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Forest Service

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Forestry Research West

A report for land managers on recent developments in forestry research at the four western Experiment Stations of the Forest Service, U.S. Department of Agriculture

Forestry Research West

In This Issue

Cover

Quaking aspen (*Populus tremuloides* Michx) is widespread throughout western forests. This scenic stand is located on the Medicine Bow National Forest in southern Wyoming. In response to an increased interest in managing for the species, scientists at the Rocky Mountain Station are studying aspen, and have come up with some important suggestions for regeneration. Details begin on page 16.

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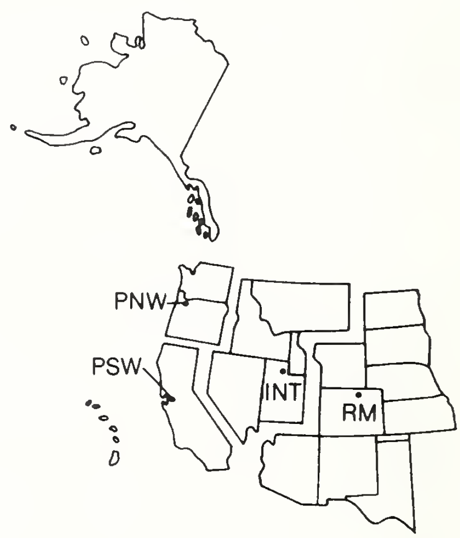
Berkeley, California 94701

Intermountain Research Station (INT)
324 25th Street
Ogden, Utah 84401

Rocky Mountain Forest and Range Experiment Station (RM)
240 West Prospect Street
Fort Collins, Colorado 80526-2098



Forestry Research West was recently judged to be one of the top government publications by the National Association of Government Communicators. The magazine won third place in the periodicals division of the Association's Blue Pencil Competition. Over 800 entries were included in the contest, held annually to recognize outstanding government publications and their producers.

The impacts of air pollution on forest resources

by Paul Miller
Pacific Southwest Station

Charles R. Colver, PSW, checks bulk-deposition collector at Tanbark Flats, San Dimas Experimental Forest.

The gray-brown haze that blankets the Los Angeles and Central Valley regions of California during the summer months is no longer a purely Californian phenomenon. Photochemical smog is now a problem in other western cities, including Denver and Tucson. The best known effect of smog on California forests is the injury to pine trees by ozone. But smog is a complex mixture of several chemicals. Recently, scientists at the Pacific Southwest Station began investigations to determine the impacts of the other chemicals in smog, both alone and in combination with ozone, on forest resources, including timber, soils and water.

The greatest amount of ozone injury to forest vegetation is found in the San Bernardino and San Gabriel mountain ranges to the east of Los Angeles. Ponderosa pine, Jeffrey pine, white fir, and California black oak show various levels of foilage injury, defoliiation, and growth loss. Mortality from ozone injury is low, except in dry years when drought stress and insect pests combine to remove the ozone-weakened trees. On the western slopes of the Sierra Nevada, extending south from Sacramento to Bakersfield, forest surveys have identified most of the injury to sensitive pines as slight or occasionally moderate. Several locations in the Sequoia National Forest, mainly the Marble Fork drainage of the Kaweah River in Sequoia National Park, show pockets of moderate injury. Ozone injury to pines is monitored on a regular basis by both Forest Service and National Park Service units, but now there is an increasing awareness that there is more than just ozone in the gray haze.

An integrated, nationwide effort to understand the phenomenon of atmospheric deposition has spurred interest in measuring other air contaminants. In California, emphasis is on measuring the dry deposition of gaseous and fine particulate pollutants that are an integral part of smog. Dry deposition refers to the accumulation or adsorption of pollutants on plant and soil surfaces. The compounds of interest include sulfur dioxide, sulfate, sulfuric acid, nitrogen dioxide, nitrate, nitric acid, ammonia and ammonium. The expected biological effects of these compounds range from leaf tissue injury by sulfur dioxide, alone or in combination with ozone, to a nutrient or fertilizing effect from some of the nitrogen compounds.

A wet deposition network of approximately 100 stations is operated under the unifying guidance of the National Atmospheric Deposition Program (NADP). Several stations are located in California, including sites at Giant Forest in Sequoia National Park and at the San Dimas Experimental Forest (SDEF), east of Los Angeles. Early results at both sites suggest that greatest rainfall acidity (pH values between 3 and 5) occurs in light rains that come in the spring, summer, or early fall. During these periods, the rains result from convective storms that draw acid-forming dry gases and particles up from nearby valleys. It is still unknown whether foilage injury results during these events. Certainly, the winter rains are cleaner, with pH values above 5 in most of California and the West.

The relative amounts of nitrate nitrogen and sulfate sulfur that accumulate in chaparral ecosystems are also being monitored, under the sponsorship of the Man and the Biosphere Program. Bulk deposition (wet and dry combined) and throughfall collectors are located at the following four sites: Santa Cruz Island, the Santa Monica Mountains National Recreation Area (Point Dume), the San Dimas Experimental Forest (SDEF), and Sequoia National Park.

Early results

Early results suggest that SDEF has the highest deposition rate and Santa Cruz Island has the lowest. These measurements confirm that a pulse of dry deposited nitrate and sulfate appears in the throughfall collectors when foilage is washed by the first rainfalls of the winter season; these amounts far exceed the accretion of nitrate and sulfate delivered by subsequent winter rains.

Three replications of bulk-deposition collectors in close proximity help cross-check precision of system.

In related work, PSW Soil Scientist Philip Riggan, has sampled the nitrate content of stream water and reported nitrate concentrations in several streams draining the San Gabriel Mountains that exceeded the Federal Standard for drinking water (10 ppm). In waters draining from areas more removed from the influence of urban oxidant air pollution, much lower concentrations were recorded.

A more in-depth evaluation of the chemical nature of dry deposition and its possible effects on the prominent chaparral shrub, *Ceanothus crassifolius,* will be carried out this year in the San Dimas Experimental Forest. This work will include continuous monitoring of gaseous and particulate pollutant concentrations, and biweekly analysis of dry deposited materials washed from leaf surfaces, polycarbonate petri plates, and nylon filter discs. The amounts of dry deposited nitrate and sulfate will be compared on leaf surfaces of *C. crassifolius* shrubs enclosed in filtered air chambers, ambient air chambers, and those not enclosed in chambers. At the end of the summer, the nitrogen concentration in leaf tissue will be compared among the chamber and nonchamber treatments. This work will be the initial step towards understanding the magnitude of dry deposition, the best methods for monitoring it, and its possible effect on foilage.

Ozone + sulfur

Another topic which was the subject of a 2-year investigation in the southern Sierra Nevada, east of Bakersfield, was the possible effects of mixtures of ozone and sulfur dioxide on forest vegetation. This work was carried out in 1982 and 1983 under the sponsorship of the California Air Resources Board, University of California, Riverside, and the Pacific Southwest Station. The field portion of the study involved the following: monitoring ozone and sulfur dioxide levels in the atmosphere and recording

Enclosures used to measure filtered and unfiltered air as it passes over native seedlings in Giant Forest.

Tamara Franklin measures rate of airflow as it passes over Jeffrey pine seedling in "clean" area in Sequoia National Park.

weather conditions at two mountain stations; measuring sulfate in surface soils and subsoils; recording the sulfur content of pine needle and lichen tissue along two transects stretching a distance of 32 miles east and southeast of Bakersfield; and surveying foilage of digger, Jeffrey and ponderosa pines to determine if observed leaf symptoms were attributable to the combined effects of ozone and sulfur dioxide.

An attempt was made to determine if there was a similarity in the stable sulfur isotope ratio between sulfur collected from the atmosphere near Bakersfield and that accumulated in soils and plant tissues in the mountains east of Bakersfield. The concentrations of extractable sulfate in surface soils, and sulfur in pine needles and lichens tended to decrease with increasing elevation and greater distance east of Bakersfield. The sulfur isotope comparisons were inconclusive, but these data provided a baseline that will make it possible to spot future changes. The combined evidence from analysis of sulfur in soil and in plant tissue, air monitoring, and the survey of foilage symptoms clearly indicated that sulfur dioxide and ozone were not acting jointly to cause the observed tree damage at these sites. All symptoms could be attributed to ozone.

Seedlings of ponderosa, Jeffrey and digger pines and of giant sequoia were exposed to mixtures of ozone and sulfur dioxide in open-top fumigation chambers in Riverside. Top and root growth of newly germinated seedlings were both decreased more by mixtures of the two pollutants than by either alone. Pollutant concentrations were in the range of what could be expected in the ambient atmosphere near large industrial sources of sulfur dioxide and the worst case conditions of ozone exposure in the San Joaquin Valley. Root growth was more affected than top growth. These results suggest that the success of forest regeneration may be decreased if seedlings were exposed to these dose levels during the early establishment phase. Finally, the fumigation of older seedlings with pollutant mixtures resulted in the expected needle symptoms, namely a shift from the light yellow chlorotic mottle caused by ozone alone, to a "brassy" colored mottle symptom.

NPS studies

The National Park Service is involved in an important nationwide research program to investigate present impacts of air pollution on vegetation and other resources in several Parks regarded as the "crown jewels" of the National Park system. In the Pacific Southwest Region, the Forest Service has joined with the National Park Service to do the groundbreaking research required to establish reliable methods of detecting vegetation response to oxidant air pollution. In

Victoria DeHart records measurement of tree-ring width.

Sylvia Haultain, Sequoia King National Park, collects soil samples for use in soil moisture measurements.

Sequoia and Kings Canyon National Parks, investigations are being made into the sensitivities of several tree species to air pollution impact. Of particular interest is the impact on establishment and survival of giant sequoia seedlings. Methods developed in this investigation will aid in identifying the ozone dose required to produce effects, such as leaf injury, and will provide a biomonitoring capability for assessing the locations at greatest risk. Ability to estimate year-to-year trends in vegetation injury may also result.

Researchers are also examining the pattern of ring growth in Jeffrey pines. Increment cores have been collected from trees in similar stands at two widely separated locations in Sequoia and Kings Canyon National Parks. The control or "clean air" sampling site is located in the headwaters of the Kern River, east of the Great Western Divide. The cores from trees showing various levels of chronic ozone injury have been collected from sites that receive the immediate impact of polluted air transported upslope from the Central Valley. Dated chronologies have been developed from examination of cores from "control" and "exposed" areas, and analysis is continuing. If tree age and climatic effects are taken into account, it may be possible to determine if a low frequency trend towards decreased growth has developed in trees in the "exposed" area. An exploratory analysis of the concentration of metals in tree rings formed before and after the advent of smog is being done in an attempt to provide additional evidence that declines in ring width may be related to air pollution stress.

While improved methods for detecting the presence of subtle ozone

Victoria De Hart takes core samples in Giant Forest area.

injury are being investigated in the Sierra Nevada, there is also a concern about the chronic effects of higher ozone doses on the mixed conifer forest of the San Bernardino National Forest. From 1978 to 1984, tree growth measurements were made at 18 vegetation plots along a gradient of high to low dose. Over this period, increases in basal area of trees of the same species with different levels of chronic injury, and between competing species, were dramatically different. Ponderosa pines with only one annual needle whorl retained in the live crown have put on less than half of the growth of pines with an average of three annual whorls. White fir, incense cedar, and sugar pine are all outgrowing ponderosa pine where these species compete. A decrease in productivity of the most commercially important species (ponderosa pine), and increasing numbers of fire sensitive species in the understory (incense cedar and white fir), form a fuel ladder that could cause fire to destroy the crowns of the remaining overstory trees.

At present, the only managerial tool being tested to relieve this problem is the use of thinning in affected stands to remove excess stems in the understory and to remove weakened overstory trees. Three such plots are being monitored in the San Bernardino National Forest, under the leadership of Silviculturist, Jim Bridges.

California remains the focus of concern in the West because its coastal climate and large metropolitan areas produce factors that combine to allow the buildup of ozone during many summer days and its subsequent transport to forested areas. The potential for forest damage in continental climates typical of Tucson and Denver will be better defined as these urban centers expand in population. Continued surveillance will be required to monitor the possible development of injury. The major protective measure is through the continued implementation of pollution emission control programs. Forest vegetation can be a valuable tool for demonstrating the success or failure of control strategies, and land managers can provide information to help justify the implementation of control strategies.

Shrubland research—re-shaping use of an abused land

by Mike Prouty
Intermountain Station

Cut it. Chain and plow it. Spray it with herbicides. Burn it. This has been typical treatment of western shrublands since early pioneers crossed the lush grasslands of the great prairie and encountered seemingly endless stretches of sagebrush and other native shrubs and forbs.

The traditional view (and one still held by some) has been that these shrublands are an unproductive nuisance, and should be converted to grass to better support people and their livestock. In some settings shrubs are unproductive, but the notion that all shrubs should be eliminated is not only inaccurate, it's unrealistic. Unlike the white pine forests in the Lake States or the great prairie in the Plains States, western shrublands have not easily succumbed to the efforts of man. In fact, the war on shrublands has not only been unsuccessful, at times it has been counterproductive. Despite efforts to convert it, the extent of shrubland has actually increased in the past 50 years from overgrazing, dryland farming, and firewood cutting. Shrubs are now predominant plant species on over 400 million acres in the western U.S. and southwest Canada.

An undeserved reputation

Historically, shrublands have been poorly utilized. The notion that they are unproductive is not shared by scientists at the Intermountain Research Station's Shrub Sciences Laboratory in Provo, Utah. Forest Service scientists and others there have been waging a 30-year campaign to change the popular perception of shrubland, by developing new information on western shrub

Soil Conservation Service managers and other shrubland managers have a keen interest in the performance of newly released shrub varieties.

species. Durant McArthur, project leader of shrub research at the Laboratory, maintains, "Historically shrubs have provided critical winter forage for livestock and wildlife, stabilized soil, and been used for medicinal purposes by American Indians." Today, in addition to these traditional uses, shrubs are used in landscaping, drug production, food and drink flavoring, predicting site potential, and rehabilitating disturbed land.

Scientists at the Laboratory have learned that the most healthy and productive shrubland consists of a mixed stand of shrubs, forbs, and grasses. Shrubs and forbs extend the grazing season; they stay green and succulent longer than grass, and by growing above normal snow levels shrubs provide browse to animals when grass is inaccessible. By providing shade and by fixing nitrogen, some shrubs also enhance the quality and extent of grasses. And, a mixed stand of plants results in a hardier ecosystem, one less susceptible to eruptions of pests and disease. Scientists have also found that as the diversity of plants increases so does the diversity of animals that occupy shrublands.

Research begins

But despite the value and utility of shrubs, only a dramatic event could trigger popular interest and legislative support for the study and management of western shrublands. Unusually heavy snows and high numbers of deer in the Wasatch Mountains in the late 1940's and early 1950's threatened Utah's mule deer herd with starvation. As decimated animals wandered down into the populated valleys along the Wasatch Front in search of browse, a public outcry arose to improve the quality of Utah's big game winter range.

Shrubs provide nutritious forage while grass is covered by snow.

In the mid-1950's scientists from the Intermountain Research Station and the Utah Fish and Game Department (now Utah Division of Wildlife Resources—DWR) joined forces in Ephraim, Utah, to conduct studies aimed at improving Utah's big game winter range. This work laid the foundation for today's shrub research by devising techniques for collecting, handling, and planting seeds from wildland plant species.

In 1975, as a result of the success of these early efforts, shrub research was extended when the Intermountain Research Station established the Shrub Sciences Laboratory. The mission of the Laboratory expanded on the previous big game winter range work to include all aspects of evaluation and improvement of western shrublands. Scientists from a variety of professional fields, all sharing a common interest in shrub research, were drawn to the facility.

This tradition of multi-disciplinary research still exists, as Botanist Nancy Shaw, Plant Physiologist Bruce Welch, Plant Pathologist David Nelson, Geneticists Durant McArthur and Stewart Sanderson, Ecologist Steve Monsen, and Wildlife Biologists Richard Stevens and Jim Davis constitute today's cadre of scientists at the Laboratory. The Shrub Sciences Laboratory is one of few institutions in the world where basic and applied research are devoted to shrubland ecosystems.

The Laboratory is ideally situated to fulfill its mission. Of 24 broad shrub types found in the U.S., 23 occur in the West. The Provo location is virtually in the center of this shrubland empire.

Situated on the campus of Brigham Young University (BYU), the Laboratory was founded in a tradition of cooperative research with universities and other Federal and State agencies. Of the scientists currently working at the Laboratory, Sanderson is a BYU research associate, and Davis and Stevens are Utah State DWR biologists. The close working relationship with these organizations is considered critical to carrying out the research mission of the Shrub Sciences Laboratory. Ties to the Utah DWR, the Idaho Department of Fish and Game, and Soil Conservation Service (SCS) Plant Material Centers are carefully nurtured. The Laboratory has always provided offices for Utah DWR wildlife biologists, and has engaged in joint research with them for over 30 years.

Putting research into action

How do scientists at the Shrub Laboratory translate their research mission into action? After all, it's easy to decry past and present shrubland management; it takes rigorous, imaginative, and persistent research to create new knowledge and transfer this information into practical management opportunities for developing and managing improved wildland shrubs. Scientists have developed a systematic approach to meeting this challenge.

The first step is to understand the needs of shrubland managers. Once the problem is understood—whether it be revegetating disturbed mined-land, rehabilitating riparian areas, or providing nongame wildlife habitat, scientists can begin to look among the several hundred shrub species growing on western wildlands for those with characteristics that may solve a particular management problem. The search for a suitable shrub may even extend world-wide.

For example, as a result of the concern over Utah's depleted big game winter range in the 1950's, initial research focused on sagebrush, rabbitbrush, and saltbush. These plants are quick growing, nutritious, and adapt to a variety of growing conditions—all important traits for shrubs intended for winter forage.

A shrub is not a shrub is not a shrub

Scientists have learned that not all individual members of a shrub species are created equal. Within the big sagebrush species, for example, some strains differ from others in terms of nutritive quality, resistance to disease, tolerance of climatic conditions, preference by browsing animals, and other traits. Scientists call these different strains of plants within the same species accessions.

Once a shrub species is targeted for research, the search begins to locate accessions with desirable traits. When such an accession is found the evaluation phase begins.

When a plant that seems to grow fast, or has other desirable qualities, is found in a natural setting, scientists cannot be sure whether the plant has these desirable qualities in its genetic makeup, or if it's merely reacting to good growing conditions. Thus a principal testing method involves planting shrubs in a uniform garden, and then evaluating how well they survive and grow under controlled conditions. For after all, a plant must first be able to grow well in a variety of conditions before further testing is warranted.

Samples of the shrub are also subjected to greenhouse and growth chamber tests. This intensive testing provides a variety of information. Scientists learn if a shrub has good seedling vigor and if it's resistant to drought, disease, and insects. They also learn the nutritional requirements of the plant—what amount of minerals, sunlight, and water results in optimum growth.

Next, another series of sophisticated laboratory tests reveals the shrub's genetic characteristics, its seed physiology, and its nutritive value as a food source for animals.

Just like children, animals sometimes don't know what's good for them. And it's even more difficult to force a mule deer to eat a nutritious plant it doesn't like. So scientists also conduct field experiments to determine if a shrub is preferred by browsing animals, and how well animals can digest the plant's nutrients.

The moment of truth arrives when a review is made of the results from this battery of testing. At worst, a plant accession may be dropped from the research program. At best, a plant may be "released," a formal designation of approval that sets in motion a series of events leading to development of commercial sources of seed.

The analysis of test results may also result in additional tests. Accessions showing some promise are field tested again, under additional weather and soil conditions. Their performance in these additional tests will determine whether they are released.

The evaluation also may result in recommending the accession be used for plant-breeding studies. Plant-breeding studies at the Shrub Sciences Laboratory involve basic research in genetics, chemistry, and physiology. Two accessions within one species are sometimes cross-pollinated to enhance a desirable quality such as fast growth.

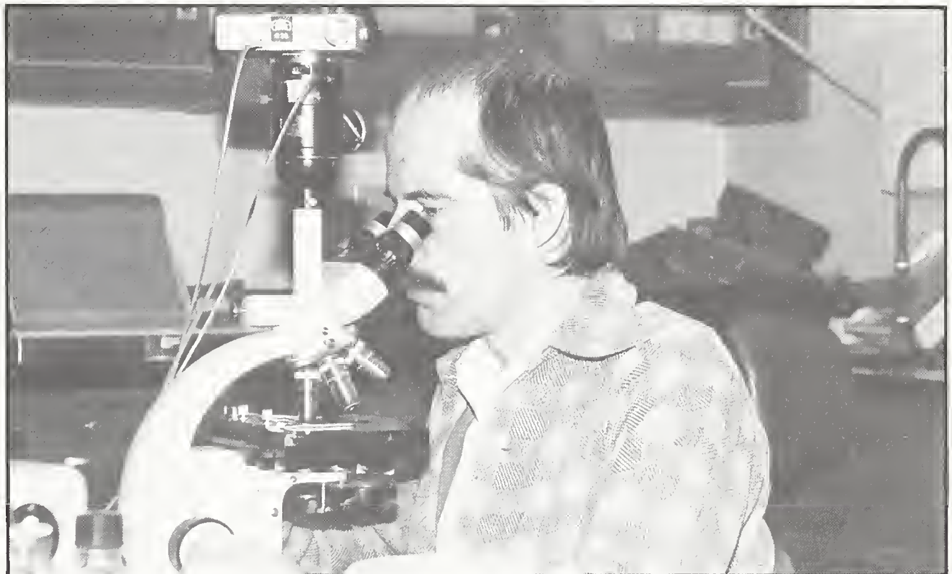
Another plant-breeding technique used at the Laboratory has been to cross two plants from different accessions, a more genetically involved procedure, in an effort to produce "super-shrubs," or superior hybrids possessing desirable qualities of both strains of plant.

After an accession is used in plant-breeding tests, it must again pass through the entire evaluation phase before being released. Ten to 25 years may pass between when a shrub accession is selected for study and when it is released.

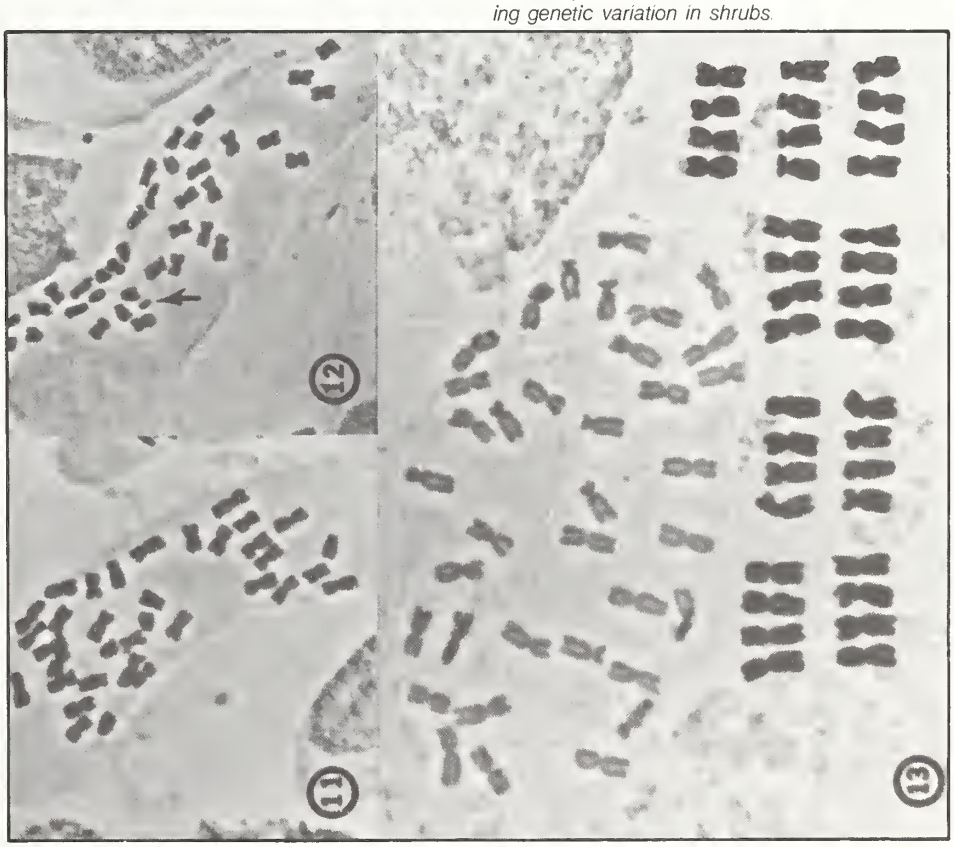
The devil's advocate to a devilish dilemma

In the past, plant breeding and selection programs have been reserved for agricultural crops, ornamental shrubs, and trees that receive long-term care and cultivation. Efforts to breed and select wildland shrubs must solve the dilemma of enhancing desirable traits while retaining the ability of the shrub to survive and prosper in natural settings.

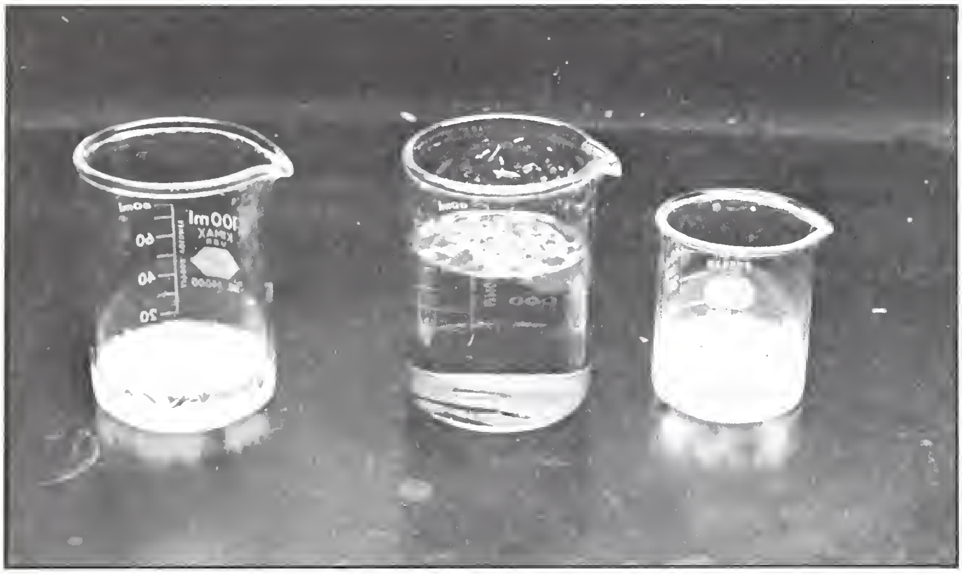
This concern has caused the Laboratory's plant pathologist, David Nelson, to play a devil's advocate role. "The emphasis has been to select and refine shrubs on the basis of a few criteria, which tends to narrow their genetic base," says Nelson. "However, my role has been to encourage the other scientists to consider disease resistance as another selection criterion. Disease and pest resistance require a broad genetic base. Although this causes a built-in conflict in our research, we'll hopefully avoid the kind of disease problems that have plagued agriculture and forestry," says Nelson.



Geneticist Stewart Sanderson performs detailed laboratory work, an essential step in determining genetic variation in shrubs.



By revealing plant chromosomes, Sanderson's work is a first step in genetic plant improvement.



Flourescent chemicals found in the leaves of some plants aid in their identification. Crushed leaves in the center beaker lack such chemicals.

Putting results to work

The formal release of a shrub marks the culmination of research at the Laboratory. But if left at this juncture, the mission of shrub research would not be met. Thanks to the cooperation of Agricultural Experiment Stations, SCS Plant Material Centers, USDA Plant Introduction Centers, and western State resource agencies, the results of this research are put into the hands of shrubland managers.

Cuttings and seeds of improved plant materials are provided to Plant Material Centers. They maintain this foundation stock, and work with seed growers to begin seed production.

The successful effort of these cooperators in transferring research results into on-the-ground practices is made dramatically apparent by the evolution of the native seed industry in the West. As a direct result of shrub improvement research, about 15 wildland seed companies now commercially collect and sell seeds from over 60 species of wildland plants. Thirty years ago this industry did not exist, and commercial sources for wildland shrubs were virtually non-existent.

Occasionally, seed production from natural stands of accessions is sufficient to satisfy demand for the plant. In this case, the SCS and State agencies work with State seed certification committees to certify the stand and allow collection of the seed.

Although shrubland managers may not be intimately familiar with work at the Shrub Sciences Laboratory, they have traditionally looked to the SCS and State resource agencies as the source of new information and materials. The Shrub Sciences Laboratory, by tapping into this historical partnership, has gained access to an established and effective way of quickly putting its research results into practice.

Growing respect for shrubs

The expertise of scientists at the Shrub Sciences Laboratory has been utilized beyond formal evaluation and development of improved shrub species. Their knowledge of the ecology, culture, handling, and propagation of wildland shrubs has helped expand the use of these plants. For example, shrubs are being used to stabilize disturbed land along road cuts, to revegetate mined-land areas, and to stabilize the vegetation structure of fire-prone areas.

Shrubs are now being interplanted with grasses in range rehabilitation and improvement projects. Such interplanting projects represent a complete cycle in the history of shrub management. In the beginning shrubs were removed and pure stands of grass planted. Now that the merits of shrubs are better known, interplanting reintroduces shrubs to the same areas from where they were removed! In all of these projects, scientists from the Laboratory have been asked by managers to help select suitable wildland shrubs, and have advised

Seed orchards like this will eventually produce commercial quantities of seed.

in the ensuing collection, handling, and planting efforts. In the mid-1950's many of these same scientists were called weed farmers.

In 1983, the Shrub Research Consortium formed to coordinate research and management of shrublands by sponsoring workshops and symposia. The Consortium has grown to include 16 members, including State and Federal resource agencies and 10 western universities. Scientists at the Laboratory play a leadership role in this organization.

Growing interest in shrub research has also resulted in outside funding from various sources including the National Science Foundation (NSF). NSF grants have supported more exotic research such as use of shrubs for rubber production and in characterizing plant breeding systems.

Work at the Shrub Sciences Laboratory has sparked international interest. Scientists from around the world, particularly from arid and underdeveloped nations, have visited the Laboratory. The Laboratory has provided these groups with information, materials, and directions. The Laboratory has also tested foreign plants, such as the "Immigrant" forage kochia, and released them for use in this country.

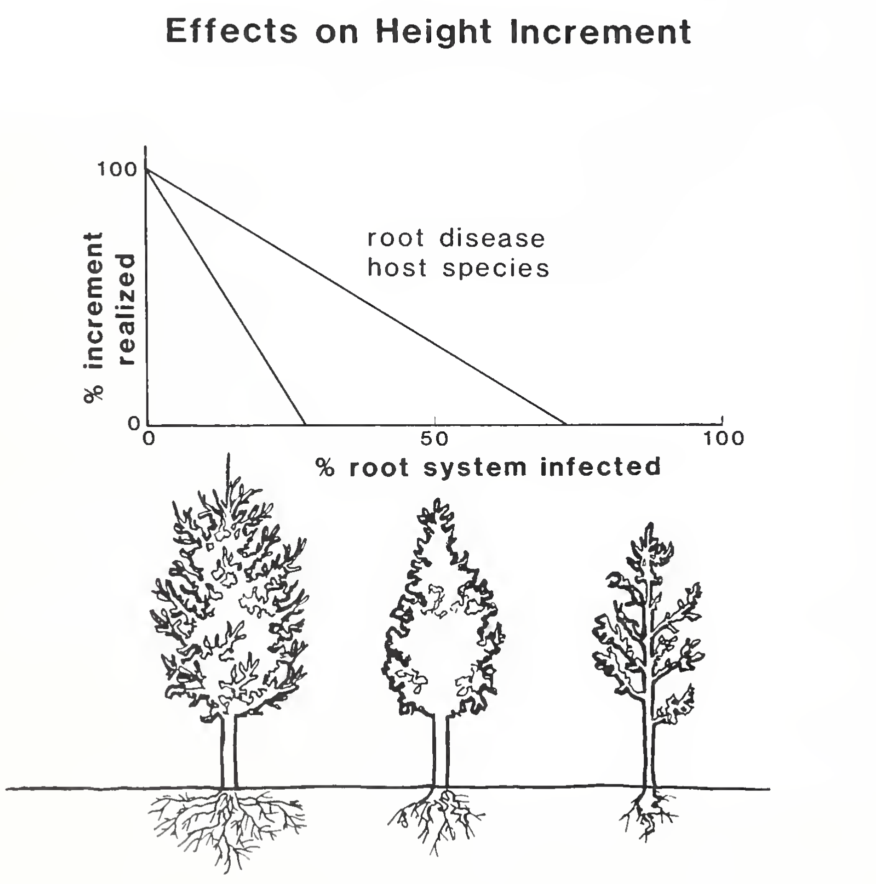
"The shrubland in western North America is ecologically similar to the south-central portion of Eurasia," says Durant McArthur. Scientists on both sides of the world have been interested in exchanging plant materials for genetic shrub improvement work. Unfortunately, international politics have restricted the scope of such exchanges.

The growing recognition of shrubs as an important natural resource is the accomplishment scientists at the Shrub Sciences Laboratory are most proud of. Since 1975, they have worked on only a small fraction of the shrub species that occur in the West. But as they work to improve other wildland shrubs, the popular estimation of shrublands and the future of shrubland management look bright.

Scientists, managers, and modelers work on root diseases

by Martha Brookes
Pacific Northwest Station

In a wooded setting high on the south rim of the Columbia Gorge in Oregon, a group of experts on root diseases reconvened for a week in February 1985 to scrutinize and evaluate an infant version of a westwide root-disease model initiated over 18 months earlier. The model eventually will be linked with existing stand-growth models, such as the Prognosis Model developed by reasearchers at the Intermountain Station's laboratory in Moscow, Idaho (see Forestry Research West, June 1982, p. 1-3). The model will help managers understand the relation of root rots and current management practices. Economic incentives are strong to do so: root diseases cause an estimated timber loss in the West of about 240 million cubic feet, annually.



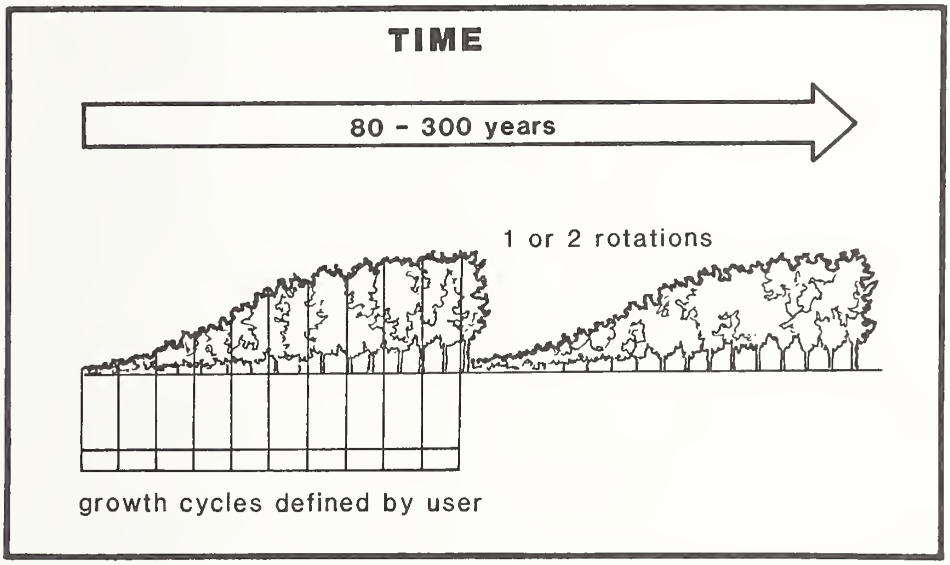
Core team

A smaller group had met in September 1984 to develop a structure for the model, to select experts to make up a team to supply the required information, and to plan two workshops where the model would be constructed. Representatives from the, Canadian Forestry Service, Pacific Forest Research Centre, Intermountain and Pacific Northwest Stations, and Northern and Pacific Northwest Regions of the Forest Service make up the core team. The four modelers, most of them students of C. S. Holling, of the University of British Columbia, are one-third of the technical staff of Environmental and Social Systems Analysts, Ltd. (ESSA), based in Vancouver, B. C.

The core team selected a working group that includes managers, professors, administrators, planners, and researchers from all over the West—from industry, State and Federal agencies, and universities—all with knowledge about the various root diseases and concern for their effects on forest trees.

The group contains admitted crusaders, like Terry Shaw, who believes that because the slow and silent root diseases probably cause more economic loss than the more dramatic insect outbreaks or fire, they should be given much higher research priority. Shaw expects help from the model in demonstrating the magnitude of root-disease damage; from increased awareness, he believes, will come increased priority for research.

The effects of root rot on height growth are related to tree species and the percentage of root system that is infected. These differences can be accomodated within the model.



The model is set up to accomodate one or two rotations lasting from 80 to 300 years. The growth cycles represent intervals when the data base can be updated.

First workshop

During the first workshop in November 1984 at the Priest River Experimental Forest in northern Idaho, the working group designed a conceptual model of how root rots influence and are influenced by other components of the forest, including management activities.

In the intervening months, the modelers have put together a series of computer models that represent—insofar as the working group was able to supply the necessary information—the biology and ecology of the root diseases, as set out in the conceptual model.

Second Workshop

How well do the computer models represent actual processes? A look at the workshop in progress demonstrates the approach to refining the model. First, the baseline for the chosen stand is displayed—with no root disease, no management, and no cutting. Then, various combinations of treatments, root diseases, and cutting regimes are projected, and the experts are asked to judge whether the predictions seem reasonable. As each set of conditions fed into the computer foretells consequences to the forest stand, the group responds:

"Those curves are way to far apart, and why do they rise and fall together?"

"I can't believe you'd get a growth increase like that, just from the thinning effect of tree mortality."

"What would happen if you removed all of the stumps instead of 90 percent of them?"

"I think the infected areas you're using are way too big; what we have are lots of small patches scattered through the stands."

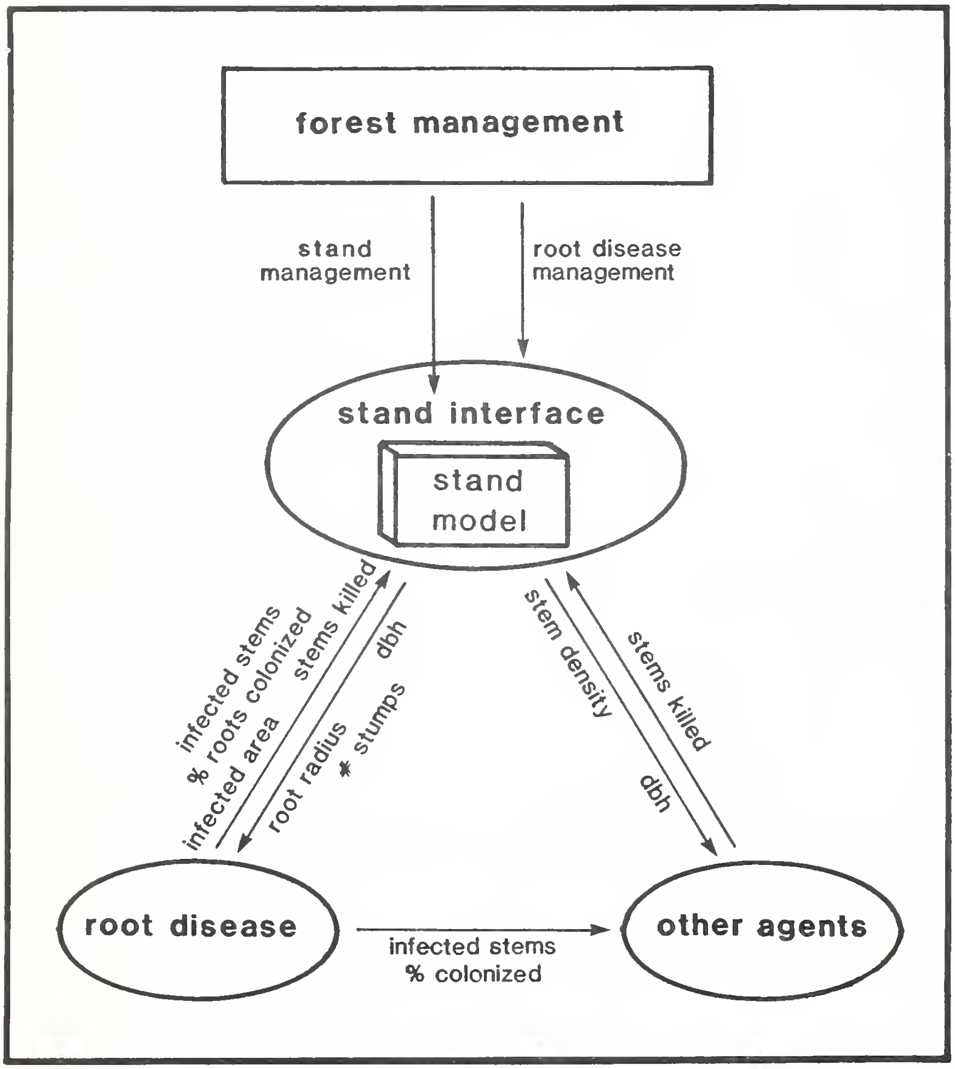
"That's the way *Armillaria* spreads all right, but you'll need a different subroutine for *Phellinus* and *Fomes.*"

Workshop dynamics

In a process as systematic as the model they are creating, the modelers lead the group through an orderly series of steps, drawing on the experience and wisdom each of the experts brings to the task. Three subgroups spend the morning discussing demonstrations of model behavior. Marveling at the similarity of their findings, the three groups reunite for the afternoon to see how their suggested changes affect model output. Spilling over into night sessions, the work so absorbs the group that they cluster around the display terminals, posing tests of model behavior, questioning trends, debating explanations.

"The model shows a growth decline after 20 years under these conditions. Does that seem reasonable?" Modeler Pete McNamee queries. "In our area," responds Sue Rainville, silviculturist from the Fernan Ranger District in northern Idaho, "we'd expect the decline to show up within 10 years." Heads nod around the room, and a note goes onto the flip chart to remind the modelers to adjust the program.

Frequent challenges from the young modelers spark the discussion: "Will you accept that rate of mortality? Does that scale look right? What should be happening to those smaller trees, now that the big ones have died?" Participants frown and concentrate, searching their own mental computers for the answers the modelers need to fill the gaps or refine what is already there. Sometimes when no data are available, the group is polled for best guesses, and another item is added to the flip-chart page headed "Research Needs."



The effects of management actions are built into the model, along with tree growth, the effects of root diseases, and the influence of other agents, such as bark beetles, mistletoe, and fire.

Identifying research questions and setting priorities for finding the answers is a major goal of the modeling effort. Priority will be determined, in part on how sensitive the model is to the information, how complex an experimental design is required to answer the question, and—of course—on how responsive funding agencies are to the urgency of the need.

The group listed research questions that need to be answered, such as:

How can we inventory inoculum and its potential?

What are the effects of different pathogen species on tree susceptibility (time to death), and disease spread rate? Species and size of host? Habitat characteristics? Management activities (for example, planting, thinning, stumping, and selective logging)?

What are the effects on disease spread rate and tree mortality of interactions between root pathogens?

Does the current model provide reasonable simulation of inoculum carryover to the next stand for each combination of host, pathogen, and site?

The preliminary model will be used to test the importance of research questions—that is, how sensitive the model is to the uncertainties contained in the research questions.

Synthesizing information

A gifted scientist with the ability to synthesize can collect bits of information and make sense of them, can show how one bit relates to another, identify the missing bits, fill some of the gaps with logical guesses, and then write a book that represents the dynamics of the whole. Besides needing a vast array of bits, intuition, creativity, and so on, the synthesizer also needs lots of time to reflect, to ruminate, to wrestle with the facts, with cause and effect, with contradictory evidence. Time-to-reflect is a scarce commodity for contemporary scientists, who are continually pressed to produce, to publish, and to scramble for research grants in an increasingly competitive environment.

Modeling workshops, like this one, may serve as a modern substitute for the individual synthesizer, with the model taking the place of the traditional book as the mechanism for putting the synthesized information into the hands of both data-gatherers and appliers.

As demonstrated in this second workshop, the work of a group in concentrated, nonstop sessions speeds up the data-wrestling—sometimes by dividing the problems into manageable units to be dealt with by subgroups, sometimes in plenary sessions, where concensus emerges from focused discussions of controversial issues. As each topic surfaces, it is either scheduled to be incorporated into the model, if deemed appropriate—or added to the list of research needs.

What next?

Like books, models become outdated. Newly acquired facts and new interpretations will require new editions, but the structure for change is built into the model.

The modelers will incorporate changes in the root-disease model that were identified during the workshop and refine model codes to ensure efficient use of computer time. ESSA's final report will describe their approach and actions; what the model does, management indicators, and supporting equations; data required to run the model; and sample scenarios to illustrate model behavior.

Ready to use?

In the last session of the second workshop, the modelers issued a final challenge to the working group: Who's going to decide when the model is ready to use? A third workshop is proposed for summer 1985 to give the biologists and forest managers another chance to check and refine model behavior. With guidance from this meeting, the core team will determine when to launch the model and put it in the hands of forest managers.

Additional information is available from:

Terry Shaw
P. O. Box 909
Forestry Sciences Laboratory
Juneau, AK 99802

and

Al Stage
Forestry Sciences Laboratory
1221 S. Main Street
Moscow, ID 83840

Regenerating aspen

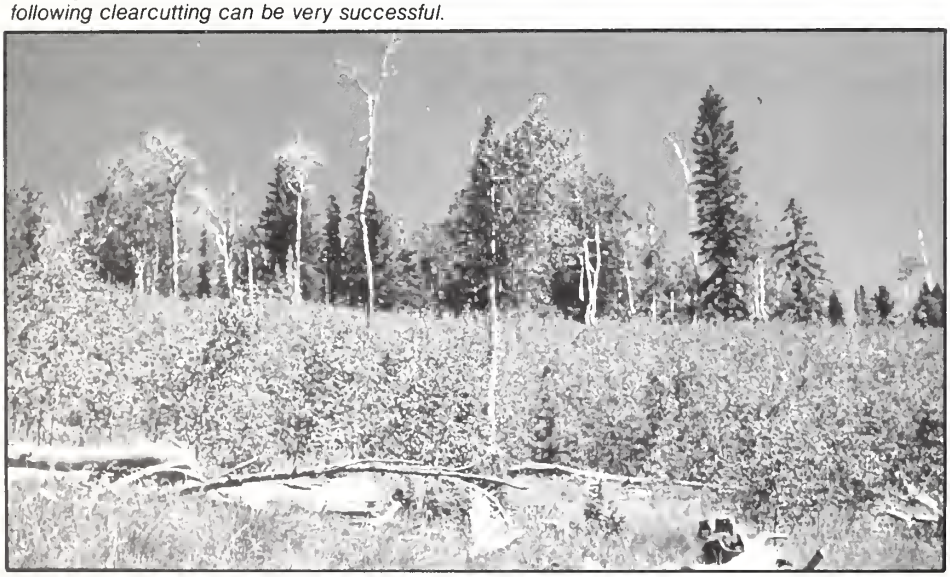
by Rick Fletcher
Rocky Mountain Station

Quaking aspen (*Populus tremuloides* Michx) is an important multiple use species in the Rocky Mountains providing wood, water, forage, wildlife habitat, and scenic and recreational values.

Although the commercial importance of aspen for wood products has traditionally been low, its use for such products as flakeboard, and paneling is now on the rise.

Aspen typically grows on all aspects and slopes in the Rocky Mountains, and is associated with montane and subalpine vegetation from 7,000 to 11,000 feet. It usually reproduces by root sprouting after an existing stand is destroyed. For centuries, fire apparently was the common regenerative force. But 20th century prevention and suppression capabilities have greatly reduced wildfires. As a result, most of the aspen stands in the western U.S. are mature (80 to 100 years) or overmature, and are subject to being replaced by other plant communities. This concern, along with the growing commercial importance of aspen, has increased interest in managing the species.

When guidelines are adhered to, regeneration following clearcutting can be very successful.



Because of its unique characteristics and silvical requirements, special considerations must be used in managing aspen. In the West, the species regenerates almost entirely by root suckering. (Although aspen produces an abundant supply of seed, very few find the moist mineral soil conditions necessary for survival).

More than most tree species, aspen needs sunlight to regenerate and grow, which brings out another unique characteristic—the stands thin themselves by shading and restricting development of smaller understory stems.

Finally, the sensitive, living bark of aspen is easily damaged—producing entrance points for diseases and insect attack.

To help learn more about managing and regenerating aspen, scientists at the Rocky Mountain Station are conducting studies throughout Colorado. Wayne Shepperd, Research Forester with the Multiresource Management project at Fort Collins, Colorado, explains, "Although it has typically been an unmanaged species throughout the Rockies, several techniques have been used to successfully regenerate aspen. Most methods that destroy the original stand will work." For instance:

1) Burning is possible in stands with oily shrub undergrowth, a mixture of conifer, or those with heavy fuel concentrations;

2) Several herbicides have been effectively used via aerial or ground application;

3) Bulldozing can be successful if the blade does not cut into the soil and destroy the root system.

For centuries, wildfires helped perpetuate aspen stands. However, as a result of today's fire suppression capabilities, not all overmature stands are reproducing and some are being replaced by other plant communities. Prescribed burns (left) still remain an effective method of regeneration (right).

4) Less common strategies involve: cutting the conifer overstory in mixed conifer/aspen stands to promote growth and suckering; fencing out browsing animals; and even doing nothing. Many stands are self-regenerating, and reproduce themselves without any intervention.

"However," says Shepperd, "the intolerance of shade, ability to reproduce by suckering, and natural thinning tendencies ideally suit aspen to even-aged management by clearcutting. This is especially true where you want to produce wood fiber."

Clearcutting

Clearcutting not only opens the stand to sunlight and promotes suckering, but prevents poor-quality residual stems from being released and dominating subsequent regeneration. Clearcutting also avoids the damage commonly associated with trees left after logging.

Although clearcutting is the recommended method, several precautions need to be taken to assure success. "Of utmost importance is protection of the root system during management activities," says Shepperd. "If the roots are destroyed, say by logging equipment, you lose the ability to regenerate the clone (sprouts from single parent root systems). Remember, you can't fall back on artificial regeneration," he says.

In designing clearcuts, forest managers should also be aware that, as with conifers, aspen is shallow-rooted and susceptible to windthrow. Avoid laying out clearcuts which run up slopes, parallel to the wind direction, or on ridgetops, or directly below saddles in ridges.

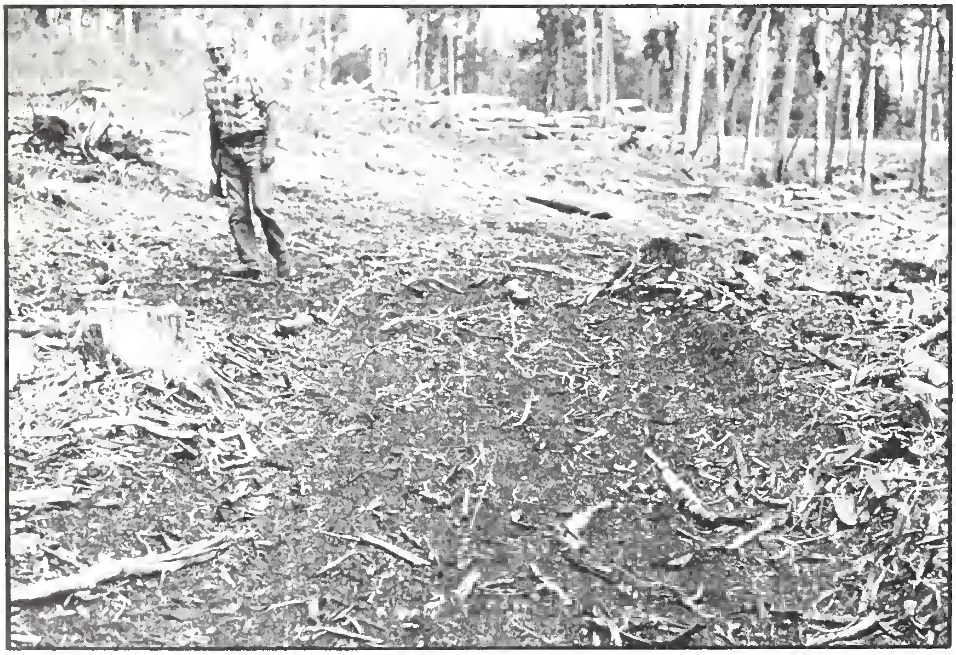
Livestock may pose another threat to regeneration. Animals are attracted to the increased forage in clearcuts, and can limit regeneration by browsing aspen sprouts. "Trampling by livestock can also occur," says Shepperd. "Sprout stems and branches are often broken and scraped, opening wounds to disease and insect attack. The problem will continue until the trees are large enough that livestock go around them instead of over and through them, and are large enough that their top leaves can't be browsed," (usually at about 5 years of age) he said.

Recent observations indicate that livestock may prefer aspen sprouts more during late summer. If this is the case, relocating or fencing out animals during this time of year may help reduce damage.

Land managers also need to be aware of snow damage. Early research findings show that sprouts can be broken or damaged by settling of snow that is blown in and trapped by the clearcuts. Scientists believe that by using different shapes and distribution of cutting blocks, deposition of windblown snow and the resultant damage could be reduced. Efforts are currently underway to further study this phenomenon.

Another concern is deteriorating clones. These are mature and overmature clones that are breaking up but not regenerating. In healthy

This exposed root system illustrates the suckering capabilities of quaking aspen.



The number one priority when clearcutting is protecting the root system. Here, log skidding has destroyed the root system and has erased any hopes of regeneration through suckering.

clones, the abundant production of suckers following clearcutting, fire or other major disturbance is apparently caused by a hormonal imbalance in the root system that promotes suckering. In deteriorating clones, the overstory has died slowly, and concurrent deterioration of the root system has maintained the hormonal balance and, thus, inhibited suckering. These clones are frequently isolated and show evidence of stem damage, insect and disease attack, heavy understory browsing, and root compaction or trampling damage by big game animals or livestock. "Cutting such weakened clones," says Shepperd, "is likely to result in sparse suckering, which may require additional protective or cultural measures to successfully regenerate the stand."

So when do you want to regenerate aspen? "It depends on what you've got to work with," says Shepperd. Existing stand conditions, genetics, physiographic and ecologic limitations can all restrict your regeneration options. We can expect that vigorous, healthy stands will be easier to regenerate, while poorly stocked, low-vigor stands will require more care.

"Choice of regeneration method also depends upon what you want. If perpetuation of the species is all that's needed, maximum stocking or growth is not necessary and we can choose any method that results in at least some survivng sprouts. If, on the other hand, you want to perpetuate a particular stand condition, or provide a specific resource, choose a method of regeneration that meets the objective.

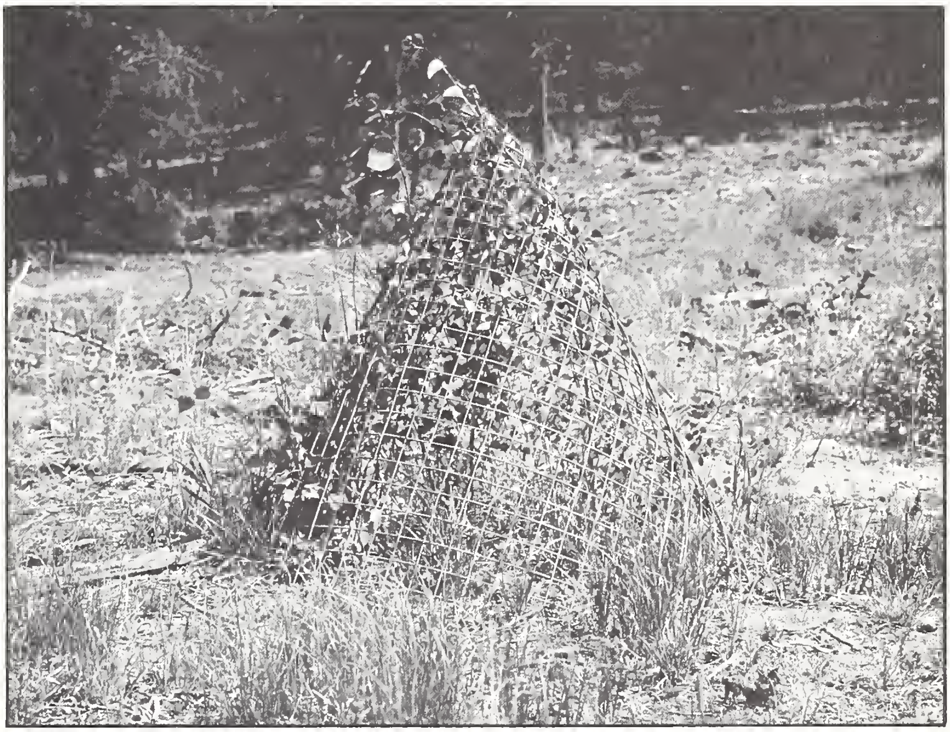
"Finally, the choice of regeneration method depends on costs involved. Commercial logging, or even doing nothing, may be much more cost effective than paying to have trees felled, bulldozed, sprayed, or burned,'' said Shepperd.

Experts join forces

In recognition of the tremendous value of the aspen resource in Colorado, the USDA Forest Service (Region 2) and the Colorado Department of Natural Resources have established an aspen management panel of experts. The panel, which includes representatives from the Forest Service, State of Colorado, Society for Range Management, Western Colorado Congress, and the timber industry, is developing recommendations for field operating guidelines for aspen management on National Forest lands in Colorado.

A draft document of their findings has been compiled. It is now available for public input. These recommendations are targeted for inclusion in land management plans for National Forests throughout the central Rockies.

A new slide-tape program on managing aspen in the central and southern Rockies is also being produced by scientists at the Rocky Mountain Station. When it's completed, copies will be distributed to all National Forests in the Southwest and Rocky Mountain regions of the Forest Service that manage aspen. It will be the sixth in a series of programs produced at the Rocky Mountain Station to help forest managers write prescriptions and evaluate stands and treatments for the major timber types throughout the central and southern Rockies and Southwest.



This aspen is being protected from browsing by a piece of wire fence. Note the lack of aspen regeneration in the surrounding clearcut due to browsing. This tree would probably be killed if the protective cover was removed.

If you would like to read more about aspen regeneration research at the Rocky Mountain Station, request *Regeneration of Aspen Clearcuts in Northwestern Colorado,* Research Note RM-407; or *Aspen Regeneration After Commercial Clearcutting in Southwestern Colorado,* a reprint.

New publications

Hardwoods get attention in two states

Two recent reports from the Pacific Northwest Station provide information about the hardwood resource—now in increasing demand. One report contains information on the volume, distribution, and ownership of hardwoods in western Oregon; the other presents the first volume equations for California hardwoods.

In western Oregon, hardwoods make up 8 percent of the total volume and almost one-third of the total non-federal timberland area, but they account for less than 1 percent of the total timber harvest. Privately owned land covered by hardwoods decreased 7 percent between the 1961-62 and 1973-76 inventories. Of the 11 primary hardwood species, red alder is most common and most valuable. It accounts for 54 percent of the hardwood inventory. In addition to figures on volume, ownership, growing stock volume, harvest, and change over time, the report presents information on the area of softwood forestland occupied by hardwood stands and discusses the potential loss of softwood growth.

Despite the increasing value of hardwoods and concern for managing forestland containing hardwoods, reliable ways of estimating the volume of many species has been lacking. A forest inventory in California, completed in the early 1970's, found that 13 major hardwood species occupied an estimated one-sixth of the 6.6 million hectares of commercial forest land. Hardwoods also accounted for 10 percent or more of the stocking on 1.1 million hectares of commercial conifer types. Now, in the new report, equations for estimating the volume of 13 California hardwoods are available for the first time. The equations were developed under a contract for the Pacific Northwest Station and are being used in the current compilation of the California inventory that was completed in 1984. This was the the first inventory to include the oak woodlands in the State's great central valley and foothills.

Both reports are available from the Pacific Northwest Station. They are *The Hardwood Resource in Western Oregon,* by John H. Poppino and Donald R. Gedney, Resource Bulletin PNW-116, and *Equations for Total, Wood, and Saw-Log Volume for Thirteen California Hardwoods*, by Norman H. Pillsbury and Michael L. Kirkley, Research Note PNW-414.

Reclamation principles outlined on video tape

Five universal surface mining reclamation principles are described in a video tape produced by Intermountain Research Station Scientist Bland Z. Richardson. The 15-minute color presentation, "Reclamation: before a single grain of dirt is moved," uses sites on the Bridger Teton National Forest to illustrate the principles. The presentation discusses differences between "watershed protection" and "native plant" schools of thought in reclamation.

The video tape is available on loan from the Intermountain Research Station.

Long-term effects of MPB attack

Severe outbreaks of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) often kill more than 40 percent of a ponderosa pine stand (20 to 40 cm d.b.h.). However, not all attacked trees succumb. Some continue to survive and may appear to be healthy, thriving trees.

However, a new study just completed by scientists at the Rocky Mountain Station shows that, while the blue stain infection commonly associated with pine beetle attack is not extensive enough to completely block the sapwood and kill the tree, the water-conducting capacity of the sapwood is sharply reduced. Consequently, the foilage area of the surviving tree is reduced through physiological feedback mechanisms—greatly reducing radial growth and overall vigor. Scientists believe that full recovery may take several decades, and, in fact, may not occur at all. The study showed that 7 years after an attack, there was no evidence that the vigor of the surviving trees was improving.

Salvage logging is often prescribed after a pine beetle epidemic. Because of the questionable and very lenghty recovery time of surviving attacked trees, study results indicate that poor vigor trees should be considered for removal as well. This will facilitate the development of both the remaining healthy trees and newly established seedlings.

Details of this study are in *Vigor of Ponderosa Pine Trees Surviving Mountain Pine Beetle Attack*, Research Note RM-448, by Merrill R. Kaufman and Robert E. Stevens. Copies are available from the Rocky Mountain Station.

Oregon's forest products industry in 1982

In 1982, the forest products industry in Oregon accounted for about half the State's manufacturing-based employment and payroll. In many places the local mill was the only employer. A new report from the Pacific Northwest Station, based on information collected from all 327 of the primary wood processing firms operating in Oregon in 1982, provides a comprehensive picture of the mill characteristics and log consumption of an industry whose importance to the State's economy extended well beyond direct employment and payrolls.

The information, gathered by mail and telephone, covers the processing sectors of lumber, veneer and plywood, pulp and board, shake and shingle, post, pole, piling, and exports. Similar reports were made in 1968, 1972, and 1976.

Oregon processed 6 billion board feet of logs in 1982, down from 9.3 billion board feet in 1976. The largest users of logs were the sawmills, followed by veneer and plywood mills. Pulpmills and board mills used 5.8 million tons of wood fiber, 84 percent in the form of mill residue. In fact, more than 99 percent of the wood and bark residue created at mills was used, 54 percent going to pulp and board manufacture and 39 percent for fuel. More than 90 percent of the bark residue and 26 percent of the wood residue was used for fuel.

Four counties led in the processing of roundwood: Lane, Douglas, Coos, and Klamath.

The industry in 1982 was quite changed from the one that existed 20 years earlier: fewer mills, greater diversification, a wider range of products, and more efficient use of the timber. Charts comparing data for 1968, 1972, 1976, and 1982 show that in just 10 years (1972-82) the number of industry mills was reduced by 154; 100 of these were sawmills. Although the number of sawmills and veneer and plywood mills declined by 133 (34 percent), the capacity at these mills dropped only about 18 percent.

For copies of *Oregon's Forest Products Industry: 1982,* by James O. Howard, Resource Bulletin PNW-118, write to the Pacific Northwest Station.

Spruce-fir discussed

Engelmann spruce/subalpine fir is the most productive forest type in the Rocky Mountain region. Spruce-fir forests yield valuable runoff for downstream water needs, provide wildlife habitat, and offer important recreational and scenic areas.

To help resource specialists better manage this forest type, scientists at the Rocky Mountain Station have issued two reports: *Silvical Characteristics of Engelmann Spruce,* General Technical Report RM-114, and *Silvical Characteristics of Subalpine Fir,* General Technical Report RM-115.

Each report covers genetics, life history, habitat conditions, botanical description, distribution, and properties and uses of the wood.

Copies are available from the Rocky Mountain Station.

Forty-four years of range research summarized

Managers and users of Intermountain rangelands are offered a series of specific guidelines in a new Intermountain Research Station report summarizing 44 years of study at the Benmore Experimental Range in north-central Utah.

Vegetation and livestock studies by the Forest Service, Utah State University, the Soil Conservation Service, and others at the experimental range have increased understanding of rehabilitating and managing Intermountain rangeland. Authors Kirk A. Astroth and Neil C. Frischknecht consolidate information from over 80 reports in the publication, *Managing Intermountain Rangelands—Research on the Benmore Experimental Range, 1940-84.*

The report provides guidelines on brush removal and control, seeding, rangeland management, shrub/grass competition, wildlife habitat, noxious weeds, and fertilization. It also provides a history of past range practices in the West, and describes the development and administration of the experimental range. Request General Technical Report INT-175.

Native shrubs revegetate road cuts

Quickly revegetating forest road cuts precludes future problems such as slope erosion, stream siltation, and loss of scenic value. Many fill slopes in National Forests of northern Idaho and western Montana are successfully revegetated with grass and legumes, but this treatment fails on harsh sites and on cut banks.

Research Forester Roger D. Hungerford evaluates the effectiveness of planting native shrubs and forbs along western Montana road cuts in the new Intermountain Research Station report, *Native Shrubs: Suitability for Revegetating Road Cuts in Northwestern Montana*. The report describes how well 18 species of shrubs and herbs native to northern Idaho and western Montana revegetated road cuts in the Coram Experimental Forest.

The report indicates road cuts can be revegetated with some native shrubs. Wood's rose, red-osier dogwood, thimbleberry, bush penstemon, and blackcap survived and grew well over a 9-year period. Only Wood's rose, bush penstemon, and blackcap regenerated successfully. Most of the other species planted either died or did not grow and develop. The report also shows grasses and legumes can be effectively sown in combination with shrub plantings. Request Research Paper INT-331.

Managing wooded draws

Although wooded draws and natural prairie woodlands occupy only one percent of the northern Great Plains, they are valuable and important ecosystems. These unique communities are habitats for wildlife and livestock, help stabilize soils and maintain watersheds, are sources for firewood, and provide recreational and esthetic attributes.

The Rocky Mountain Station has issued a report that describes wooded draws, and provides suggestions for their regeneration and management. Green ash, Rocky Mountain juniper, cottonwood, bur oak, quaking aspen, paper birch, and ponderosa pine habitat types are described. The report details management considerations for the wood and livestock habitat components of wooded draws.

For your copy, write the Rocky Mountain Station and request the reprint *Wooded Draws in Rangelands of the Northern High Plains.*

Financial analysis added to DFSIM

Users of DFSIM (Douglas-fir Stand Simulator) who also want a financial evaluation can now get that readily, thanks to a new version of the widely used simulation program. DFSIM WITH ECONOMICS has a financial analysis option that permits users to simulate financial results right along with growth and yield results. The user can make proportional adjustments to yields to better fit small-plot research data to operational conditions or to calibrate DFSIM to local conditions. Salvage of mortality can also be simulated in the financial analysis. Timber prices can vary by diameter, and logging costs can vary by diameter and volume harvested.

The program is available in FORTRAN-77 for both main frames and the IBM-PC. An interactive program (SIMIN2) is also available to assist users in preparing the input.

Copies of the new version are available from the Pacific Northwest Station. *DFSIM WITH ECONOMICS: A Financial Analysis Option for the DFSIM Douglas-fir Simulator*, by Roger D. Fight, Judith M. Chittester, and Gary W. Clendenen, General Technical Report PNW-175, is an amendment to the original DFSIM user's guide *(A new stand simulator for coast Douglas-fir: DFSIM user's guide,* by Robert O. Curtis, Gary W. Clendenen, and Donald J. DeMars, General Technical Report PNW-128) published in 1981. The user's guide is also still available.

To order any of the publications listed in this issue of *Forestry Research West*, use the order cards below. All cards require postage. Please remember to use your Zip Code on the return address.

Please send the following Pacific Northwest Station publications:

- ☐ *The Hardwood Resource in Western Oregon*, Resource Bulletin PNW-116
- ☐ *Equations for Total, Wood, and Saw-log Volume for Thirteen California Hardwoods*, Research Note PNW-414
- ☐ *Oregon's Forest Products Industry: 1982*, Resource Bulletin PNW-118
- ☐ *DFSIM WITH ECONOMICS: A Financial Analysis Option for the DFSIM Douglas-fir Simulator*, General Technical Report PNW-175
- ☐ *A New Stand Simulator for Coast Douglas-fir: DFSIM User's Guide*, General Technical Report PNW-128
- ☐ *Levels-of-growing-stock Cooperative Study in Douglas-fir, Report No. 7*, Research Paper PNW-323
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Please send the following Rocky Mountain Station publications:

- ☐ *Regeneration of Aspen Clearcuts in Northwestern Colorado*, Research Note RM-407
- ☐ *Aspen Regeneration After Commercial Clearcutting in Southwestern Colorado*, a reprint
- ☐ *Wooded Draws in Rangelands of the Northern High Plains*, a reprint
- ☐ *Silvical Characteristics of Engelmann Spruce*, General Technical Report RM-114
- ☐ *Silvical Characteristics of Subalpine fir*, General Technical Report RM-115
- ☐ *Vigor of Ponderosa Pine Trees Surviving Mountain Pine Beetle Attack*, Research Note RM-448.
- ☐ Other ______

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Please send the following Intermountain Station publications:

- ☐ "Reclamation: before a single grain of dirt is moved", a video tape
- ☐ *Responses of Grass Species to Tree Harvesting in Singleleaf Pinyon-Utah Juniper Stands*, Research Paper INT-334
- ☐ *The Limits of Acceptable Change (LAC) System for Wilderness Planning*, General Technical Report INT-176
- ☐ *Managing Intermountain Rangelands—Research on the Benmore Experimental Range, 1940-84*, General Technical Report INT-175
- ☐ *Native Shrubs: Suitability for Revegetating Road Cuts in Northwestern Montana*, Research Paper INT-331
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