An Expert System for Prescribed Burning of Rangelands

Henry A. Wright, James R. Burns, Hwalsik Chang, Keith Blair

Prescribed burning is an effective tool to improve rangeland—remove litter that inhibits plant growth, increase forage yield, improve forage quality, control brush species, and manage species composition. However, many land managers are afraid to use fire. In order for prescribed fire to be more widely used, we need to quantify expert knowledge and find a way to transfer this knowledge to beginning burners in an easily learned and usable form. This paper explains the development of an expert system [A computer system consisting of expertise (in a knowledge base) and an inference processor that is able to infer conclusions from the expertise] for rangeland burning that is based on 30 years of experience. It is user friendly and can greatly aid the training of students as well as assist experienced burners.

This expert system consists of Pre-Burn Planning, Blackline Burning Feasibility, Blackline Operation Optimization, and Headfire Burning Feasibility. Still under development are Burning Area System, Learn About Prescribed Burning, and Weather Analysis. This system is being developed by the Department of Information Systems and Quantitative Sciences and Range and Wildlife Management at Texas Tech University. It will be nearing completion in fall, 1992, and is being field-tested in 1992. It should be available for marketing in spring, 1993.

Several other research groups have endeavored to develop expert systems for prescribed burning, including a Canadian group, McRae et al., 1991, and an Australian group, Ludwig 1988, 1990.

The Canadian Prescribed Fire Ignition Expert System (PFIES) is in the development stage. It will be designed for planning any prescribed burn that utilizes the Canadian Forest Fire Weather Index System in setting the weather prescription (McRae et al. 1991). Main goals of PFIES are to have good fire coverage over the burn area and to maintain safety (control) of the burn.

SKRUBKILL (Ludwig 1988, 1990) and MALLEEFIRES, a derivative of SHRUBKILL (Ludwig et al. 1990), are decision support systems which provide expert advice on the use of the fire to control non-desirable shrubs in the semi-arid woodlands of eastern Australia. Each of these support systems consists of three modules: BURNTIME, to get advice on whether and when to burn; BURNWAYS, to get advice on how to burn and; BURNECON, to get a cost-benefit analysis for the planned burn (Ludwig 1988).

Authors are with the Department of Information Systems and Quantitative Sciences and the Department of Range and Wildlife Management at Texas Tech University, Lubbock 79409. This project was funded by the Higher Education Coordinating Board for Texas, Advanced Technology Program, Roger Elliott, Assistant Commissioner. This is Journal Article T-9-634 of the College of Agricultural Sciences.

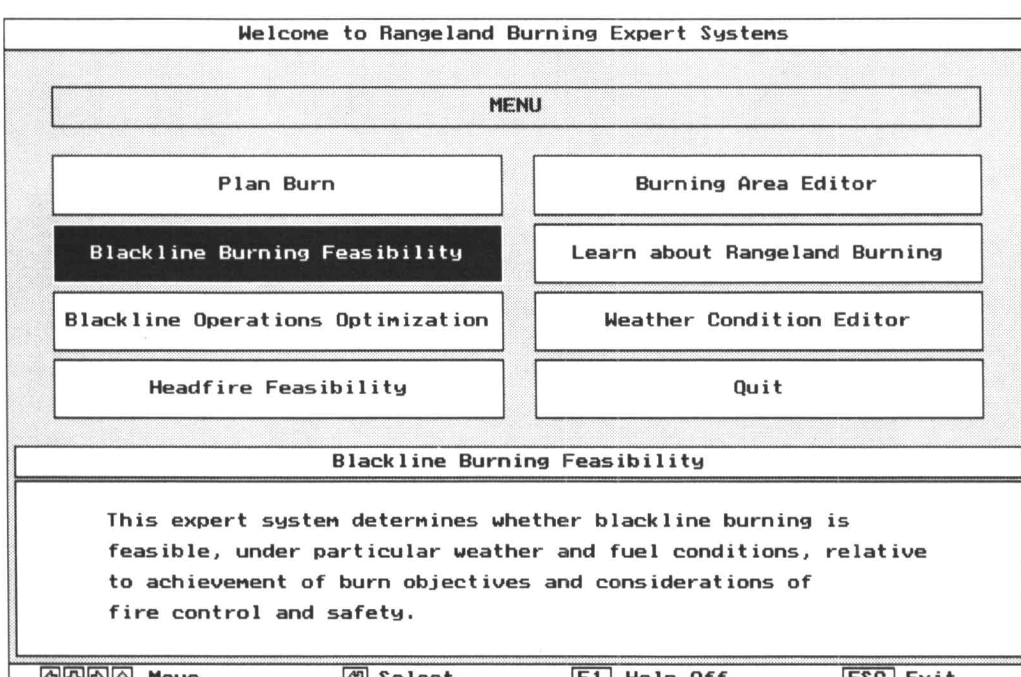

Fig. 1. *The computer screen, highlighting the Blackline Burning Feasibility Unit.*

BURNWAYS is described as a comprehensive information base on how to plan and safely conduct a prescribed fire in a target paddock. The consultation with BURNWAYS is described as lengthy. No details are given as to its knowledge base, output, or technique for burning.

Expert System

Our expert system is applicable to high and low volatile fuels (high volatile fuels will give off fire brands that are capable of starting fires), can be used by hand crews for manual burning and/or by a helitorch unit for burning by helicopter, and is sensitive to unit size and fuel types. Written for IBM compatible microcomputers, this system will have broad application for many fuel types in the western and central United States and should be especially useful to teach beginners in prescribed burning and be an aid to those with intermediate fire experience. The system is intended for use in pre-burn planning as well as initiation and execution of the actual burn in real-time (the expert system is able to return actions and decisions sufficiently fast to be used on-line in the field).

The total expert system will eventually have nine units as outlined in the introduction. Figure 1 illustrates the computer screen, highlighting the Blackline Burning Feasibility sub-unit. Each sub-unit of the expert system is briefly described as follows:

Pre-burn Planning System—evaluates the economic feasibility of prescribed burning, determines width and location of blacklines, and provides a checklist to follow before burning blacklines. Includes special prompts for equipment lists, notify sheriff, how to mop up, etc.

Blackline Burning Feasibility System—evaluates the risk and effectiveness of blackline burning based on weather conditions, ten-hour fuel moisture, day or night, green-leaf shrub moisture, fuel volatility, fuel loading, topography, and proposed ignition methods.

Blackline Operation Optimization System—determines the order for burning different fuel loads as sub-units in blacklines, the inferred smoke direction, and the most effective locations for helipads and suppression crews based on size and shape of the burning area.

Headfire Burning Feasibility System—evaluates the weather conditions, ten-hour fuel moisture, natural fuel breaks in headfire area, and width of blackline to determine whether a headfire will be safe and effective.

Burning Area System—gives us the ability to delineate the shape of a pasture to be burned, draw location of helipads and water sources, and note special areas.

Learn About Prescribed Burning—this is a menu and hypertext knowledge subsystem. If you want to know the definition of blackline, equipment, headfire, helitorch, etc., just place the cursor over the word in the menu, and it will give you a definition.

Weather Analysis System—gives us the ability to predict on-site changes in air temperature, relative humidity, and wind speed based on current weather conditions and time of day.

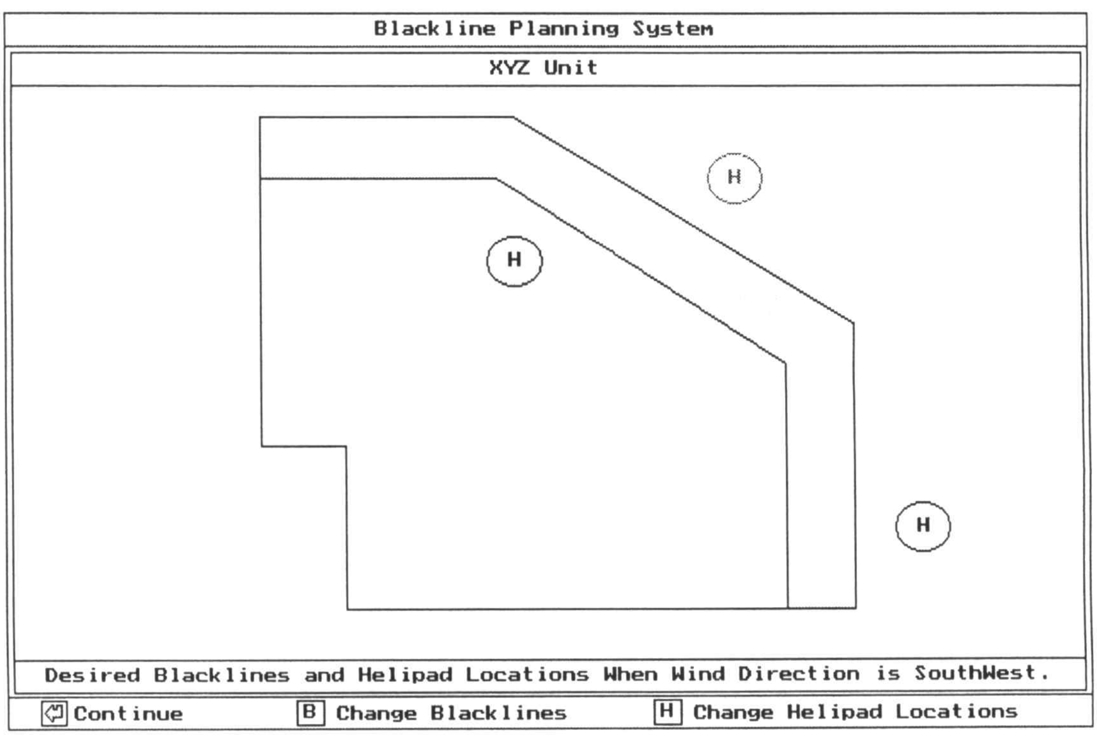

Fig. 2. *Display of the location of blacklines and helipads given weather and region, shape, and other considerations.*

Each of these subunits is described in greater detail below:

Pre-Burn Planning System

In the planning phase sub-unit, the expert system takes the burn planner through all of the details that need to be considered before conducting a prescribed burn. Some details include: rainfall since October 1 (date will vary with region), desired wind direction to burn blacklines and headfires, size of burn unit, dominant fuel type, proposed width of blacklines, fine fuel load, green fuel moisture of living shrub or trees, location of blacklines, location of dozed lines, width of dozed lines, crew size to tion of dozed lines, width of blacklines, crew size to conduct burn, equipment needs, and the need to doze around power lines. This sub-unit also prompts the planner to notify the local fire department, sheriff, and neighbors on the day of the burn, which is usually the responsibility of the landowner. Other factors of importance are the location of roads and natural breaks to assist spot fire attack, the need to cut dozed lines to mineral soil, (these need to be field-checked), and familiarization of the pumper crew with unit roads and boundaries of the burn unit. This information is followed with procedures for "mopping up"—i.e., how to handle smoldering logs and burning debris that are covered with soil, etc., following the burn. Many escaped fires happen a day or so after a successful prescribed burn. Always mop-up after a burn.

The fire planning sub-unit also evaluates the economic feasibility of prescribed burning. To determine the economic feasibility of burning a unit, the planning system analyses various factors, including alternative treatments, rainfall in the previous and current year, fuel type and distribution, alternative grazing pasture, size and shape of unit, and any existing artificial objects within the burning units.

To determine blackline locations, the expert system examines variables related to the prevailing wind direction, topography of the burning area, dozed line conditions and road and any previously burned area. The planning system provides suggestions for many other decisions, such as ignition procedures for blackline and headfire depending on wind direction and fuel loading, crew size determination, equipment preparation, values at risk outside of the burn, and fuel loading outside of the burn area. Finally, the system allows users to learn important facts and rules about prescribed burning.

For example, after you have gone through the steps of planning a burn, the Fire Planning System will ask if you want some "hints for pre-burn preparation." If you do, answer yes. Then it will give you a detailed list of equipment; tell you to notify neighbors, local fire departments and sheriff on day of burn; tell you how to mop up after the burn; give you a list of burning restrictions according to state law, etc.

Typical screen produced by the blackline planning expert system is shown in Figure 2. This screen shows where the blacklines should be placed as well as placement of the helipads.

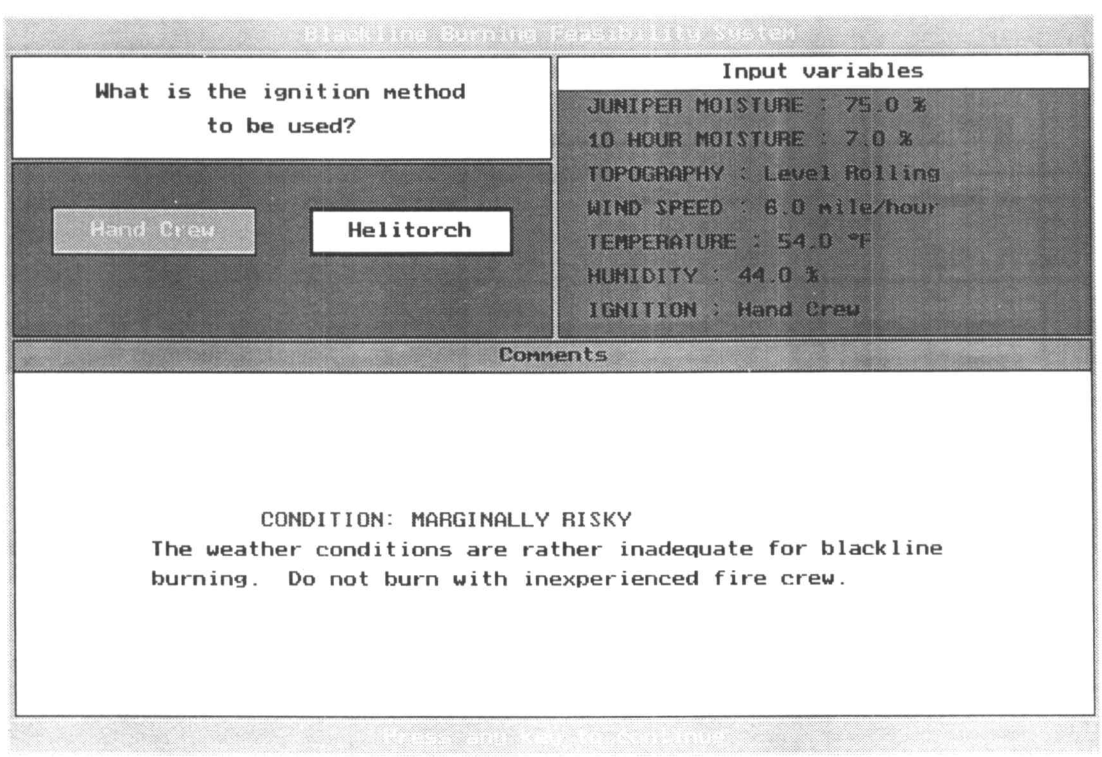

Fig. 3. *User interface (phase 1—query mode) for the blackline burning safety system.*

Blackline Burning Feasibility System

This system evaluates the risk and effectiveness of blackline burning based on (1) weather conditions, such as wind speed, relative humidity, air temperature, sunshine, and 10-hr fuel moisture, (2) rangeland conditions, such as topography, green juniper moisture content, and fuel type and load, and (3) ignition methods. The session with this system requests information for the following items:

Do you expect a cold front moving into the area within 12 hours?

Is the time of the prescribed burn daytime or nighttime?

What is the fuel type?

What is the ten-hour moisture?

What is the percentage of shrub or tree fuel moisture?

What is the topography of the burning area?

What is the temperature?

What is the wind speed?

What is the humidity?

What is the Ignition Method to be Used (Hand or Helitorch)? End of questions.

Figure 3 illustrates how these queries are presented to the user. Based on user responses to these questions the system will infer a burning decision, that is whether burning is feasible or not. Additional output of this system is a verbal explanation of the situation, inference process, and expert system's conclusion. The system will then take you into the next phase only if a cold front is not expected within the next twelve hours, and only if the ten-hour fuel moisture is in the proper range (7 to 11%).

Following the input of all data, a graphic display of five colors (Figure 4) shows the dot location of input data relative to safety risk for burning. As we go from left to right on the 5-color screen, red indicates conditions in which fire brands are certain to cause fires, and it is too dangerous to burn. Yellow indicates marginal conditions for burning. We generally burn under these conditions with hand crews, but narrow the strips for a strip-headfire and put the most experienced person on the lead torch to set the pace. Burning generally proceeds slowly with good suppression crews. Green is OK to burn for safe and effective burns with hand crews or helitorch. Light blue gives conditions in which burns by hand crews will be spotty, but the helitorch will be effective. Dark blue indicates weather and fuel conditions that will stop burning.

The colors on the graphic display are not static. They change according to day or night time, fuel type and volume, topography, and whether ignition is by hand or helitorch. Across the bottom of the screen, wind speed is displayed as a third variable to further assist the fire boss as to how burning conditions will change over time.

The two-dimensional grid of the display plus the wind speed scale displays a lot of information instantly that enables the fire boss to make decisions quickly. For example, if the dot comes up in the yellow area and wind speed is in the yellow area, the fire boss may elect to wait an hour or so to begin burning blacklines so that he has a greater margin of safety against spot fires. He might make this decision because he either has a moderately experienced suppression crew or only has a skeleton suppression crew. When the fire boss elects to begin burning, he should enter current weather and ten-hour data to see if conditions have changed and are now safe. This kind of a support system will greatly assist fire bosses in the con-

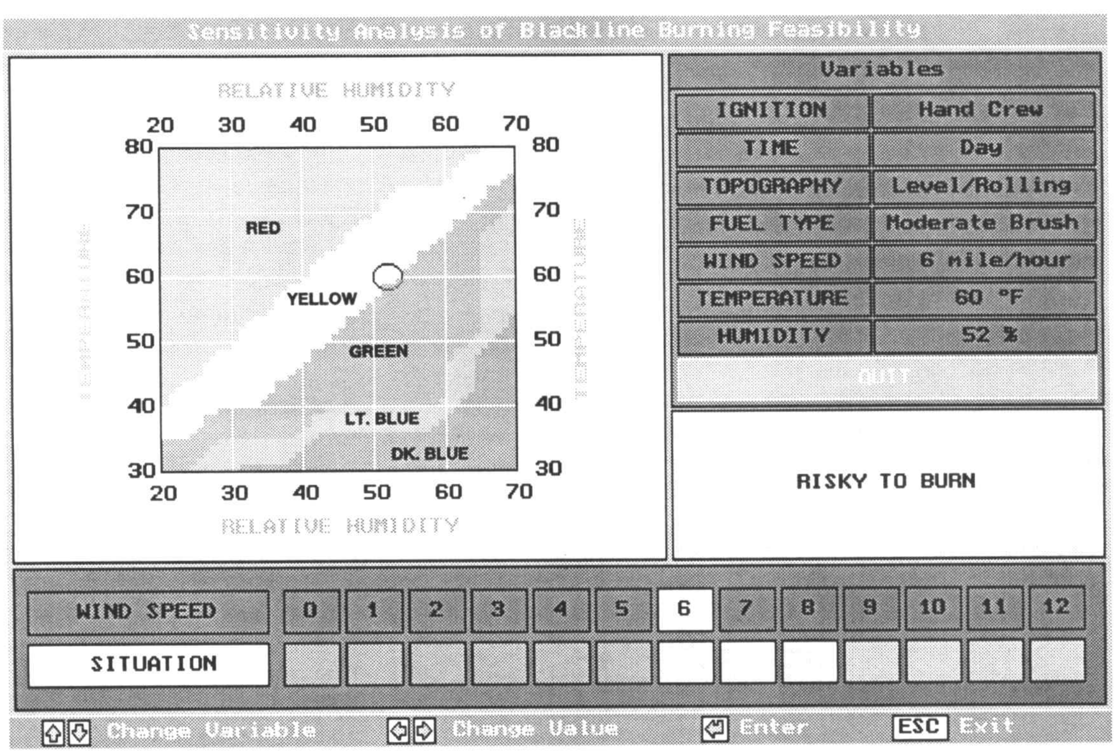

Fig. 4. *Graphic display for weather and fuel variables (upper right of graph) entered.*

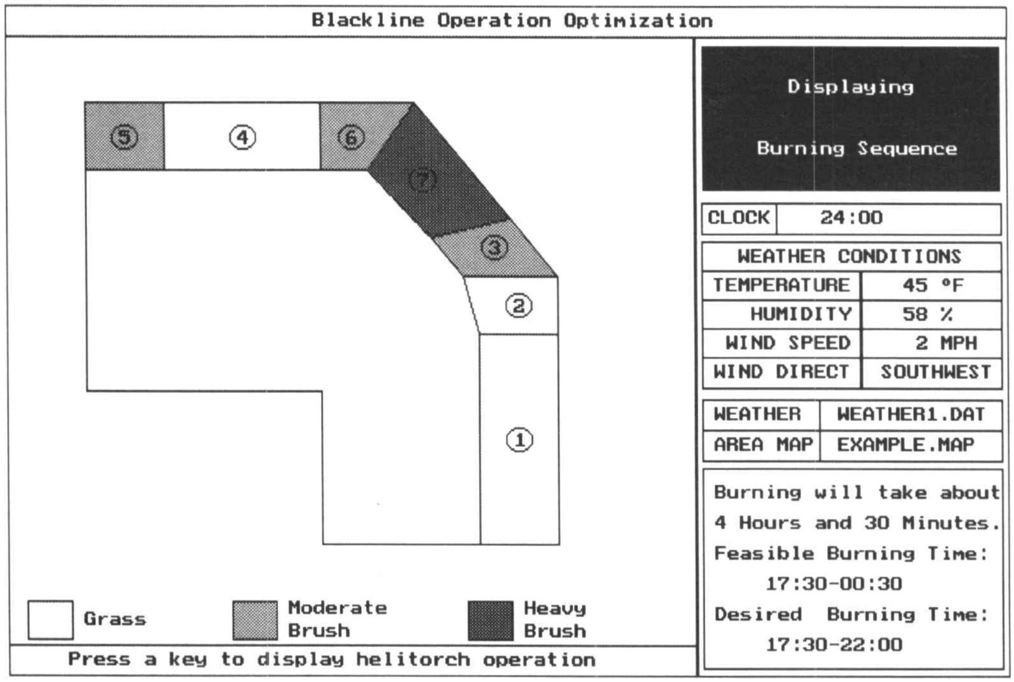

Fig. 5. *Display of blackline operation optimization system.*

ducting of a safe and effective prescribed burn.

This portion of the expert system for burning blacklines has been field-tested and checked with burning conditions for over 100 safe (no spot fires) and effective burns in west Texas. It has also been verified with field data from past fires in which over 50 spot-fires occurred. Our next step is to test this system in other regions of Texas and in other states to verify prescriptions and make refinements. It appears that the current system will have broad application in grasslands and shrub-grasslands of the western and central United States.

When dozed lines are completed around the blackline area, generally a 100 or 400-foot wide area on north and east sides of a pasture, the blackline is divided into subunits according to fuel loading (grass, chain juniper and grass, heavy chained juniper) and topography so that each sub-unit can be burned under the most ideal weather conditions considering safety and effective removal of herbage and dead woody material. For example, grass areas may be burned with the warmest weather in late afternoon, then grass-chained juniper mixtures after sundown, and heavy brush during late evening. This procedure is known as optimizing the burning of subunits in a blackline, which will be discussed in the next section.

Blackline Operation Optimization System

This system provides details as to operation procedure. In what order will subunits of the blackline be burned? How will you disperse your suppression and helipad crews? Where do you place them? Where will you locate the pumper and helipads? What role does crew experience play? Who will have radios? Who will be the lead person on the ignition crew? How will torches be refilled and by whom? Who will watch for spotfires? Who will be ignition boss, pumper boss, and suppression boss? How will crews move if the helitorch is being used to burn blacklines? How and when will blackline mop-up proceed? In the event of a spotfire, how will the spotfire be attacked and suppressed? Information relative to these questions is contained in this system.

After subunits of the blackline have been delineated, their order for burning relative to weather conditions is established (Figure 5). Then the system decides where to initially locate the suppression crews and how their positions will change with the order of the subunits to be burned. If necessary, helipads will be located depending on the inferred smoke direction at time of operation. Lastly, the system analyzes the weather change patterns based on user-provided forecasts and uses them to determine when to burn the different sub-units of the blackline that best utilizes the weather conditions.

Headfire Burning Feasibility System

A program for conducting headfires is being developed that will operate similarly to the program for blacklines. The air temperature is generally 70 to 80° F and acceptability of this temperature range and the associated relative humidity and wind speed depends on volatility of fuel, fuel loads adjacent to the burn, and width of blacklines. Burns can be conducted with hand crews or a helitorch with a "rain-drop ignition pattern." Sometimes blacklines may need to be widened when air temperature is about 65° F on the day of the burn before proceeding with the headfire.

This system uses the same weather, fuel, and topographic variables as in the Blackline Burning Feasibility System. The difference is that weather conditions are more favorable for burning with a headfire in order to get

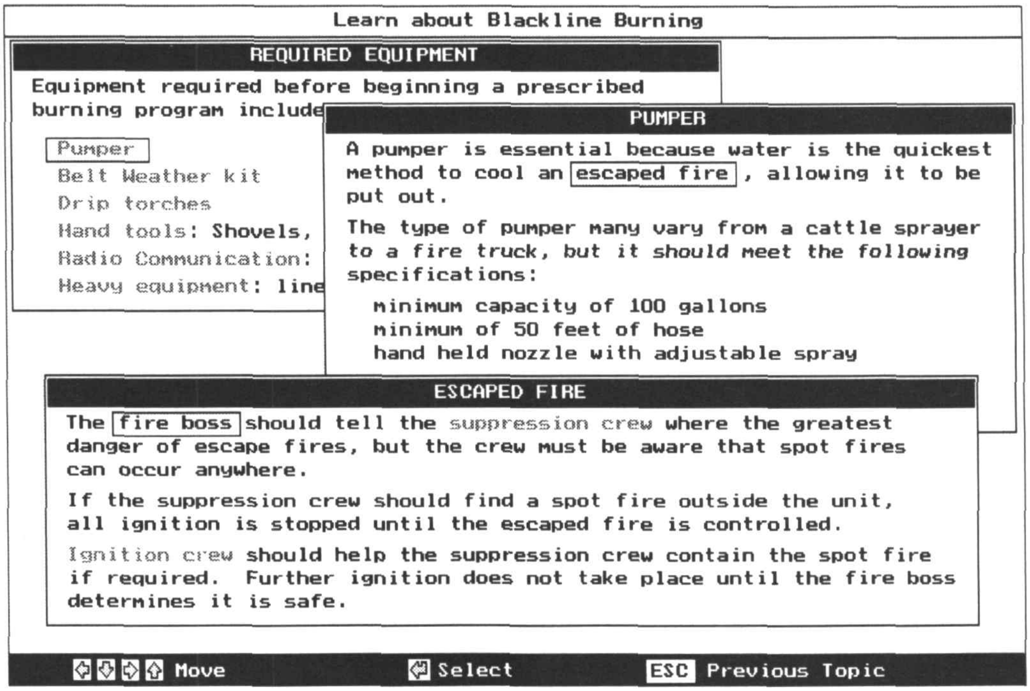

Fig. 6. *Display of Learn about Prescribed Burning.*

an effective burn. The headfire prescription is always dependent on a blackline for the headfire to burn into. The width of blackline needed will vary from 50 to 500 feet, depending on height and volatility of fuel. For example, the blackline width for broom snakeweed-grass is 50 feet, tobosa-sprayed honey mesquite is 100 feet, sagebrush-grass in Idaho or south Texas brush is 200 feet, chained juniper is 400 feet, and dozed juniper is 500 feet. Output is a two-dimensional graph (relative humidity and temperature) with five colors of burning safety plus a windspeed effects bar as discussed in the section on Blackline Burning Feasibility System.

Other subsystems that are being developed are as follows:

Burning Area System

The Burning Area System will allow the user to select or draw a pasture shape with location of helipads, and water sources. It will be used to facilitate generation of the fire plan.

Burning Area System

This system will permit the user to look up the meaning for any of the terminology used in the software program. For example, GRASS is fine fuel in the range of 600 to 5,000 lb/ac and does not contain volatile fuel. DEAD MODERATE BRUSH contains grass and 5 to 20 tons per acre of highly volatile dead juniper that was chained in past years. DEAD HEAVY BRUSH contains more than 20 to 100 tons per acre of highly voltaile dead juniper brush. The system will aid users when there is any question about the meaning of terms. A typical screen produced by the sub-system appears in Figure 6.

Weather Analysis System

Current weather conditions (windspeed, air temperature, and relative humidity) will be used to forecast weather conditions hour by hour for the next 6 to 9 hours. This data will enable the fire boss to determine when burning can begin, what order he wishes to burn different blackline fuels (e.g., tobosagrass-mesquite first, then dead moderate brush, and lastly, dead heavy brush); and how to allocate time for the burning of each of these fuels.

Summary

Thirty years of prescribed burning experience were used to develop an expert system for prescribed burning on rangelands. The system will eventually contain nine sub-units – a Pre-Burn Planning System, a Blackline Burning Safety System, a Blackline Operation Optimization System, a Headfire Burning Safety System, a Burning Area System, a Learn About Prescribed Burning System, and a Weather Analysis System. This expert system will be usable in most grass or grass-shrub fuel types, is applicable to both high and low volatile fuels, and can be used by hand crews for manual burning or by a helitorch. For beginners in prescribed burning and those personnel with intermediate fire experience, this expert system should enable them to learn the art of prescribed burning quickly and to burn with confidence.

This expert system, written for IBM compatible microcomputers, will have broad application in grasslands and grass-shrublands of the western and central United States. It is intended for use in planning the burn as well as initiation and execution of the burn on-site.

User License

Single machine-single user licenses have been granted to the Soil Conservation Service in central Texas, Welder Wildlife Refuge, Utah State University, and University of Idaho to test this expert system outside of West Texas. A limited number will be granted to other potential users upon request.

References

McRae, D.J., B. Todd, and C.J. Ogilvie. 1991. A prescribed fire ignition expert system for Canada. *In:* 11th Conf. on Fire and Forest Meteorology, Missoula, Montana. p. 33.

Ludwig, J.A. 1988. Expert advice for shrub control. Aust. Rangel. J. 10(2):100–105.

Ludwig, J.A. 1990. SHRUBKILL: a decision support system for management burns in Australian savannas. J. Biogeography 17:547–550.

Professional Bias, Public Perspectives, and Communication Pitfalls for Natural Resource Managers

Mark Brunson

I. Recognizing Bias in a Changing Managerial Landscape

Range managers, like other natural resource professionals, sometimes find it difficult to communicate effectively with an ever-broadening range of client publics. Frustrated managers may find themselves blaming certain interest groups, especially those that are relative newcomers to the resource policy debate, for harboring biases that prevent them from accepting "the facts" about natural systems.

Such complaints are not entirely unfounded. But bias is not restricted to any segment or society. We in natural resources have our own characteristic biases. Some are rooted in personal experience, others may be born of long association with the clients we serve. Still others grow out of our professional culture—the way we all are taught to think about natural resources. This paper will examine causes, consequences, and antidotes for bias among resource professionals. As a social scientist who studies forest management issues, I hope to be able to help range managers recognize and avoid the kinds of communication pitfalls that have helped make the debate over Northwest forests so intractable.

Finding the "middle." We live and work in a world that is increasingly polarized. Disputants in resource conflicts typically describe opponents in terms of villainy, taking positions that are increasingly far from the realm of reason or compromise (Clark and Stankey 1991). A National Audubon Society publication introduced the society's television special on public lands grazing with a blaring headline, "Western Range Reels Under Cattle Onslaught" (NAS 1991). It looked like a review of a new horror movie—*Friday the 13th, Part 10: Night of the Living Cow.* Yet environmentalists don't have an exclusive franchise on hyperbole. The article contained this quote by a spokesman for the National Inholders Association, which led a boycott of the Audubon special's sponsors: "By sponsoring this show, General Electric is declaring war on rural families throughout America." That's ridiculous, too. G.E. wasn't declaring war on anyone; it simply wanted to sell products to people who watch Audubon specials.

In such a polarized world, it's easy to take pride in being "in the middle." But the "middle" is a pretty big place. Exactly where in the middle are resource managers? Is our middle the same as "the public's"? Or do our biases put us someplace other than where we think we are?

Vining and Ebreo (1991) recently examined this question in a random telephone survey of Illinois residents. Respondents were asked to rate the importance of various national forest outputs (timber, water, wildlife, etc.). Environmental group members and Mark Twain National Forest employees were also surveyed, and the results were compared.

Managers gave roughly equal weight to every output; i.e., they espoused a standard multiple-use philosophy. However, both the environmentalists and the general public placed greater value on things like wildlife and scenery—the so-called amenities—and less value on

Author is assistant professor, Forest Resources, Utah State University, Logan 84322-5215.

A version of this paper was presented to the Pacific Northwest section, Society for Range Management, Oct. 25, 1991, in East Wenatchee, Wash., under the title "The Role of Personal and Professional Bias in the Range Management Profession."