It is to be hoped that in time other sections in the Arts and Letters will be added to the scientific group and thereby contribute further in disseminating information concerning the state as a whole. The Greater University of Montana has aided the Academy in publishing its transactions. This financial assistance has been greatly appreciated by the members of the Academy since it has assured publication being continued during the war years. The plans for future meetings are tentative but it is hoped that continuity can be maintained for the duration. The present officers of the Academy are: President: Dr. D. Q. Posin, Montana School of Mines; Vice President: Dr. Harold Chatland, Montana State University, Dr. J. J. Livers and Dr. Ellsworth Hastings, Montana State College; Secretary-Treasurer: Prof. Melvin S. Morris, Montana State University.

The Academy of Sciences in Montana will foster interest in regional and national scientific organizations. As the benefits of the state organization become apparent, members will see the opportunity for securing further stimulus and understanding in other scientific groups. State academies can act as clearing houses for problems of their individual states. Those problems which are of regional interest may then be taken to meetings of the Northwest Scientific Association. Many members of the Montana Academy of Sciences are at present members of the Northwest Scientific Association and participate in their meetings and organization.

PRINCIPLES OF FUEL REDUCTION

C. K. Lyman

Associate Silviculturist, Northern Rocky Mountain Forest and Range Experiment Station

All foresters, ecologists, botanists, and wildlife experts in the northern Rocky Mountain region are familiar with the tangles of snags, windfalls, and other forest debris covering small patches to large portions of our forests or wildland area. Created by past forest fires, by insect epidemics, disease, and sometimes by logging, these concentrations of fuel for future forest fires not only constitute a perpetual fire menace but also interfere with the future productivity and best use of lands.

Fire protection costs are increased through the necessity of maintaining fire lookouts, smokechasers, firefighting crews, and roads and trails in the vicinity of such bad fuel areas. Firefighting costs are greatly increased due to the extreme difficulties of fire suppression when lightning or man starts a blaze within these bad fuels. The possibility of maturing the young trees which regenerate on such areas is greatly diminished. The safety of all surrounding timber is decreased. Neither livestock nor wildlife can fully utilize the forage within such tangles of windfalls. And the hunter, the fisherman, or the mountaineer attempting to cross such an area is seriously impeded in his or her enjoyment. Analysis of methods, costs, and benefits is likely to show that removal and the breaking up of bad snag patches and concentrations of dead ground fuels is the most economical means of correcting these unfavorable conditions.

POST-WAR OPPORTUNITY

Removal or reduction of these bad fuels, which are actually much more than a fire menace, should prove to be one productive and beneficial use of post-war labor. Tens of thousands of acres will probably need the work of hundreds of thousands of man-days. But the selection of the areas to be worked on and the character of the work to be done on each area cannot be left to the personal judgment of each local ranger, supervisor, county commissioner, state officer, or work relief official. There are too many beneficial projects awaiting work to permit the chance of wasteful "leaf-raking."

To establish the criteria which should be used, first in selecting areas worthy of post-war work and second in accomplishing the desired objectives with a minimum amount of work, the Northern Rocky Mountain Forest and Range Experiment Station is now developing what will probably be called the "Guiding Principles of Fuel Reduction." This research in the development of principles has been under way for only a few months. It has the background, however, of many years of research in both fire control planning and fire danger measurement. From those standpoints the principles are quite clear. From the standpoint of economic and social benefits, however, the derivation of principles is not at all self-evident. The present report is therefore intended to be both informational and an appeal for advice.

FUEL REDUCTION METHODS

Several well tested methods of fuel reduction can be employed to meet the local requirements for treating bad fuel messes. A few areas contain merchantable material such as cedar snags which can be utilized for fence posts and shingles, or dead spruce which is still usable for pulpwood. Here adequate fuel reduction can be attained simply by harvesting this still merchantable wood and then disposing of the worst concentrations of debris left after logging. Obviously the greatest benefits will result by using this method wherever practicable. Unfortunately there are relatively few areas where it will be profitable unless the future market for fence posts and pulpwood is better than it was before the war. Eventually technological developments may create a demand for and a practical means of harvesting the masses of dead wood on forest lands. For instance, if chemical conversion of wood becomes highly profitable, operating costs may be sufficiently reduced by developing special machinery such as portable "wood-hoggers" to grind wood into small chips right out in the forest, and big auto-vans to transport the chips direct to the factory "cook pot." When something like this can be done, fuel reduction will become a profitable venture not requiring Governmental subsidy. But until such advancements are made, there is sound justification for using other more destructive means of reducing fuels.

Just falling the snags will suffice on some areas where dead ground fuels of less than average amount are well shaded and protected by dense reproduction. The large volume of dead material on other areas will require snagging followed by carefully controlled broadcast burning. Many tests have been made proving the feasibility of broadcast burning large areas without chancing disaster. A few areas were treated in this manner when the Civilian Conservation Corps was available for such work.

On the very largest bad fuel areas where size prohibits treating the entire area, wide strips will probably have to be cleaned up and later planted with some fire-resistant tree species. Larch is known to be such a species. Careful analysis of local conditions may show that spot burning or the construction of narrow fire lanes will be adequate in other places.

The character and interrelationship of all factors such as fuels, topography, weather, ecology, soil conditions, fire, etc., must be judged when prescribing methods best suited to different localities.

FIRE CONTROL BENEFITS

Probably the most obvious benefit of fuel reduction is the increased chance for successfully controlling fires after bad fuel messes are properly reduced. If man creates easier fuels having few snags in the air and only a small volume of dead fuels on the ground, fewer fast-spreading fires will develop before suppression crews can reach them. Also, more fires can be controlled more easily and more quickly after men arrive because fewer snags have to be felled and good fire lines can be constructed without cutting and throwing out as much debris. All this means savings in the cost of suppressing fires. Other important savings can be made because more severe weather conditions are required before fires will spread dangerously fast in the easier fuels. Fewer smokechasers and fire crews will have to be employed. Fewer facilities such as fire-guard stations, trails, and roads will be needed.

Reliable estimates of these potential savings cannot be made without information concerning the number of large fires and the area of burn that can be avoided by reducing fuels. Past records provide adequate guides for judging this.

From 1931 to 1943 over 690,000 acres were burned on lands protected by the Forest Service in North Idaho and western Montana. More than 80 percent of this burn was created by fires that started in or first "blew up" in fuel types classified as worse than medium, rate of spread and medium resistance to control (Medium-Medium). Even more surprising—60 percent of this 690,000 acres burned was caused by fires starting or "blowing up" in very bad fuel types classified as High-High and worse. Yet these High-High and worse fuels comprise less than 5 percent of the total area protected.

One factor which must not be overlooked in planning for future fuel reduction is Nature's effect on fuels. Special studies have been made to analyze the relative effects of this factor. Nature increases fuel badness for the first few years after dangerous fuels are created. (The period varies from 15 to 30 years.) Then she starts reducing the menace partly by weathering, leaching, and decaying dead wood and wind-throwing snags, and partly by providing shade which itself helps to lower the fuel type rating by maintaining more moist fuels and lower wind velocity. She reduces some by reburning them a second or third time. Today more than 75 percent of the bad fuels created by the 1910 fires have been reduced to the easier fuel type ratings as a result of Nature's own processes. Many of the present-day High-High and worse fuel types are expected to rate less by 1950. Today there are only 647,000 acres of these really bad fuels. By 1950 only about 320,000 of these acres will rate as bad. Close figuring of costs and a willingness to assume some risk may therefore show justification for taking a chance with the bad fuels which Nature herself will reduce within the next few years. One of the first principles of economic fuel reduction is therefore to rely on Nature to do the job, IF she will do it soon enough.

When all physical effects such as the above are properly appraised, economic methods can then be employed to help determine the amount and type of fuel reduction that will create the most benefits per dollar expended.

ECONOMIC APPRAISAL

There was a time—and not so long ago—when the appraisal of needs and justification for public work projects were founded almost entirely on judgment, opinion, or even politics. Needs were expressed in words flavored with "hunch" and "personal preference." The benefits to be derived were considered but only in a figurative and qualitative sense. Recent progress in the science of social economics, however, shows that the responsibilities of promoting maximum public welfare cannot be met without using economic evaluations as a guide in planning and policy formulation.

One primary objective of our fuel reduction study consequently is to select and evolve practical methods of applying economic principles which can be used in making the most accurate and complete appraisals possible. Principles are needed that will enable planners to determine the most favorable relationships between costs and benefits.

Because money is the only commensurable standard of value, costs and benefits should be evaluated in monetary terms whenever possible and practicable. But dollar values should be assigned *only* when the knowledge of fire effects permits reasonably accurate measurement or estimation and when the wildland resources in question are or will be needed and can be made available.

The effects of fire in damaging timber is one factor which can be measured and which can be evaluated in monetary terms if the timber has present or potential merchantability and accessibility. Other evaluable factors are: (1) costs of fuel reduction; (2) savings in fire protection expenditures; and (3) benefits from increasing the volume and quality of timber or from improving range lands. There are other factors, however, which are irreducible to monetary terms. The unfavorable and favorable effects of fire on soil and water yields are factors which existing knowledge and difficulties of measurement do not permit evaluating in dollars and cents. No one has yet discovered a practical means of expressing the monetary value of aesthetics and recreational enjoyment. These irreducibles or intangibles cannot be ignored, but they must be considered, using judgment guided by the best available evidence.

A brief discussion of some important fuel reduction benefits will help to explain the nature and scope of the economics involved. If some large fires can be prevented, a great deal of timber damage can be avoided. The present value of timber that can be saved by fuel reduction now represents one of the major benefits to be obtained. Heretofore timber damage appraisal has not included anything beyond stumpage value. Recent progress in a national fire economics research project under the immediate supervision of Bernard Frank, however, is providing practical means of more fully evaluating the interests of society in the timber killed by fire. Methods are being devised that will permit appraising the net monetary losses not only to the landowner but also to the logging and mill operators, the wage earners, and the service industries such as grocery stores, service stations, and liquor stores dependent upon these workers. The losses in taxes paid by these industries and workers is also receiving attention.

Actually, the effects of fire on the landowner are not fully represented by appraisals of stumpage value alone. The value the landowner receives from salvaging burned timber should be deducted from the loss in stumpage value. His future costs of managing timberlands may either increase or decrease when large quantities of timber are fire-killed. For instance, the need for costly timber cruising may be eliminated, or if bad fuel messes are created the costs of fire protection may be radically increased. Also, management plans may have to be revised. All of these effects must be accounted for if the true influence of fuel reduction are to be judged.

Logging and mill operators always suffer losses whether they own the damaged timber or not. Their profits and operating income are reduced immediately if their crews have to take time out to fight fire. They may have to contribute men, supplies, and equipment to the control of the fire. When large quantities of merchantable timber are lost and cannot be replaced by cutting elsewhere, the output of mills and logging concerns will eventually have to be reduced, and the discounted value of the lost profits should be considered as a part of the fire damage. Of course this loss ordinarily will not equal the gross income loss in the timber business because some of it can be made up by investing money and energy elsewhere. Research is needed to determine how *conservative* estimates of this factor should be made.

Similar losses are suffered by laborers and wage earners. There may be an immediate loss in their income because of work stoppage or wage reductions created by the necessity of fighting fire. Reduced work opportunities or lower rates of pay resulting from timber depletion may cause future income losses. Here again the effects should be moderated to account for alternative opportunities of work in fields other than timber production. Most men will find other employment, and in many cases there will be some earning loss resulting from unemployment while hunting other jobs. Studies are needed to determine just how this factor should be measured.

The earning power in a community has an important influence on the profits of service industries such as grocery stores, garages, and even barber shops. This influence is readily susceptible to evaluation once labor and capital income losses are known.

The sum of all these losses represents the major portion of society's interest in fire-damaged timber. The total amount is likely to equal as much as two or three times the stumpage value. If research proves there is a direct relationship between total public losses and stumpage value, a practical method of appraisal can be devised. Total economic loss can be figured simply by applying a conversion factor to stumpage value.

The public interests in wildland resources other than timber are similar to those discussed above. If the effects of fire on those resources can be measured or accurately estimated, a similar method of evaluating public interests is applicable.

SOCIAL BENEFITS

Important social benefits can be obtained if fuel reduction work is used to provide highly productive post-war jobs for men who want and need employment. The extent of such benefits will vary depending upon the unemployment situation at the time work is undertaken. Some will say, "They are impossible to evaluate." Others who have studied the problem in detail, think reasonably reliable monetary values can be assigned. J. M. Clark[1], who made a comprehensive study of this problem, shows how social or "secondary labor" benefits can amount to as much as 100 per cent of Government relief expenditures. He explains, however, that the secondary benefits decrease with an increase in the proportion of labor outlay to total expenditures. Considering this, Forest Service economists believe 50 percent of the total expenditures can well be charged to the social benefits derived from work such as fuel reduction where a high proportion of expenditures goes direct to labor.

There are economists who believe the social benefits from federal expenditures designed to prevent unemployment are equal to the amount of relief that would otherwise have to be paid to the unemployed. Arthur C. Bunce indicates a preference for this method in his book, "Economics of Soil Conservation." He believes that the net federal cost of unemployment labor is the wages paid *less* the relief costs avoided. The difficulty here, of course, is in estimating the "relief costs avoided."

The additional employment stimulated within the timber industry by logging and milling dead wood from fuel reduction areas also has a social benefit because it helps to avoid the need for relief. Several difficulties of measurement are yet to be solved, however, before this can be evaluated.

Fuel reduction can benefit society indirectly but very materially by reducing tax losses and by helping to stabilize purchasing power. Federal subsidies and costs for relief, roads, schools, etc., eventually increase when the tax income of local governments is seriously decreased and wage earnings are reduced as a result of timber depletion. There are counties in this region where this is evident. But the specific effects are not well known and are only just now being explored by research. Probably several years' study will be required before they can be accurately expressed in monetary terms.

Much investigation and study is needed in regard to the social influences of forests and forest fires. The subject is not only wide open for discussion but needs it. This office will be glad to receive any comments, criticisms, or suggestions if sociologists will begin to take a sincere interest in the subject. Such correspondence should be addressed to the Director, Northern Rocky Mountain Forest and Range Experiment Station, Missoula, Montana.

CONCLUSION

The lack of factual information and specific knowledge regarding fire influences and the techniques of relative social and economic appraisals is a handicap to the development of sound principles of fuel reduction. Estimating and theorizing may have to be relied on more than is desirable. But if the work is done systematically, cautiously, and prudently, the guides that are developed should produce *much* better results than can be obtained by relying on the hurried judgments of many different administrators. The problems of fuel reduction are so complex that busy administrative men can do little more than guess, and such guesses are an obviously inadequate basis for guiding the expenditures of millions of dollars for post-war work.

[1] Clark, J. M. Economics of Planning Public Works. A study made for the National Planning Board of the Federal Emergency Administration of Public Works. U. S. Government Printing Office. 1935.