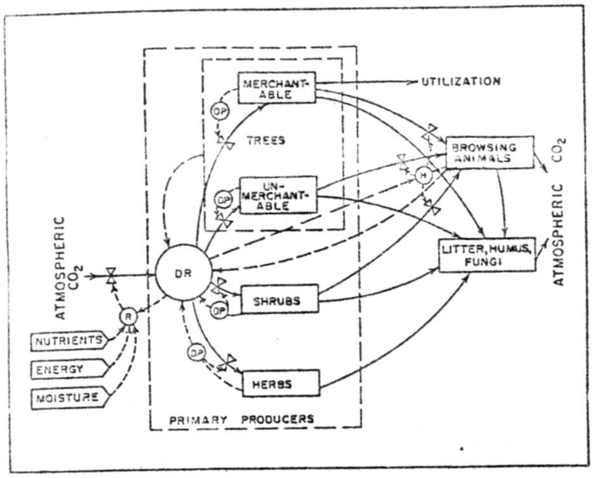

Figure 6. Simplified forest ecosystem model illustrating the allocation of site resources to various vegetation groups, and thence to various consumers. Rectangular symbols represent organisms capable of storing carbon; pentagonal symbols are site factors, or resources; "bowties" are internal controls; dashed lines are feed-back. DR, dominance ratio; DP dominance potential; H, habitat; R resources (from Newton, 1973b).

carrying capacity for herbivores totally dependent on grasses, especially those of limited geographic feeding range. Warm summer rains can move nutrients toward a leaching sink if devegetation is continued year after year, but areas with dry summers and those with the usual incomplete vegetation control do not sustain measurable losses (Miller 1974). These treatments are usually applied no more than once or twice at the time of reforestation, and their impacts are brief, leading to establishment of a forest cover.

The brushkillers (i.e., the phenoxys, picloram, amitrole, dicamba, glyphosate and ammonium ethyl carbamoyl phosphonate), are usually used either in forest site preparation or in range or forest release operations involving application of broadcast sprays to complex mixed seral communities. These sprays damage target woody vegetation considerably but generally leave most of the herbs and some resistant trees and shrubs. While the herbicide is still active in sensitive woody cover, primary production decreases briefly and herbaceous cover increases rapidly. Growth of resistant woody and herbaceous vegetation increases shortly after application. Structure of the treated ecosystem changes substantially in terms of the dominance ratio of component species (Newton 1973a). Increased growth of herbs and sprouts often increases carrying capacity for herbivores. Resistant trees and shrubs increase in dominance, eventually resuppressing the ground cover.

Herbicides are used in combination with fire to an increasing degree. They permit controlled burning when surrounding areas are unlikely to be flammable. In this procedure, the herbicides may be used for sprout control, fuel desiccation, or both. The herbicides have a substantial effect on vegetation, but the resulting fire has an overriding effect on every species present. The immediate effect of the fire is to empty every "box" in the forest ecosystem. The interval before "green-up" has been described as very brief (Roberts 1975), but the total temporary effect on ecosystem composition and structure is very great. It is worth pointing out that this treatment is usually very costly and is reserved for forest rehabilitation operations on very productive land supporting highly stable subclimax communities from which past management has excluded conifers. In such circumstances, the practice totally removes the woody component from dominance, followed within weeks by development of a dense herb cover in which sprouts begin to develop. This change is not a consequence of toxic action but of the physical event of fire.

INTERACTION BETWEEN PLANTS AND ANIMALS

We have thus far considered the direct action of herbicides on animals and plants and have found herbicides to be directly effective largely on plants. Figure 6 illustrates, however, that herbivores are directly dependent on the plant community for food and cover and the other animals are dependent on herbivores and cover.

Changes in primary producers clearly have a major influence on the animal community, independent of the direct effects of the herbicide. Numerous effects have been documented. Phenoxy herbicides were studied two decades ago for their potential use in improving big game habitat. The action of the herbicides in reducing the level of dominant canopy, and also of stimulating sprouting, was beneficial for the winter range condition of deer (Krefting et al. 1960; Mueggler 1966). Keith et al. (1959) observed that the composition of the herb community in a part of the Rockies had an important effect on the populations dynamics of the pocket gopher. More recently Borrecco (1973) and Borrecco et al. (1972) demonstrated that several species of large and small mammals were responsive to management of herbaceous cover with herbicides. Their findings support the generalization that herbicides do not have an immediate effect on animals, but as vegetation responds, the animal community appears to follow a successional pattern in accord with the changes in habitat (Newton 1973a). Vegetation management is now regarded as a potential tool for regulating animal damage to forest plantations in the Pacific Northwest.

ANALYSIS OF LONG-TERM EFFECTS

There are clear patterns of short-term effects of herbicides on forest and range communities. In rangelands, the usual pattern after treatment is an increase in herb cover. In forest lands with substantial shrub and crop-tree component there is an increase in herbs after brush control and an increase in woody cover after herb control. These short-term effects are the initial phases in long-term pathway of ecosystem development. This may be termed succession in the classical sense, except that the initial inhabitants are there by design. Furthermore, the dominance ratio (Newton 1973b) is managed by repeat applications if the plant communities show signs of wavering off a planned path.

Ecosystem development under forest management can be very similar to natural forest succession. It is very different from succession in forests from which the dominant high-valued species are chronically subjected to utilization pressure. Figure 6 indicates that the removal of any component of a forest ecosystem will merely focus productivity among the remaining vegetation. Plants or trees in a dominant position after some harvesting tend to remain dominant. The cause-effect patterns is precisely the same when comparing the effects of removing high-quality timber by harvest or by suppressing the low-quality material with herbicides and the development of undamaged parts of the system is accelerated. This is one of the fundamental silvicultural or agronomic concepts, and is the basis for all weeding.

The course of forest ecosystem development after application of the herbicide is controlled by three principal factors other than soil and climate. The first, and most important factor, is the population of rapidly growing tree species after herbicide residues become inactive. Trees with high dominance potential will dominate the site continuously if they are present and dominate immediately after treatment (Newton 1973b). If no such species are present, the introduction of trees by planting has a major influence on the long-term direction of ecosystem development after herbicide application Figure 7. Because the usual purpose of treatment is to promote the

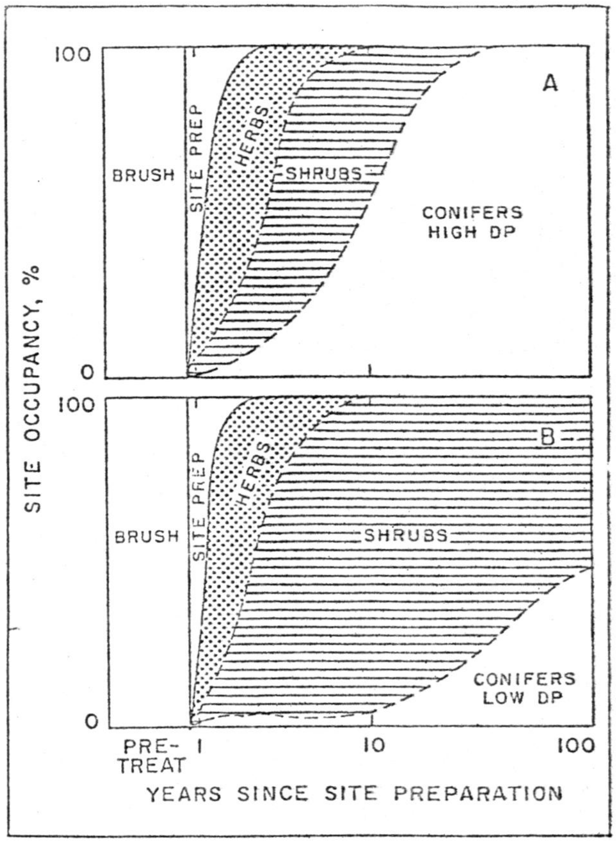

Figure 7. Development of plant groups after a disturbance to a forest. Components are analogous to compartments in Figure 6. Note that when conifers of high dominance potential are planted, as in A, succession is dominated by conifers and ground vegetation becomes sparse. In B, however, the diagram reflects low conifer stocking or vigor, and the low-stature woody vegetation remains dominant for much longer. The conifers are causal, but non-target species will be affected.

growth of trees, the shift to tree dominance is the most common long-term effect of herbicide use on the general structure of forest ecosystems. Development of the dominant tree layer has a very great impact on all non-target biota, because if affects

Table 2. Comparative Magnitude and Duration of Environmental Impacts of Forest Practices[1]

Practice	Timber Values	Water Quality	Water Yield	Big Game	Small Mammals
Tree planting[2]	Great(+) (if successful) Long	Small(+) Long	Small(-) Long	Great(-) Long	Variable Long
Vegetation Control:					
Chemical:[3] Herbs	Great(+) Long	Small(-) Short	Small(+) Short	Moderate Short(-) Long(+)	Moderate(-) Short and Long
Brush	Great(+) Long	Small(-) Short	Moderate(+) Short	Moderate to great(+) Short	Variable Long
Weed trees	Great(+) Long	Small(-) Short	Moderate(+) Short	Moderate to great(+) Short-long	Small(+) Short
Mechanical: Herbs	Moderate(+) Long	Moderate to great(-) Short	Moderate(+) Short	Great(+) Short	Variable to great(-) Short
Brush	Great(+) Long	Moderate to great(-) Short	Moderate(+) Short	Variable (+ and -) Short	Great(+-) Short
Weed trees	Great(+) Long	Great(-) Short	Small Short	Moderate(+) Short	Small(+ and -) Short

1/ Plus or minus relates to a presumed value change relating to a specific resource.

2/ Impact of planting depends on success, which in turn may be determined by the effectiveness of cultural measures.

3/ Selectivity range of the particular herbicide will determine whether residual vegetation is more or less favorable habitat.

all subordinate vegetation. When the dominant tree species are natives, this effect approaches the natural balance of some sort of subclimax vegetation. In rangelands, the promotion of herb cover at the expense of trees is likely to result in the slow re-invasion of trees because of their higher dominance potential. Pressure from livestock on the grass will accelerate the upswing in woody vegetation in the absence of fire. In all situations, the long-term impact of the management practice is largely determined by the subsequent character of the new woody plant dominants in the community.

Most forests are managed in a mosaic of small management units. Herbicides used in an even-age management system are used infrequently, and in a pattern of adjacent vegetation that offers diversity and escape opportunity for wildlife subjected to temporary shortages of cover or forage. These patterns have been described as favorable for many species of wildlife, even with more frequent applications than those used in forestry (Bramble and Byrnes 1972). The scale of range treatments reduces escape opportunity under some circumstances, and local changes in plant community structure can have effects on herbivores whose preferred forage has been removed.

Any evaluation of the effects of herbicides on non-target species and non-timber values must take into account the comparative effects of alternative practices for achieving the same goals. Table 2 lists an array of relative impacts of herbicides and bulldozers on various non-target species, including aquatic species and their habitats. Fire is intermediate in effects on most groups between chemical and mechanical methods. Insufficient data has been recorded for manual methods to evaluate their silvicultural or range benefits or impacts.

CONCLUSIONS

We have outlined our interpretations of effects of several kinds of disturbances in the management of range and forest lands. Herbicides constitute one special type of disturbance, unique in substituting certain biochemical properties for physical impact. In an evaluation of their effects on non-target forest and range biota, the following conclusions are germane to impact analysis in Environmental Statements:

1. Environment impact of herbicides on forests and ranges must be evaluated in the framework of management systems that have already had an effect, and whose effects will become more severe with no maintenance, to the detriment of major renewable resources.

2. The non-target species in ecosystems previously disturbed by management are already off natural baselines, including populations that are above and below natural levels.

3. Direct toxic hazards of herbicides on non-target species are a matter of public concern. They therefore need to be mentioned. However, the likelihood of direct effect of herbicides is low and such effects need to be examined in terms of the consequences and hazard of using alternative methods, including non-treatment, to achieve the same resource management goal. The infrequent use of herbicides and their short lives and non-cumulative effect are documented; they reduce the risk of surprise adverse effects.

4. Short-term effects of vegetation management are determined by physical impact and ecosystem resiliency. In decreasing order, the environmental impacts of alternative practices are: mechanical scarification, burning, and herbicides. On the basis of limited evidence and adaptation to the criteria by which other methods are judged, hand clearing probably falls between burning and chemical methods. Projected development of surviving plant species groups are useful for comparing and evaluating habitat change, regardless of method. Impacts on animals can be expressed in terms of habitat suitability and stability.

5. Long-term effects of herbicides are totally confounded by the management system in which they are used. In general, the goal of such management is maintenance in perpetuity of forest or range communities in a condition where non-target range and forest species have good opportunity to thrive, regardless of tools used.

6. Herbicides are unique in being able to reverse past management impacts

without causing physical impact on soils and watersheds, or loss of ecosystem productivity.

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