Fire in the Pacific Northwest—Perspectives and Problems

ROBERT E. MARTIN,[1] DAN D. ROBINSON,[2]
and WALTER H. SCHAEFFER[3]

INTRODUCTION

WE are pleased to be able to talk to you at the first fire ecology conference in the Pacific Northwest. From this time, we look forward to future gatherings in the Northwest to discuss fire's role in ecosystems and man's handling of our forest and range ecosystems, taking full advantage of the natural agents—fire, insects, and microorganisms—which are the regulating forces in nature.

The program for the conference proceeds from the role of fire in specific locations, to implications of fire for land managers, and finally to environmental impacts and interagency coordination regarding fire impacts. The program was designed to blend into the Northwest Fire Council program which follows immediately.

Obviously a day-and-a-half program cannot cover our knowledge of fire in the Pacific Northwest. We hope, however, it will bring into perspective the knowledge we do have, with papers from British Columbia to Northern California and covering a range of subject

---

[1] Project Leader, Cooperative Fire Science Program, U.S.F.S., and Professor of Fire Science, University of Washington, Seattle.

[2] Professor of Forest Management, Oregon State University, Corvallis.

[3] Professor, Forest Management, University of Washington, Seattle.

matter on the relationships of fire to soil, air, water, vegetation, and wildlife. Hopefully, we'll set the stage—exposing the gaps in our knowledge, inspiring new ideas for management and research—so that in 2 or 3 years we can meet again to discuss our progress.

In this paper, we'll attempt to put into perspective some ideas concerning fire, vegetative complexes, and Pacific Northwest related problems. We'll begin by looking at fire history and differences in the frequency and intensity of fires that occurred. The differences should imply the need for varied management strategies in regard to fire in our forest and range lands. We'll then look at the energy base for vegetative development, the type of material produced by a forest, and what happens to fuels over time in forest stands. By developing better knowledge of the progression of vegetation and fuels, we have better tools for making management decisions. We will then propose ideas for the role of fire in modifying ecological succession and for its role in affecting insects and pathogens. Finally, we will discuss some problems in fire management, as we see them, in the Pacific Northwest.

FIRE HISTORY OF THE PACIFIC NORTHWEST

The natural vegetation of the Pacific Northwest varies from desert with less than 10 inches (25.4 cm) of precipitation annually east of the Cascade Range to cool rain forest with over 100 inches (254 cm) of precipitation west of the Cascade and Olympic Ranges. Elevations rise from sea level to fields of perpetual snow and glaciers on the higher mountains.

With such a range of climatic and resultant vegetation conditions, we can expect fire interactions to be quite different in the dry forests and ranges east of the Cascades and the wet rain forests. Drawing on information from forest type maps (U.S. Forest Service, 1936), the dominant forest vegetation helps us to look at some fire prehistory west of the Cascades. The most striking overall observation is the predominance of the cedar-hemlock (*Thuja plicata* Donn and *Tsuga heterophylla* [Raf.] Sarg.) type on the western slopes of the Olympics in contrast to Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) of varying ages mixed with cedar and hemlock in other areas west of the Cascades. The climax cedar-hemlock forest would indicate very infrequent disturbances, such as fire or wind, allowing the very tolerant climax tree species to predominate. The Douglas-fir forest would indicate periodic severe disturbance—timber-killing fire or windthrow. A notable area of prehistory fire may lie in the legendary Cowlitz fire of around 1800, as about 2,000 square miles of Douglas-fir timber originated around that date (Clevinger, 1951). Interspersed in the area are remnants of 300- to 400-year-old Douglas-fir in which the fire spread, with the survivors furnishing seed to restock the area. Apparently the area was shown clearly in the 1902 forest type map of Washington (Plummer et al., 1902), although we have not been able to locate the map.

Fire east of the Cascade crest apparently was much more frequent and also less damaging to timber stands. Early travelers often described the forests as "open yellow pine" (*Pinus ponderosa* Dougl. ex Loud.) in which one had good view and in which one might let his horses "take their head." Weaver (1959) reported fire intervals between 11 and 47 years on ponderosa pine stumps in the Warm Springs Indian Reservation in north central Oregon. Soeriaatmadja (1966) examined over 300 stump sections on the same reservation and arrived at fire intervals which were directly correlated with elevation and ranged from 6 to 36 years. His observation seems quite logical with the increased precipitation and fewer days of very low relative humidity at higher elevations. On the Klamath Indian Reservation, Weaver (1961) recorded a fire interval of just over 10 years on ponderosa pine. Further evidence of eastside fire frequency and ecology will be presented later in this conference by George Fahnestock, Frederick Hall, and Arlen Johnson.

Farther north, toward British Columbia, C. D. Howe (1915) reported that: "One is impressed by the occurrence of a large number stands of mature fir in which the trees are nearly all of the same age. In the stands of medium sized trees, the prevailing ages were 315, 170, and 124 years. In fact, representatives of these age classes were found on every area studied, whether on the island (Vancouver) or the mainland. The uniformity of age, however, was not so pronounced among the largest and oldest trees. The largest observed was 7 feet in diameter and was 910 years old. Fire scars disclosed the fact that the tree was burned 856 and 335 years ago. The large trees near Chemainus were 540 years old. Those near Cowichan Lake and Gibson landing were 425 years old. In both places they showed fire scars 230 years ago." It is readily apparent that western British Columbia forests were not spared of infrequent and catastrophic fires.

Moving on into recorded fire history, we find the Pacific Northwest has been and still is revisited by large destructive wildfires

TABLE 1. A brief summary of the most notable large fires of Oregon and Washington.

Year	Month	Fire	Size, Thousands of Acres	Comments
1846	Oct.	Yaquina	450	
1849	Sept.	Siletz-Siuslaw	800	
1860	May	Nestucca Bay	320	Started near Oregon City
1865	May	Silverton	1000[1]	
1868	Sept.	Coos and Curry Counties	300	
1868	Oct.	Coos and Douglas Counties	125	
1868	Sept.	Washington and British Columbia	—	Unknown acreages But fires were reportedly burning in many places
1902	Sept.	Yacolt	110	
1902		Washington and Oregon	700	Many separate fires from Bellingham to Eugene
1910	All summer	Eastern Washington, northern Idaho, and western Montana	3000	
1933	Aug.	Tillamook	311	270,000 acres in 30-hour period
1936	Sept.	Bandon	144	
1951	Sept.	Forks	180	
1966		Oxbow	43	
1970	July-Aug.	Wenatchee-Okanogan	120	

[1] William G. Morris, formerly of the PNW station, has found no evidence that this fire ever achieved the size indicated. Personal communication.

(Table 1). These fires have occurred in both the "virgin" forest and in logging slash. There is a preponderance of catastrophic fires west of the Cascade crest, while evidence indicates frequent light fires east of the crest.

Since fire protection was initiated in British Columbia in 1912, there have been 3 years in which more than a million acres of fires were recorded: 1922, 2,591 fires destroying timber on 1,568,585 acres; 1929, with 2,252 fires on 1,643,000 acres, and 1961, with 3,102 fires on 1,227,159 acres (Smith, 1970).

When talking about fire frequency in given ecosystem types, we can probably put upper and lower bounds on the fire frequency we would expect to maintain that type, as Hendrickson (1972) has done. Expanding on his proposal, and using the information available in the Pacific Northwest, we have proposed the "normal" fire frequencies for forest types for the Northwest (Table 2). We must recognize a wide variety in the range types and, therefore, a broad fire frequency spectrum. Such a fire frequency table has many shortcomings. What is needed to understand better the role of fire in a given vegetative type is the development of probability data on expected fire frequency that holds a successional system at a given stage, keeping it from moving a given measure toward a later successional stage. The system developed should also allow for a gradation in type. For instance, ponderosa pine grows in a system with semidesert grasses and shrubs at lower elevations but with subalpine plant species at higher elevations. The expected frequency of disturbance by fire or other agent would vary from the lower to the higher elevations.

TABLE 2. Hypothesized fire frequency for vegetative types of the Pacific Northwest.

Type	Fire Frequency, Years
Range	3-40
Ponderosa pine	5-25
Lodgepole pine	25-200
Eastside mixed conifers	50-300
Westside Douglas-fir	50-400
Western hemlock	>150

FIRE IN RANGE AND FOREST MANAGEMENT SYSTEMS

The fitting of fire in an overall system description—whether unmanaged or managed—is of primary importance in a discussion of fire's role in such systems. So often in research or management planning, we consider only a small segment of the total system our decisions affect. We do this because we do not understand the overall system nor the interrelationships that exist. Also, the larger system may be so complex that we can not afford to evaluate all the effects. We should, however, at least appreciate that our decisions affect many other factors distributed in space, time, and characteristics.

As an example, the decision to broadcast burn or YUM (Yarding Unutilized Material) following clearcutting affects many other factors. At the present time, such decisions are based on criteria established within an agency system as well as the judgment of the local manager. Both alternatives may ease the local fire protection problems, although YUM in itself does not remove the flashy smaller fuels. Broadcast burning produces more smoke and may adversely affect water, soils, and some types of vegetation. YUM undoubtedly disturbs the soil, with possible adverse effects on water and soil. YUM does enhance utilization potential, as much material is subsequently used; however, waste disposal at the mill is increased, which may increase urban air pollution. Further, piling requires the production of fuel to run the equipment, which in turn requires production of steel and, further, iron ore. The pollution problems are thus exported.

Benefit-cost analysis is an important tool in measuring the results of our decisions, and well it should be. Much of our analysis is limited, however, to only the most immediate results and does not incorporate the benefits and costs within a larger framework. Further, our analyses are in monetary figures, even though we have difficulty in assessing the monetary value of some consequences. We have no better system at present, but we should look toward assessment in more comprehensive terms. Rappaport (1972) has suggested the use of exotic energy in assessing benefits and costs. Since his paper, we have entered a period where energy availability is critical; perhaps his suggestion will become more meaningful in the future. As our fossil fuels are consumed, much of the energy available to us will be limited to that coming directly or indirectly from the sun.

ENERGY BASE FOR FIRES

Forest and range fire is a phenomenon which rapidly converts chemically-stored energy into heat and light energy, while producing many chemical by-products. We might ask how much energy is stored and how much energy is potentially available to produce biological materials.

Let's begin with the solar constant—the amount of energy from the sun impinging on the outer layers of the earth's atmosphere. The constant is approximately 2 cal cm^{-2} min^{-1} or a total amount of 2.4×10^{15} kcal/min based on the total area of sunlight intercepted (Daniels, 1964). Obviously, only half the earth is exposed at one time, and much of the energy is not usable at the earth's surface because of losses due to reflection, absorption, and reradiation. The intensity of radiation at the earth's surface varies from zero to about 1.5 cal cm^{-2} min^{-1}, depending on time of day, latitude, season, clouds, and dust (Fig. 1). Of the radiant energy recieved at the surface, only about 1 percent is converted into stored energy by plants (Geiger, 1966)—since the plant cannot use many frequencies of sunlight and since some of the captured energy is used to carry on life functions.

Solar radiation follows a curve depending on the time of year and latitude. Daniels (1964) has shown that radiation received on a horizontal plate at Madison, Wisconsin (latitude 43°N), in June was 678 cal/cm^2 for the day, compared with 165 cal/cm^2 in December. His curves are similar to those for clear days in the Northwest. Of importance to us is the production of vegetative material at a given location. The rate of conversion of solar energy to organic matter is about 10 billion calories per acre per year (Geiger, 1966). We can consider this as the potential productivity for the food and fiber we need and also for the fuel to support fire.

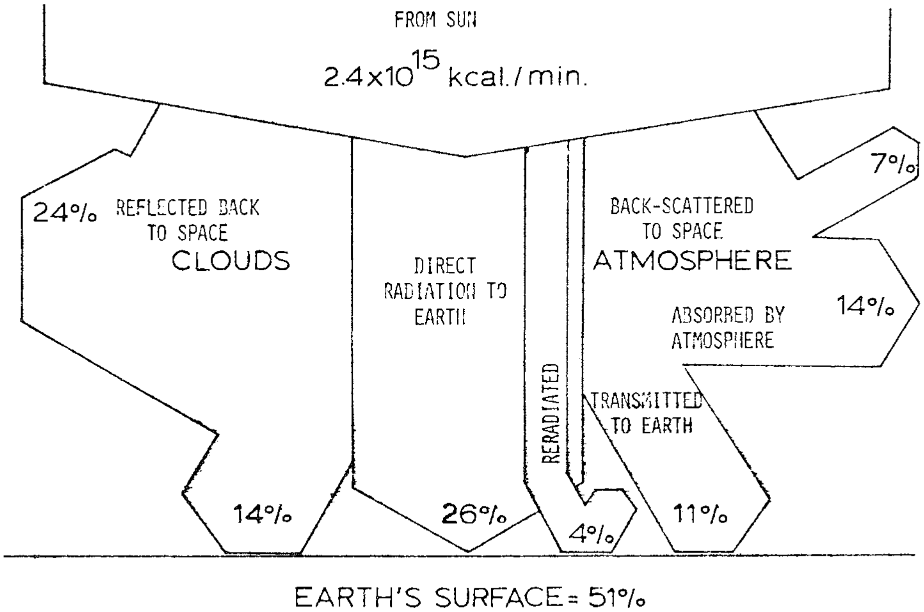

Fig. 1. Disposition of sun's radiant energy arriving at the earth's outer atmosphere. Percentages are a composite of information from various authors.

MATERIAL PRODUCED

What is produced is often just as important as how much. The adaptations of various plants and animals to different environments restrict those available for any given area and site. Within the biota available for an area, the various perturbing agents may periodically swing the plant and animal composition in one direction or another. The land manager is not only a perturbing agent himself, but may also modify greatly the effects of other agents. Obvious examples are man's cutting or clearing of forests, protection from fire, and spraying for insects. For the most part, perturbing agents return natural succession to an earlier stage (Fig. 2). Sometimes, however, the agent may advance succession, such as the thinning of overdense stands, allowing the stand to move toward its mature condition. The severity of the perturbation and susceptibility of the vegetation will influence the direction and degree to which succession is modified (Fig. 2).

Let's look more closely at production on an area of land. We deal mostly with secondary succession, that is, on an area where a biological community has previously existed but has been removed.

We must first clarify some terminology. We will talk about fuel, but one should remember that we are also talking about biomass. In discussing fuel, we can refer to its availability to burn, and thus the degree to which a fire will modify conditions on the site. Using Byram's (1959) classes, we'll separate fuel into:

Available fuel—that fuel which is available to burn under a given set of conditions.

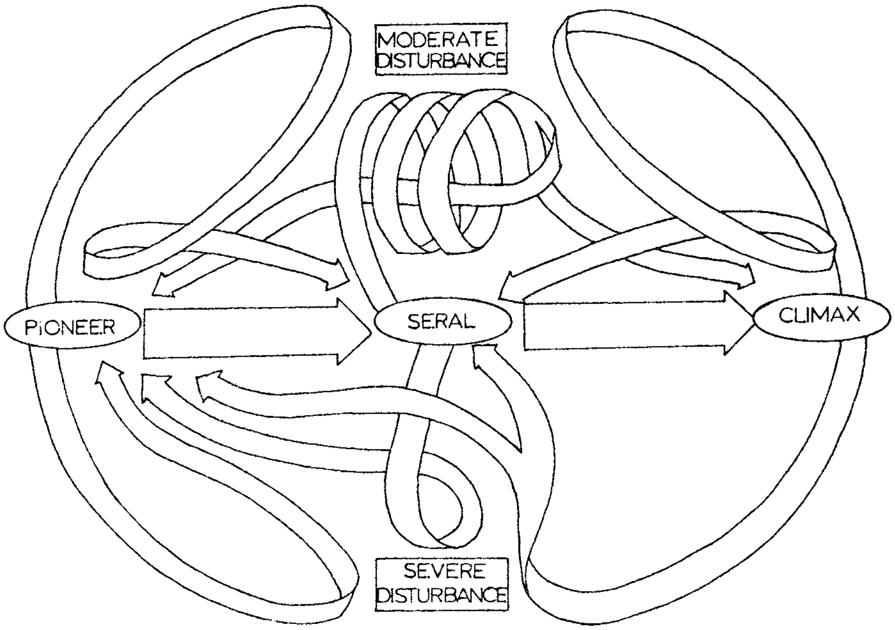

Fig. 2. Severity of disturbances or perturbations as well as the susceptibility of the vegetation will influence the direction and degree to which succession is modified. Moderate disturbances may occur many times without moving the system forward or backward in succession, whereas severe disturbances will move the system toward earlier successional stages.

Residual fuel—that fuel remaining at a location following a fire.

Total fuel—all the fuel at that location.

Total fuel must equal the sums of available and residual fuel, or:

$$F_T = F_A + F_R$$

Total fuel must equal or exceed available fuel.

We'll also separate fuels based on vertical position (Davis 1959):

Aerial fuel—all fuel greater than 6 ft (1.83 m) above the ground surface.

Surface fuel—those fuels between the decayed organic matter on the forest floor and an arbitrary level of 6 ft; includes low brush and loose surface litter.

Ground fuel—all organic matter below the loose surface litter; includes humus, roots, peat, and muck.

The vertical height of 6 ft is an arbitrary elevation, and Brown and Davis (1973) have used a height of 4 ft (1.22 m) as the demarcation between surface and aerial fuels. Either height may be satisfactory in a given situation, depending on continuity of fuel conditions both horizontally and vertically, burning conditions, and the purpose for which one is classifying the fuels.

Other factors we must consider in looking at fuels or biomass are rates of production, decomposition, and accumulation. For our discussion, we'll consider production on an area to be the net of combustible materials—that is, foliage, branches, stems, flowers, fruit. We will talk here only about the above-ground fuels. Decomposition is the process in which biological and physico-chemical agents break down organic materials. On any site, decomposition might eventually equal or exceed production, although the accumulation curve may never be level due to fluctuations in both production and decomposition rates.

Following a major perturbation, such as a fire which completely kills a timber stand, we may have a considerable amount of aerial fuel remaining, although fine surface fuels would have been reduced to nearly zero (Fig. 3). At the time of the fire, available surface fuel is reduced to zero, as by definition, all available fuel is consumed.

We recognize, however, that more fuel could become available immediately following the fire due to exposure to better drying conditions, drying by the heat of the fire, and killing of plants.

If we assume rather complete surface fuel consumption and killing of a stand but no crown fire, our residual fuels may progress as in Figures 3a, b. Available surface fuels are near zero, but total fuels would not reach zero. Surface fuel components remaining from the original stand increase over time due to contributions from the aerial components.

Available aerial fuel remaining after the fire increases from zero to a high level as foliage and small twigs become dry and available for burning. The available aerial residuals later tend to decrease rather rapidly with time, as foliage, twigs, and branches fall to the ground. After many years, snags start to fall, resulting in a further decrease in total aerial fuels remaining after the fire. The surface fuels increase rapidly after the fire due to the input of foliage and small twigs from the aerial components. Another increase in surface fuel occurs as snags rot and fall. There are no processes for increasing total surface and aerial fuels remaining from the fire, as we have postulated complete stand kill. The total does decrease, however, due to decomposition, so that the organic matter left from the time of the fire will eventually become zero. Some may persist for very long times as ground fuel in the partially decomposed state, especially in very wet or cool situations.

New vegetation begins producing biomass in the first year after the fire (Figs. 3c, d). Generally, we might expect a few years in which herbaceous plants predominate, followed by a gradual increase in woody plants and materials.

Shrubs appearing from old rootstocks as well as seed will probably be a major component for several years, but eventually, if seed or root sources are available, tree species may again become the dominant plant, with much of the biomass concentrated in tree boles. When fire occurs in a stand of trees with serotinous cones, tree seedlings may represent much of the biomass in the first year following fire.

Graphically, new surface fuels would appear in the first year following fire, whereas new aerial fuels would probably not appear for a few years, except in the case of root suckering by trees such as aspen or stump sprouting by hardwood or some conifer species. Surface fuel accumulation would probably begin on an increasing curve due to incomplete spatial and time utilization of the site. Even though herbs may cover much of the ground almost immediately, a limited root depth and limited growing season before curing might

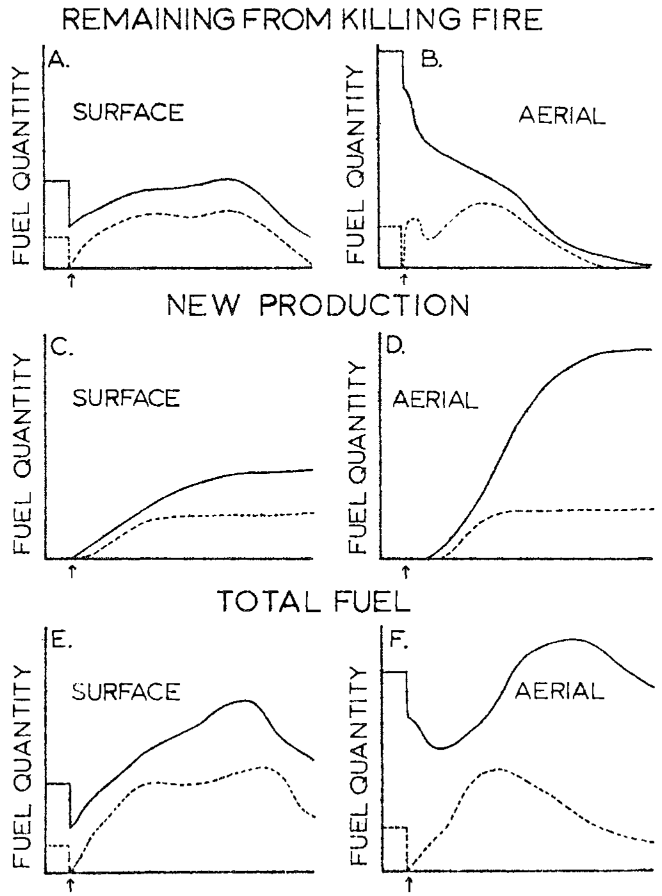

Fig. 3. A hypothetical view of total (—) and available (- -) fuels over time following a natural catastrophe, such as fire (arrow), which killed the overstory stand. Conditions at any site may modify the fuel levels.

mean incomplete site utilization and a low biomass production. Also, the rate of decomposition of the herbaceous materials will be much more rapid than for woody materials. Eventually, however, as the site is more completely occupied and woody vegetation becomes dominant, surface fuel accumulation should reach a maximum rate and eventually level off. As decadence sets in, total surface fuel may not increase as rapidly as available surface fuel, because much previously unavailable bole wood could become available. Surface fuels may continue to increase as aerial fuels level off or even decrease. Some period of incomplete site utilization may again occur during decadence.

Finally, we have combined the trends in both the residual fuels and those from new vegetation (Figs. 3e, f).

We have presented a hypothetical situation, and many factors can modify the fuel curves on any given site. We should develop better data along these lines to enhance management decisions regarding fire and its relationship to land use.

Of great concern to us is the type of biomass produced. Ecologists have conducted many studies on biomass production—different studies separating material into various categories, including foliage, branchwood, bole, litter, roots, and subordinate vegetation (Ovington, 1956, 1957; Forrest and Ovington, 1970; Dice, 1970; Zavitkowski and Stevens, 1972). Fire researchers have done similar work, but have also been interested in the size classes of fuel components (Fahnestock, 1973; Woodard, 1974). Although much is yet to be done, a synopsis of the work done indicates the following trends:

1. Total tree bole, branch, and foliage weight increased with age and d.b.h.; but the number of trees decreased with age. The general results are not surprising to any naturalist, but the balance between these two trends gives us some interesting relationships.

2. The weight of foliage per unit areas becomes constant following the time of stand closure. One would logically expect that for any species and site, the limitations of sunlight, water, and nutrients would bring this about. Some change might possibly occur over time as more nutrients are tied up in organic matter or as the site is modified by the stand.

3. The amount of branchwood per unit area becomes constant

some time following crown closure. Again, this result would be expected. If one separated size classes of branches, he could probably expect that smaller branch quantity would level off shortly after foliage, since litterfall in the small classes would occur very quickly. Progressively larger branch sizes would level off later, due to both the later development of large branches and the longer period before they are dropped. It could even be expected that the largest branch classes would continue to increase in weight per unit land area.

4. Foliage-to-branch ratios tend to become nearly constant at 1:1 or 1:1.5 at the time of crown closure.

5. Tree boles continue to increase in weight per unit area for a long period of time. Any thinning or mortality would temporarily decrease living bole weight per unit area, as it would foliage and branch weight per unit area. Bole weight would continue to increase again later, provided the stand was able to utilize the site completely; whereas foliage and branch weights would come only to a level dictated by species and site.

6. Biomass of understory vegetation decreases rapidly at the time of stand closure.

7. As the height of a stand increases, the average height of live and dead crowns and the average length of clear boles increases.

We might summarize the accumulation of tree components to be expected from the above statements (Fig. 4). Foliage and twigs increase rapidly in the early stages of stand growth but level off early (at about the time of stand closure for needles, shortly after for twigs due to the time required for shedding). Successively larger components are produced later in the life of the stand but continue to increase in quantity for longer periods of time. Even the boles would eventually level off in quantity and decline due to senescence and decomposition.

Having considered what is produced on an area of land, let's consider in general terms what fire consumes. Although we won't go into detail as to what a fire is, we might look at it as a rapid decomposition process, similar in nature to biological or other slower physico-chemical decomposition processes. The rapidity of the process produces high temperatures, however, and some products of combustion are quite different from those of decomposition.

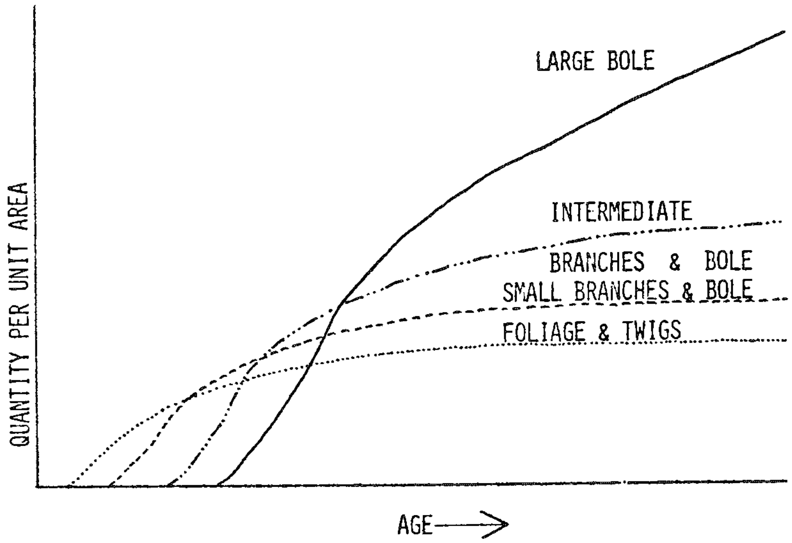

Fig. 4. Production of above-ground tree components in a forest stand, as synthesized from the work of several authors. The quantity of needles and twigs level off early in the life of the stand, whereas successively larger components increase for longer periods of time.

Light fires in a range community or the understory of a timber type may be somewhat similar in their consumption of material. Both will consume most of the dead herbaceous and small woody material, litter, and some humus, as well as a smaller percentage of green herbaceous material, living foliage, and small, living, woody material. As the severity of burning conditions increases, the percentage of all components available for combustion increases; the impacts of the fire increase—more fuel consumption means more heat release, more nutrient release, and often greater mineral soil exposure.

Slash fires are used to expose mineral soil and reduce fire hazard. The degree to which both are accomplished depends on the severity of burning conditions and the condition of large woody materials. A high percentage of the small fuels—foliage, twigs, and branches—will be consumed, the amount consumed increasing with severity of burning conditions. As we get into progressively larger fuels, smaller percentages of the total fuel are consumed.

Dry, punky logs may eventually be consumed by the fire, but we seldom have the luxury of waiting long enough for this to happen. Fire hazard from the flashy small fuels is reduced, meeting one objective of the slash burning operation. Some (or many) large logs remain and will slowly decompose over time; but for 50 or 100 years they will persist as readily-ignited punky materials and the cause for extensive mop-up work following any fire—either prescribed or wildfire. It would seem that we can do best in reducing long-term fire and management problems if we can increase the utilization level on any site. There are short-term benefits to burning, however, both in hazard reduction and ease of planting.

Fire reduces biological materials and at the same time releases a large amount of heat, averaging about 8500 BTU/1b (4700 cal/gm) (Byram, 1959). But there are other effects such as the release of nutrients and the production of smoke. We are beginning to develop more data concerning where the nutrients go. Papers later in the conference will touch on this subject—the presentations by personnel of the Wenatchee Hydrology Laboratory and by Henry Anderson. How much smoke do we get and what is it? What conditions, types of burning, and kinds of fuel affect smoke production? Dave Sandberg will give you information along these lines.

FIRE EFFECTS

Coverage of the above effects—on flora and fauna, soils, nutrients, water, and air—takes care of the direct effects—the *sledgehammer* effects of fire. Although our knowledge of these effects is somewhat limited, we know much more about them than about the more subtle indirect or long-term effects. It's only natural that our knowledge should be so proportioned. But we must concentrate more on understanding the down-the-road effects—those that are second-, third-, and further removed interactions within the system. How does fire influence changes in soil flora and fauna, in microclimate, as well as in macro-flora and -fauna of our range and forest lands? In forests developed with periodic fire, does fire exclusion in fact change not only many direct but also indirect factors which modify the susceptibility not only to disastrous fires, but to insect and disease attack?

While recognizing that much thought and many words have gone into controlling forest and range pests, let us suggest just a few ways in which changes in fire frequency might increase susceptibility to some pests. Which, if any, might be operative factors, we cannot say, but some of these points should be examined:

1. Fire has been the agent thinning or eliminating older stands, providing regeneration of healthy younger forests. Fire control has removed fire as the perturbing agent and an insect has taken over this role.
2. Tree species have moved into off-site locations—that is, sites where they can thrive for a period but eventually become susceptible to insects or disease.
3. The microclimate of the site is altered over a period of time, permitting development of an insect or disease pest.
4. Soil properties and nutrients are modified, with resulting changes in soil flora and fauna and whatever influence these might have on pests.
5. Competing, parasitizing, predatory, or symbiotic fauna and flora might be influenced by fire periodicity and severity; thus any changes could modify likelihood of an insect or disease outbreak.

We propose a range of indirect effects fire could have on insects and diseases (Figs. 5 and 6). The pathways suggested here are only

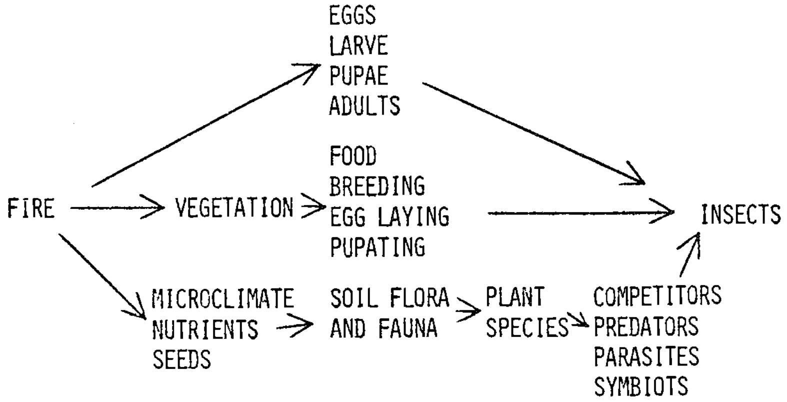

Fig. 5. Hypothesized pathways by which fire may influence the prevalence of an insect.

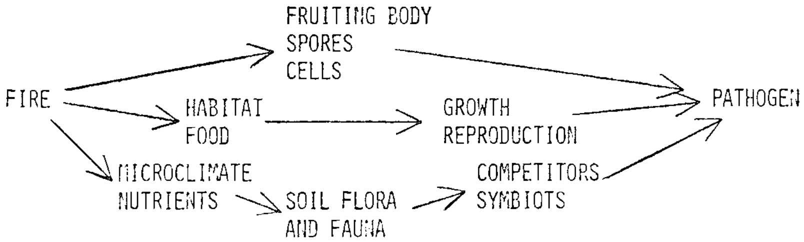

Fig. 6. Hypothesized pathways by which fire may influence the prevalence of a pathogen.

hypothetical, but they are indicative of the knowledge we need to consider the overall effects of fire, insects, and disease on our forest and range ecosystems. (One might also consider the effects insects and diseases could have on fire frequency and severity.) The point we wish to make is that we cannot consider only the sledgehammer, or direct, effects of fire on any species of the flora or fauna, but must include broader systems and long-term effects.

PROBLEMS

The large number of catastrophic fires west of the Cascade crest, where recorded light fires creeping under the tree canopies are scarce, might indicate that we can reduce fire hazard for only that brief period following logging. Once a stand is regenerated and we begin to accumulate the small and intermediate fuels (such as those in the 1-, 10-, and 100-hour timelag classes) in a vertical fuel array, perhaps we have to allow for an occasional catastrophic fire. Most of the available fuel is in crowns of living trees, and fire has certainly demonstrated its ability to move rapidly through the dense conifer crowns.

Let's look more systematically at our fire alternatives west of the Cascade crest. When we log, we produce large amounts of readily available fuels. Treatment of these residue fuels provides temporary relief. Burning reduces a higher proportion of the fine fuels, whereas improved utilization selectively reduces the large fuels. Methods such as chopping and piling modify the fuel distribution and continuity. All these methods reduce fire spread rate and resistance to control.

Within the first few years, however, we have a fuel complex of annuals, shrubs, and tree seedlings. These might support a fast spreading fire, but one of relatively low intensity and resistance to control. Soon, the seedlings will have progressed into sapling and pole stands. Once the stands are at this stage, assuming we want to maintain high-yield stands of conifer timber, we will have a high hazard. Our excellent detection and initial attack capabilities generally prevent fire starts from becoming serious. Suppose, however, we have an initial attack force incapable of responding to fires at some given time, due to previous commitments or multiple fires started by lightning or a dedicated arsonist (one who is strongly motivated and has the knowledge to choose his time and conditions carefully) under adverse conditions such as east winds and a long dry spell.

Although there are some areas with obvious east wind problems, many other areas west of the Cascades could be susceptible to these conditions at times. Today we have many breaks in the continuous conifer forest west of the Cascades in the form of alder-maple forests, pastures, and dwelling areas. Although man may have disrupted the continuous forest, his presence changes our greatest liability from timber loss to loss of human lives.

The higher values at stake mean that we must be prepared for the potentially catastrophic wildfire. Hardwood or open belts on a planned basis, as recently suggested by Johnson (1974) for Michigan, may be one answer. Traditional fuelbreaks of 100 to 300 feet will probably not be too helpful. We must still prepare for an occasional disastrous situation with advanced planning that includes cooperation with police, municipal fire fighting and rescue units, and all forest fire control groups. Although we might not yet have the data necessary, we can begin putting together the probabilities for conditions that would foster a potentially disastrous situation and be able to allow for the 25-, 50-, and 100-year fires just as the meteorologists and hydrologists have come to allow for floods.

We must also allow for the increasing problems of fire management caused by the forest and range interface with the suburban and urban communities (Butler, 1974). The interface increases not only the difficulty of preventing wildfire, but also the losses to be incurred should a disastrous wildfire occur.

East of the Cascades, at least at lower elevations before we get into the Douglas-fir and true fir (*Abies* spp.) forests which predominate at higher elevations, we should probably be using fire not only to prevent potentially disastrous fuel accumulations but also to maintain productive forest and range conditions. Apparently, fire started by lightning or Indians had been a frequent visitor to these forest and range lands before European man arrived on the scene. We need further information on fire and its effects, but we certainly have strong indications as to fire's value in these vegetative types.

We must recognize that as we use fire in the eastside forest and range, we are not necessarily duplicating the fires of prehistoric times. In fact, we may not want such a duplication, as those fires left a record which was destructive of timber values (the very means by which we know they occurred). Our use of fire should be modified in such a way as to meet man's goals and yet work within the natural system rather than bucking it by attempting fire exclusion.

One point we might consider in attempting to use fire in eastside forests, however, is that conditions have changed. Researchers and managers have pointed out that open park-like ponderosa pine stands are now choked with shrubs and tree understory. These conditions pose a serious fire threat if left untreated and will also make the introduction of prescribed fire more difficult. We must thus talk about "reclamation burning" in putting fire back into these forests, defining this as the process of reclaiming the forests so that we might be able to use fire efficiently and without undue risk of escape and damage. Stoddard (1963) talked about reclaiming the forest for fire, wildlife, and forest management.

Often, researchers and managers have reported that fire could not be used economically due to high cost, excessive damage, or threat of escape. Although their observations are justified in some instances, often they have neglected to observe the need for a reclamation period. In the Southeast, this period is said to require "a year for a year"[4] a year of reclamation for a year of fire exclusion. Usually the time is shorter.

Reclamation burning is more expensive than maintenance burning for several reasons. Most obvious is the heavy fuel accumulation, especially brush, reproduction, and standing and fallen dead fuels created by absence of fire or by earlier prescribed fires. The heavier fuels necessitate more careful prescription selection and slower burning. Another factor of expense is heavier protection effort due to inexperience of the management team and due to potential repercussions should a prescribed burn escape. Finally, the costs and damages of an escaped fire are higher due to the larger percentage of an area still supporting dangerous fuel loadings.

Quoted costs for prescribed burning vary widely. In the Southeast, costs for burning in the coastal plain have been given as low as $0.03/acre[5] to $0.36/acre,[6] the latter figure being equally divided between the costs for planning, line plowing, and burning. A figure of $1.50/acre was given for ponderosa pine burning in southwestern United States,[7] and Weaver gave a figure of $0.65 to $0.70/acre for ponderosa pine prescribed burning in the Pacific Northwest.[8] McComb has burned for wildlife habitat in eastern Washington at costs as low as $11/acre.[9] His data cover areas of heavy fuel, which indicate that costs may be much higher where small areas or high fuel loadings are concerned.

SUMMARY

Fire was a part of the Pacific Northwest before the arrival of European man. Prehistory fire was no problem, whether started by

---

[4] E. V. Komarek, Tall Timbers Res. Sta., Tallahassee, personal communication, 1965.

[5] E. V. Komarek, personal communication, 1962.

[6] J. Riebold, then Supervisor, Appalachicola N.F., Fla. personal communication, 1962.

[7] H. MacLean, Residue Red. Sys. Prog., Portland, personal communication, 1973.

[8] H. Weaver, formerly Bur. Indian Affairs, Portland, personal communication, 1972.

[9] C. R. McComb, Wash. Dept. Game, Colville, personal communication, 1974.

lightning or Indian, as the timber resource had little value and fire usually improved habitat for wildlife. With the advent of European civilization, fire became a problem due to the value placed on timber, loss of human lives, and destruction of buildings and towns. We moved through a period of rampant fire into fire control and only recently into fire management.

We can trace our fire problems, as well as our biological productivity, to the energy arriving from the sun. The sun's energy is converted into various materials, and the fireperson looks on some of these as fuels. Fuel accumulation, both live and dead, can be predicted within reasonable limits for different types of situations, when vegetative development can be predicted.

Development of fire management has not alleviated the severe fire problems—or opportunities—facing the land manager. Long years of attempted fire exclusion have allowed unnatural fuel accumulations to build up in some lands that were once visited frequently by fire. Vegetation changes allowed by fire control may have enhanced the potential for some forest pests. Protection costs have increased to the point, in some instances, that they exceed the value of the resource protected. On the other hand, we have a complex and highly dangerous intermixing of dwellings and heavy fuel accumulations which we must learn to handle more effectively.

With all the need we have to understand how much fire we should have in our forest and range lands in the Pacific Northwest, we still lack specific information on the effects of different kinds of fire on the terrestrial ecosystems, on water and air resources, and on the socioeconomic system within which we must work. We need the joint planned efforts of enlightened research and management, and cooperation of the public and other environmental agencies to arrive at optimum management strategies.

In the next day and a half, we have a forum for discussing many of these questions, and we hope it will be one more step toward solving our fire management-land management challenges in the Pacific Northwest.

LITERATURE CITED

Brown, A. A., and K. P. Davis. 1973. Forest fire: Control and use. 2nd ed. p. 83. McGraw-Hill Book Co., New York.

Butler, C. P. 1974. The urban/wildland fire interface. Pap. presented at 1974 Spring Meet. West. States Sect., The Combustion Inst., Pullman, Wash.

Byram, G. M. 1959. Combustion of forest fuels. Ch. 3, p. 65, IN: K. P. Davis, Forest fire: Control and use. McGraw-Hill Book Co., New York.

Clevinger, W. R. 1951. S. W. Washington's legendary 'big fire.' The Seattle Times Mag., Oct. 28, p. 2.

Daniels, F. 1964. Direct use of the sun's energy. 271 p. Ballantine Books, New York.

Davis, K. P. 1959. Forest fire: Control and use. P. 162. McGraw-Hill Book Co., New York.

Dice, S. F. 1970. The biomass and nutrient flux in a second growth Douglas-fir ecosystem (A study in quantitative ecology). Ph.D. thesis, Univ. Wash., Seattle.

Fahnestock, G. R. 1973. Forest-fire fuels in the Pasayten River drainage of north central Washington. Pap. presented at Northwest Sci. Assoc. Meet., Walla Walla, Wash.

Forrest, W. G., and J. D. Ovington. 1970. Organic matter changes in an age series of *Pinus radiata* plantations. J. Appl. Ecol. 7:177-186.

Geiger, R. 1966. The Climate near the Ground. 482 p. Harvard Univ. Press, Cambridge.

Hendrickson, W. H. 1972. Perspective on fire and ecosystems in the United States. Proc., Fire in the Environment Sympos., Denver. U.S.D.A. For. Serv., Div. of Fire Manage.

Howe, C. D. 1915. The reproduction of commercial species in the southern coastal forests of British Columbia. P. 212-230. Report of the Comm. Conserv., Can.

Johnson, V. 1974. Hardwood fuelbreaks for northeastern United States. Pap. presented at Soc. Am. For. Fire Working Group, New York, Sept. (Submitted to J. For.)

Ovington, J. D. 1956. The form, weights, and productivity of tree species grown in close stands. New Phytol. 55:289-304.

Ovington, J. D. 1957. Dry-matter production by *Pinus sylvestris* L. Ann. Bot. n.s. 21:289-314.

Plummer, G. H., F. G. Plummer, and J. H. Rankine. 1902. Forest type map of Washington. U.S.D.A. For. Serv., Reg. 6.

Rappaport, R. A. 1972. Forests and the purposes of man. Proc., Fire in the Environment Sympos., Denver. Div. of Fire Manage., U.S.D.A. For. Serv.

Smith, J. H. G. 1970. A British Columbian view of the future of prescribed burning in western North America. Commonw. For. Rev. 49(4), No. 142:356-367.

Soeriaatmadja, R. E. 1966. Fire history of the ponderosa pine forests of Warm Springs Indian Reservation, Oregon. 132 p. Ph.D. thesis, Oregon State Univ., Corvallis.

Stoddard, H. L., Sr. 1963. Bird habitat and fire. Proc. 2nd Annu. Tall Timbers Fire Ecol. Conf., p. 163-175.

U.S. Forest Service. 1936. Timber type maps of Oregon and Washington. Pac. Northwest For. Exp. Stn., Portland.

Weaver, H. 1959. Ecological changes in the ponderosa pine forest of the Warm Springs Indian Reservation in Oregon. J. For. 57(1):15-20.

Weaver, H. 1961. Ecological changes in the ponderosa pine forest of Cedar River Valley in southern Washington. Ecology 42(2):416-420.

Woodard, P. M. 1974. Predicting crown slash weights in Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). 94 p. M.S. thesis, Univ. Wash., Seattle.

Zavitkowski, J., and R. D. Stevens. 1972. Primary production of red alder ecosystems. Ecology 53:235-242.