ECONOMIC TRADEOFFS IN FIRE MANAGEMENT

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ABSTRACT

The economics of fire management involves the interactions of various unquantified sets of probabilities. In the absence of a planned input of fire, any wildland area will involve some set of probabilities of developing various characteristics in the absence of fire which man may consider as either costs or benefits depending on his objectives, and another set of probabilities of the occurrence of wildfires of various sizes and intensities which will change the set of probable outcomes.

The introduction of the planned use of fire into such a system will change both of these sets of probabilities. Fire management will involve costs such as the direct costs of the burning program, the probabilities of escape, the overhead costs of the planning and administration, and direct detrimental effects including contributions to air pollution and adverse effects on vegetation and soil characteristics. This use of fire will also involve consequences such as reduction in fuel volumes, the alteration of successional patterns, changes in appearance, modification of infiltration and runoff relationships for precipitation, and changes in the danger of damage to improvements from conflagrations. These consequences may be classified as either costs or benefits, depending on their nature and their relationship to managerial objectives. Uncertainty is an overriding characteristic, which in an economic sense must be classified as a cost.

There are urgent needs for changes in land management practices and for effective fuel management, both of which potentially can be achieved by fire management. Alternative manipulation methods, including mechanical means and the use of chemicals, are not complete substitutes and involve very different cost and benefit patterns. Economically as well as ecologically, the only wholly defensible generalization about fire management is that each case is unique and must stand on its own.

INTRODUCTION

Several years ago I was the leader of a research group studying the economics of wildlife control in California. Since fire control expenditures are made for the purpose of reducing the area burned and the extent of fire damage, we were interested in determining the decrease in burned area which would be associated with a given increase in control expenditures. First we ran a simple regression showing area burned as a function of the level of control expenditures. The relationship was strong, but unfortunately the results showed that the greater the expenditures on fire control, the greater the area burned.

This was easy to explain. Obviously in the years in which climatic conditions and other factors resulted in large fires, great increases in expenditures were necessary in the control effort. Our problem was to allow for the various forces which led to an increase in the wildfire workload so that we could net out the effect of control expenditures in decreasing burned area. We approached this through multiple regression methods, spending six months developing quantitative records of as many variables as possible. The final outcome of all this was a result showing no relationship whatever between control expenditures and the area burned.

While all this was disappointing, none of it was surprising. Results such as these have been obtained in many studies of fire economics. The unpublished literature of research in this field is surely far greater than the published literature.

Such results are significant to my topic in this paper, for they illustrate what I believe to be the dominant characteristic of the economics of fire management. This is the total inadequacy of the data of fire management as a basis for developing sound quantitative estimates of the relationships involved. The technical problems of economic analysis of fire phenomena are abundant, but in a sense they are of little consequence so long as we are unable to demonstrate and quantify the physical and biological relationships which are involved. My remarks here will be in large part an elaboration of this theme.

THE CONCEPTUAL FRAMEWORK

Consider, for example, any forest area or other wildland vegetation system, which is currently under a management regime which does not include the prescribed use of fire. This vegetation may follow any one of a number of widely varying patterns of development over any particular period into the future which may be of interest. The present vegetation may develop wholly unmodified by fire. A series of light wildfires may reduce the litter, substantially alter the understory, and have little or no effect on the overstory. A major conflagration may completely eliminate the present vegetation, setting the stage for the processes of secondary succession. A whole series of other events may occur, any one of which would substantially alter the outcome. To the extent that our knowledge is adequate, we should be able to describe this set of possible outcomes and estimate the probability that each possible outcome will actually be realized.

Now assume that prescribed burning is introduced into this vegetation system as an element in a revised management regime. Presumably the entire set of possible outcomes will be changed by this introduction of fire management into the system. There will now be no chance that the vegetation will develop wholly unmodified by fire. The extent of modification will, of course, depend in part on the type of burning which is prescribed and the manager's success in holding his fire within the limits of his prescription. In addition, the probabilities of the occurrence of various wildfire patterns will also be altered. The probability of a sequence of light wildfires will be modified in one degree. The probability of a major conflagration may also be modified, probably to a different degree. Again, if our knowledge were adequate, we should be able to describe this new set of possible outcomes and estimate the probability that each possible outcome will actually be realized.

Thus, in introducing fire management into various land management regimes, we do not replace one certain outcome by another certain outcome. Instead, we replace one set of widely varying possible outcomes, each with its own probability, by another set of possible outcomes.

Each of these sets of possible outcomes and the various inputs which are required by the related management regime serve to define the physical production function for that management regime. From the economic standpoint, all of the inputs constitute costs. The individual elements of each possible outcome may constitute additional costs, because of being adverse to the interests of management, or may be considered as benefits, because of being favorable to the interests of management.

If the production relationships were known with some reasonable degree of detail and reliability, the task of economic analysis would involve the appraisal of the amounts of the costs and the benefits associated with each possible outcome. Using some appropriate means for weighing each possible outcome by its probability of occurrence and discounting back to the present, it would then be possible to estimate the present value of the benefits and the costs of the set of possible outcomes associated with each management regime. If the regime involving prescribed burning had a higher benefits-cost ratio than the alternative regime, it would be the economically preferable of the two management approaches. I should hasten to add that in making such an analysis, the economist would encounter a great many problems in the pricing of goods and services which fall outside the market system and in determining the appropriate means of weighting the various possible outcomes.

Obviously, other management alternatives should also be considered. Fuels can be modified and successional patterns altered by mechanical means or by chemical treatments as well as by prescribed burning. Various combinations of mechanical, chemical, and prescribed burning treatments are also possible. A full economic study will require analysis of the various management approaches which preliminary investigations and past experience indicate may be feasible.

On the other hand, if production relationships have not been established, the economist has no basis for proceeding with an analysis and instead must fall back on two alternatives, neither of which is particularly satisfying. He may resort to the building and analysis of models of fire management, as in this paper. Alternatively, he may try himself to develop estimates of the physical production relationships, in which case he quickly moves out of the area of his specialized competence.

While there are a wide range of specific objectives which may lead to the prescribing of fire as an element in a management regime, they can be aggregated under two main headings for purposes of discussion. One general purpose is to reduce the costs associated with wildfire control and damage by reducing fuel volumes and modifying fuel structure on the management unit. The other general purpose is to alter the successional sequence to favor the development of some condition desired by man, such as the establishment of regeneration of a desired species, increasing the carrying capacity for deer, or enhancing the aesthetic and recreational attributes of the area.

My comments to this point have been intended to set the general conceptual framework for economic analysis of the prescribed use of fire. In the balance of the paper, I will elaborate on some of these elements.

SOME COSTS OF PRESCRIBED BURNING

The prescribed use of fire involves a number of direct costs, which are generally recognized and easily appraised. These direct costs include the costs of men and equipment used in the burning operation and the cost of fire control equipment held in a stand-by condition to limit the possibility of escapes. They also include advance preparation of the area for burning by means such as mechanical crushing or spraying with herbicides.

In addition, there are various overhead costs, indirect costs, and costs associated with undesired effects of the prescribed fire. It is my impression that these additional costs greatly outweigh the direct costs in many situations, yet I have not seen any empiric studies which provide adequate coverage of all these cost elements.

The costs of planning and scheduling the burning operations and of shifting men and equipment to the burning site are typical of the overhead costs involved. The costs of shifting men and equipment and holding them in a stand-by status can mount rapidly when unexpected meteorological conditions force the last-minute cancellation of burns. Generally such costs will not be high in small operations in which there is a high mobility in work assignments, but they are likely to increase significantly with the loss of flexibility which is often found in larger and more complex administrative organizations.

Another major cost consideration is the risk that the fire will escape and burn beyond its planned limits. Again we are dealing with a whole set of possible outcomes, each with its own probability. There is some, usually quite low, probability that the prescribed fire will become a major conflagration covering a vast area. There is another, usually appreciably higher, probability that the fire will spread over the control line and burn a small additional area. Every program of prescribed burning in the western United States with which I am familiar, whether for debris burning, reservoir clearing, slash disposal, range improvement, or fuel reduction, has a long history of escapes of various sizes, including some fires of major proportions.

The cost of this risk could be measured by the aggregate of the costs associated with each of the possible escape outcomes appropriately weighted by its probability of occurrence. Even a very low probability of a very high cost can be a significant cost factor.

Obviously the costs associated with any given escape will depend upon the nature of the area which is burned and the intensity of the fire. In this regard the changing patterns of land use which are now taking place are acting to increase greatly the costs associated with escapes. The fragmentation of land ownership and the development of houses and other improvements in broadly scattered locations in wildland areas is becoming a major deterrent to many programs of prescribed burning.

Another cost of rapidly growing importance is that associated with smoke and contributions to air pollution. Until recently little attention was given to this, although resort operators complained that their trade was adversely affected by smoke from prescribed burning and the effectiveness of fire detection systems was often reduced by the haze from such fires. Whatever cost was involved was manifested in environmental degradation and was not borne by the individual landowner.

Currently organized society is no longer willing to accept such contributions to air pollution and is moving to restrict the practices of landowners. In the United States a number of the individual states are imposing increasingly restrictive limitations on the conditions under which agricultural and wildland burning may be conducted. There are requirements both for the advance preparation of fuels and for sharp limitations on the meteorological conditions under which burning can be conducted. In addition, it now appears probable that the Environmental Protection Agency will move to impose national standards on such open land burning, and that in doing so the Agency will place the burden of proof on the landowner.

Such controls obviously act to increase the direct costs of prescribed burning. In addition, they act to modify, and commonly to increase, the costs associated with scheduling problems and with the risk of escape.

The argument is often made that prescribed burning is not a major contributor to smog and that, in any case, the trade-off between the contributions to air pollution from prescribed fires and the reduction in air pollution due to reduced wildfires is favorable on balance. While the argument has some merit, it suffers from three major flaws. First, there are inadequate data to demonstrate that prescribed burning does, in fact, result in a net reduction in air pollution through reductions in wildfires. Second, there are alternate means of modifying fuels which should also reduce wildfires and which would not themselves contribute smoke to the atmosphere. Third, organized society does, through its legal institutions, place a responsibility on the owner for the results of his prescribed fires and does not place an equivalent responsibility on him for wildfires, except under special conditions of negligence contributing to the development of hazardous conditions.

Finally, there are the whole series of costs associated with undesired consequences of the prescribed use of fire. Examples of such undesired consequences include the killing of regeneration which is desired, the loss of nutrients either directly in the combustion process or indirectly through accelerated runoff, the development of fire scars on crop trees, and loss of aesthetic quality during the period in which evidence of the fire is readily visible. Obviously, the magnitude of such costs will vary tremendously both with the success of the prescribed burning and from property to property.

THE EFFECTS ON WILDFIRE PATTERNS

One of the primary sources of the present high level of interest in prescribed burning in North America is the seemingly intractable problem of wildfire control. Conventional fire control programs were initially highly effective in reducing losses to fire. However, efforts to meet the problems of the 2 or 3 percent of the fires burning under extreme conditions through further intensification of these measures seem to involve operating in the zone of rapidly diminishing returns. At the same time there is abundant evidence that in many regions there is a growing problem in the accumulation of dangerous fuels as a result of the past successes of the fire exclusion policy combined with successful forest regeneration programs, extensive logging operations, and similar effects of man on the land. Further, some types such as chaparral are increasingly being recognized as fire climaxes, in which the natural development of the vegetation involves an accumulation of fuels to such a degree that fire becomes the natural element for initiating the replacement of an overmature stand of brush by a newly established stand of brush.

Out of all this has come a general recognition that fuel modification and management may be essential to the achievement of any major improvement in current efforts to control the wildfire problem. The concept of comprehensive fuel management programs involves a great many forms of action other than the direct reduction of fuels. However, prescribed burning is being given particular attention, since it is a very direct method of achieving fuel modification and throughout the ages has been man's traditional tool for this purpose.

The nature and extent of fuel modification resulting from prescribed burning will, of course, depend on the type of vegetation and the way in which fire is used. In such instances as slash burning or brushfield operations, the usual pattern is to have the fire extend throughout the fuel structure and consume a major portion of the fuel volume. In forest stands, in contrast, the usual pattern involves a substantial reduction of ground fuels and a break in the continuity of fuels between the ground and the crowns of the dominant trees, with very little effect on the overstory itself.

The logical results of such fuel modification should be a reduction in the occurrence, intensity, and rate of spread of wildfires and an increased ease of control of such fires. However, we have very little hard evidence as to extent and significance of such changes. We need to know not only what the effect will be under the "average bad" conditions beloved of fire control planners, but also what the effect will be under the extreme conflagration conditions which are the primary source of fire damage in much of North America. Evidence on this latter point is extremely fragmentary and has been subject to widely varying interpretations depending on the predilections of the interpreters.

These comments have been directed to ignorance as to the specific effects of fuel modification by prescribed burning on specific areas. Such ignorance is at least equalled by ignorance at the programmatic level. In a real sense, any program of prescribed burning for fire control purposes involves the substitution of fuel consumption by planned fires for fuel consumption by unplanned fires. But where do we come out on balance in any such process? There is a need for some broad ecosystem-type analyses covering broad areas and designed to estimate the total areas burned, the volumes of fuel consumed, and the calories of heat released over a period of years by wildfires in the absence of of prescribed burning as compared to similar data for the effects of an extensive prescribed burning program plus the residual wildfire effects. Obviously such overall effects are only a part of the story, but they are a part which I have yet to see discussed in analytical terms.

A third significant area for inquiry is that of the duration of the effects of prescribed burning. Some investigators have argued that prescribed burning results in accelererated rates of needle and twig fall and the accumulation of bark scales and other litter, which very quickly replace the fuels removed in the burning operation. Others contend that once some degree of fuel control has been achieved, it can be maintained readily through subsequent broadcast, low intensity fires. In any case, it is evident that knowledge of the duration of the beneficial effects of fuel reduction by prescribed burning is of critical importance not only to estimating the magnitude of these benefits but also to estimating the re-burning cycle that will be required and the related level of cost. And it is equally evident that in many regions of North America we have little definitive information on these points.

THE EFFECTS ON SUCCESSIONAL PATTERNS

In addition to its role in modifying fuels, prescribed fire is a highly important tool in in the processes of ecological manipulation involved in wildland resource management. It may be used to clear freshly logged sites for planting or as a stage in the conversion of brushfields to grasslands or to forest plantations. It can be used to control certain plant diseases. It can be used to favor one species over another in mixed stands. Indeed, the potential uses are nearly as varied as the vegtation types in which fire can be applied.

A large number of historical ecological studies have now clearly established that fire was a far more pervasive and significant factor in the vegetation of North America when European man first arrived here than was formerly believed to be the case. Many of our important vegetation types are in large degree fire types. The exclusion of fire can thus be interpreted as the exclusion of a natural factor, with far reaching effects on plant succession.

It is not clear, however, that this concept of fire as a natural factor in North American vegetation has any particular economic significance. The vegetative systems in which fire is prescribed today are quite simply not the same as the systems in which fire had its pre-European man role. The forest regions in which prescribed burning is of interest today represent areas subject to extensive logging, to precommercial thinnings, to applications of fertilizers and herbicides, to artificial regeneration practices, to plowing, discing, and other mechanical manipulations, to deliberate policies of either fire exclusion or regular burning, and generally to modern man's values and devices -- all of which are factors which were not in effect in the period in which fire could be considered a natural force.

Thus the central question is not the past role of fire in shaping the natural vegetation, but the present and potential role of fire as an element in vegetation management systems potentially involving all of these other forces.

Prescribed fire is simply one among many devices which man uses in attempting to modify successional patterns so as to increase the yield of those values which he desires. While its effects may be more complex than those of many of the other forces, it must be evaluated in each specific context in much the same terms as other possible management inputs.

Under intensive forest management, the need for the prescribed use of fire for ecological manipulation seems likely to be less than under extensive management. The intensive utilization which accompanies intensive management eliminates much of the residual material which in the past was a primary fuel of prescribed fires, while direct means are used in controlling species composition, spacing, and similar aspects which in the past have been indirectly controlled to some degree by fire.

SOME ALTERNATIVE MEANS

As I have mentioned at a number of points in this paper, there are various other methods of reducing and modifying fuels and modifying successional patterns in addition to prescribed burning.

The most widely used alternatives are various mechanical methods. The axe, the saw, the tractor equipped for crushing brush or slash, and the chipper are obvious examples. Other devices are being developed in response to mounting needs. In contrast to prescribed burning, the direct costs of using these mechanical means tend to be the major part of their total costs. This has often seemed to place such methods at a disadvantage relative to fire, since the indirect costs of fire have frequently not been recognized.

Whatever the balance between the two approaches today, it seems likely to move increasingly to favor mechanical means. I make this prediction in part because of the expectation that technological progress will be more rapid in equipment development than in prescribed burning methods. In much greater part, however, this prediction is based on the obvious trend of organized society to force the managing agency to bear the indirect costs as well as the direct costs of the operation and on the related growing importance of using methods which can be closely controlled.

The other major set of alternatives involves the use of chemicals. Here the situation is more confused, because we are now in a period of mounting public concern that chemicals may involve subtle but far-reaching side effects. Further research may either dispel or confirm such fears, and research may also develop alternative chemicals which are more acceptable in terms of potential indirect costs. At present, however, the effect appears to be to favor the use of prescribed fire in situations in which it is an alternative to chemical applications.

CONCLUSIONS

In concluding, I would like to emphasize that since primeval times the deliberate use of fire has been one of man's most powerful tools in managing the land. Prescribed fire remains today as potentially one of our most powerful tools in responding to two major problem areas in wildland resource management -- the management of fuels, to enable a greater degree of control of the wildfire problem, and the manipulation of ecological forces to favor successional patterns desired by man.

The economic case for the use of prescribed burning, however, is marked by major uncertainties. These uncertainties greatly reduce our effectiveness in using fire.

In these comments I have approached the economics of prescribed fire in the conventional framework of benefits-costs analysis. However, I have also stressed that the problem must be approached in the framework of multiple possible outcomes, each with its own probability. Our present inability to specify these possible outcomes and to estimate their individual probabilities of occurrence, both with and without the inclusion of prescribed burning in the management regime, was emphasized as a primary and major barrier to effective economic analysis in this field. Thus I have directed the major part of my paper to a discussion of the production relationships which are basic to economic evaluations.

Economically as well as ecologically, each case of prescribed burning is unique in some attributes and must stand on its own. The elements which have been presented here should all be considered in the judgment process on which we must rely in major degree, since we are unable to quantify any appreciable part of the relationships involved.

I believe this analysis also demonstrates the key importance of developing better prescriptions for prescribed burning. The indirect costs of this practice are in large part the consequence of uncertainties in its use. Greater knowledge of the effects of various intensities of burns combined with greater ability to control the intensity of the fire can serve both to reduce the costs and increase the benefits of prescribed burning.

This also appears to be the only route with promise to maintain prescribed burning as a management option in the face of rapidly intensifying public regulations of all processes resulting in emissions into the atmosphere. This issue may well be the key to the future economic role of prescribed burning in wildland resource management.

ALTERNATIVES TO CONFLAGRATION

Use of Fire in Canadian Forests

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ALTERNATIVES TO CONFLAGRATION (cont'd)

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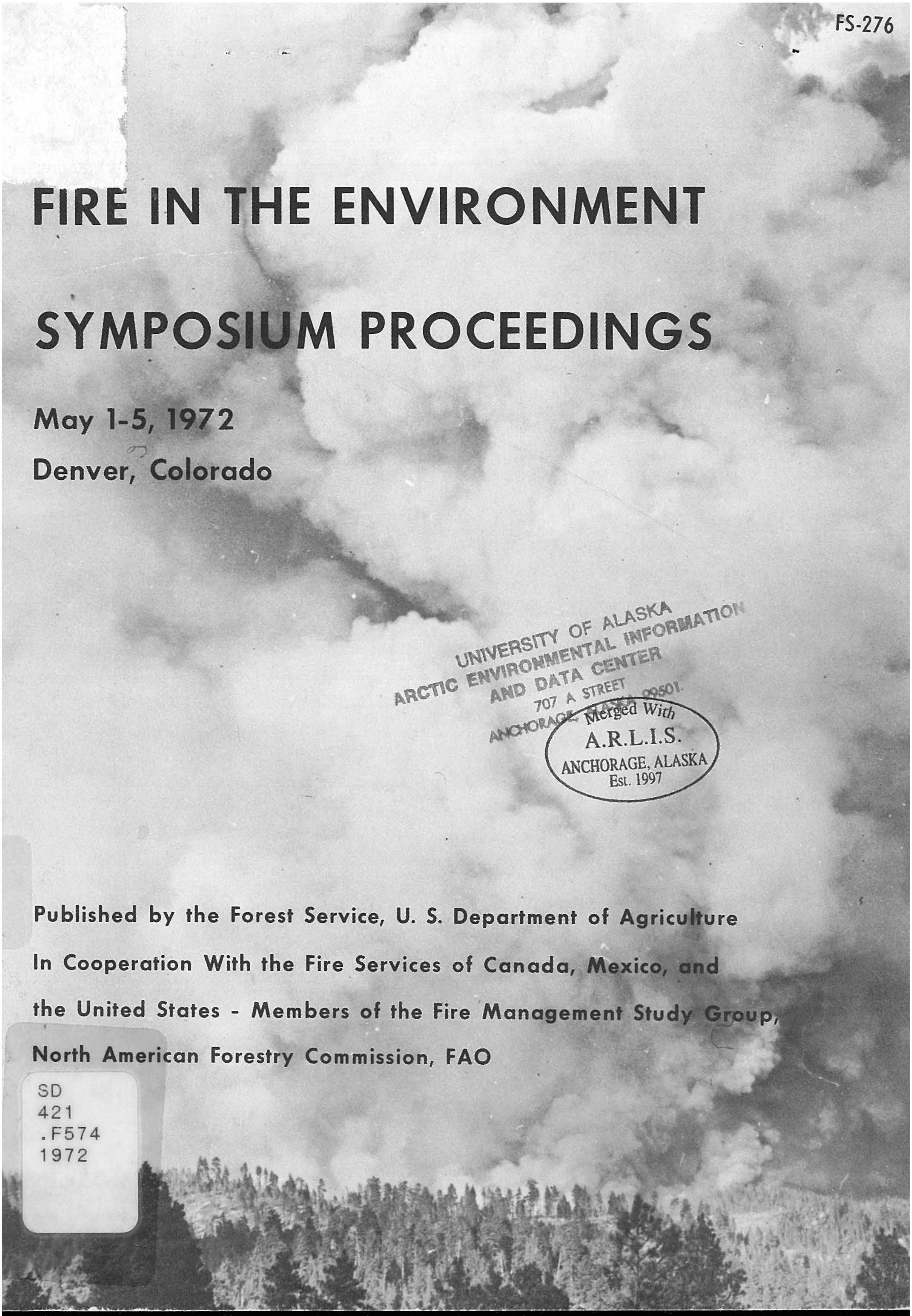

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