Prescribed Range Burning

in the Edwards Plateau of Texas

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Cover Photos:

Front - Prescribed burn in previously herbicide treated mesquite-whitebrush near Cotulla, Texas, February 26, 1979.

Back - Vegetation response May 1979 following the prescribed burn of February 26, 1979, near Cotulla, Texas. Note the openness of brush and excellent response of California cottontop (*Digitaria californica*).

PRESCRIBED RANGE BURNING IN THE EDWARDS PLATEAU OF TEXAS

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Prescribed Burning on the Edwards Plateau

Larry D. White

Prescribed burning is not a new range improvement practice to the Edwards Plateau. Before fences and the era of conservation concern against fire on rangelands, many ranchers regularly fired the land to control brush and provide nutritious forage for livestock. The resultant heavy concentrations of livestock and game on recent burns resulted in excessive grazing pressures especially as ranchers shifted to year-round cow/calf production. These abuses and lack of research were major factors leading to discouragement of burning.

The prescribed burning we are talking about is different than just setting fire. We have learned from past experiences, research, etc., how to safely and effectively conduct a burn program as a viable ranch practice.

The burn program goes in hand with total ranch management and planning. Grazing management in particular is vital to successful burning. Since successful use of fire requires grass fuels, grazing has to be planned to allow the fuel accumulation. Also, resting the pasture after the burn allows good recovery.

Due to the rough topography, volatile fuels, shallow soils, etc., prescribe fire must be carefully planned and carried out. Also, the desire to maintain a live oak (Quercus virginiana) savanna appearance in many parts of the Edwards Plateau requires cooler surface fires than in open grasslands. Such fires can be conducted successfully killing small juniper (Juniperus spp.) and improving grass and browse forage quality. These applications appear beneficial to domestic livestock and wildlife production as well as real estate value.

Fires can be used to alter the composition of grasses and forbs in addition to brush control. The season of burning, stage of plant growth, and size of plant as well as firing techniques and conditions used to generate a certain intensity of fire can be planned to best advantage. This is the difference between a prescribed fire and a wildfire.

Ranchers are becoming more interested in burning for range improvement as costs of alternative practices and lack of labor increase. Fire is considered a relatively low cost practice; however, the risk can be high especially when employed by inexperienced personnel.

If burning is to be a viable practice without adverse effects, ranchers, etc., must learn improved techniques for conducting burns. This symposium and efforts of the Texas Agricultural Extension Service range project group are aimed at providing needed information and training. If fire cannot be conducted safely and effectively, alternative management techniques must be utilized. These alternative methods may be utilizedtoinitiate the range improvement processes followed by a burning program to maintain the range productivity. Herbicides, roller chopping, shredding, chaining, dozing, etc., can be used to reduce the brush cover and produce fine fuels for successful use of fire. When combined with prescribed burning, the effective life of the more expensive control method can be lengthened, improving the economic returns over single method range improvement (Scifres 1980).

White (1980a)identified a number of questions each rancher must answer when considering a prescribed burning program:

(1) Is prescribed burning a viable practice?
(2) Do I and my employees have sufficient training and experience to do the job?
(3) Where would burns most benefit the ranch?
(4) What are the burn objectives and are they realistic?
(5) How will I evaluate the successfulness of planning, conduct of the burn, and response?
(6) Will repeated fires be necessary?
(7) Should several practices be combined with fire?
(8) What are the disadvantages and problems?
(9) What should my management program be before, during, and after burning?
(10) What preparations are necessary?
(11) What should be the burn prescription?
(12) What equipment and manpower are needed?
(13) What are the legal and community restrictions on using prescribed fire?

The symposium papers, plus experience, etc., can help answer these questions. However, the particular ranch situation must be evaluated and a local plan developed. Before a rancher initiates a burn program, seek assistance and training. At least two seasons of demonstration burns and careful study of local weather relative to weather forecasts are a necessity. Work into a successful burn program learning with each successive fire. There are no definite prescriptions or easy cures. Planning, training, experience, patience and assistance are keys to success.

"Most ranchers want to attack the most brush infested pastures first; however, these are the most difficult to burn" (White 1980b). Emphasis should be on burning more open, level pastures of high productive potential with good grass fuels. "This allows the rancher to develop experience with prescribed burning under more favorable conditions" (White 1980b).

Fire is not as dangerous as many people think, but you must learn how to handle it. The way to success is to learn the principles of fire effects on vegetation and fire behavior, then apply them under carefully controlled conditions with all necessary preparations taken. Your attendance at this symposium is encouraging; I am sure you have obtained excellent information, challenged ideas, and are pro or con to prescribed fire in the Edwards Plateau.

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NATURAL ROLE OF FIRE ON THE EDWARDS PLATEAU

Fred E. Smeins

Highlight

Vegetation of the Edwards Plateau prior to about 1850 was apparently much more open and less wooded than today. Nonetheless, cedar brakes, oak savannahs, oak thickets and mesquite savannahs existed. After 1850 and up to the turn of the century woody vegetation became more abundant and widespread. Herbaceous vegetation was correspondingly reduced in area and in stature. During this period there was a marked reduction in the frequency and extent of prairie fires. Removal of fire is considered to be a primary contributor to the spread of woody plants into the grasslands. Fire, however, interacted strongly with continuous heavy overgrazing during this period to produce the condition that existed by 1900, and that in many places, persists to the present.

Introduction

Evaluation of the natural role of fire on the Edwards Plateau is indeed a challenging subject. Many divergent opinions exist, but few documented, factual accounts are available on the subject. Most evidence is circumstantial and often conflicting. Nonetheless, I will attempt to provide an analysis of the existing information and hopefully establish a perspective for later symposium presentations on the contemporary use of fire as a management tool.

Ecological Perspective

Any ecosystem is the result, and expression, of a multitude of interacting factors. Climate, soil, plants, animals, microbes, fire and the historical, as well as the current interactions of these components all contribute to the landscapes that we observe today (Odum 1971). To single out one factor such as fire is to almost certainly error in interpretation since the impact of fire is tempered by climatic conditions, such as drought, soil and topographic factors, grazing impacts and other variables (Wells 1965; Norton-Griffiths 1979).

To illustrate, it is an historical fact that two major simultaneous changes occurred across Texas and much of the western United States during the period from about 1700 to 1900. Grazing by free-roaming large native herbivores changed to grazing by relatively free-roaming livestock and ultimately to confined livestock (Smith 1899; Webb 1931; Perkins 1977). Concomitant with this change was the influence of early settlers on the frequency, timing, placement and extent of fires (Jackson 1965; Sauer 1975). It is difficult, if not impossible, to adequately separate these two impacts since they often operate in a synergistic fashion.

If we take a longer view of history it is documented that prior to about 7,000 years ago our rangelands were populated by a diverse collection of large grazing and browsing herbivores including elephants, mammoths, camels, antelope, giant bison, horses and many others (Martin 1975). Sometime about

12,000 years ago, or earlier, primitive man arrived on the scene (Sauer, 1975). What impact did these large herbivores have on the origin and maintenance of our rangelands and how did they interact with man and fire to produce today's ecosystems? Of course, we may never completely answer these questions. However, I believe it is important to recognize the existence of these changes. If for no other reason, it points out that change, often drastic change, is a feature of natural systems that occurs with or without man. As our knowledge of these changes increases, hopefully, they will contribute to our understanding of ecosystem structure and function and ultimately, to more intelligent use and management of our grazing lands.

Fire on the Edwards Plateau

Much of the discussion thus far has been rhetorical and has dealt with a broad perspective. I would now like to restrict my remarks to the natural role of fire on the Edwards Plateau. To attack this subject the answer to several questions will be attempted. Did fires occur? How extensive were they? How frequent were they? At what season did they occur? How did they start? What impact did they have?

There are two major sources of information that can provide answers to these questions. One is the historical record which furnishes descriptions of the occurrence of fires and the kind of vegetation and wildlife found in the region. The other source is our current knowledge of how fire, vegetation and animal life interact to produce our contemporary ecosystems. These two sources can be blended to produce a reasonable interpretation of the natural role of fire.

Generally speaking the vegetation of an area is the best integrator and best expression, of the interacting factors of climate, soil, animal influences and fire. Thus, if the vegetation of the Edwards Plateau at the time of settlement can be ascertained, we have some indication of the influence these factors have had on the development of that vegetation.

Vegetation of the Edwards Plateau at the Time of Settlement

The historical record is not totally consistent and at times contradictory about the kind of vegetation that existed. Most often comments are not specifically about the vegetation but some other feature of the landscape such as difficulty or ease of travelling through an area, degree of difficulty in working livestock or in hunting game, degree of openness of the area as it influences vision, availability of firewood and building materials, etc. Most observers, of course, had their own biases about what they saw. Some were primarily interested in the amount and kind of grass present while others emphasized woody plant growth as indicators of potential cropland areas. Also, what was tall grass to one traveler may have been short grass to another, depending on their experience and frame of reference. All these things must temper our interpretation of their observations.

Some early records suggest a much more open, less wooded condition than exists today. Jack Stevens was an early settler in Bandera County. He recalls in the 1850's (Hunter 1936):

Bandera County was much more open country then than now. The hills which are now covered with brush and densely timbered were then only covered with rank grass.

Roemer (1935), while travelling near the Pedernales River, about 26 miles northwest of Fredericksburg, observed in 1847:

> Toward evening we descended from the story heights into a broad valley covered with a rich growth of grass and scattered mesquite trees, always the sure sign of fertility.

Bennett (1956) in his history of Kerr County, describes the vegetation of approximately 1850 as follows:

> The Guadalupe valley of 100 years ago was a far different picture than the present-day scene. The first settlers found the rolling hills and valleys covered with little timber other than the archaic cypress trees and some scattered sturdy oaks. Everywhere was a carpet of lush grasses and smaller vegetation, teeming with wildlife of every description.
>
> Accounts handed by old-timers to younger generations give an idea of what the pioneers saw when they first moved up the valley. All of these accounts agree that a splendid fringe of stately cypress trees lined the river banks and grew along some of the creek tributaries.
>
> . . . The ranges of the country were far less brushy than they now are. ... There was a turf of grass everywhere, and at places the grass grew waist high. ..
>
> In addition to the cypress which attracted Kerr County's first settlers, and which may still be found along the Guadalupe and other streams, the principal timber growth is live oak, post oak, Spanish oak, black jack oak and blue-fruited cedar (sabina sabinacides).
>
> In more recent years the cedar has spread over the ridges and hills to such an extent as to become noxious.

Olmsted (1857) writes of his travels after crossing the Colorado River above Austin:

> . . . The live-oaks, standing alone or in picturesque groups near and far upon the clean sward, which rolled in long waves. ..
>
> . . . We were, in fact, just entering a vast region, of which live-oak prairies are the characteristic. ... The live-oak is almost the only tree away from the river bottoms, and everywhere gives the marked features to the landscape.
>
> The live-oaks are often short, and even stunted in growth, lacking the rich vigor and full foliage of those further east. ..

Later he continues:

> . . . At noon we forded the Blanco, the principal branch of the San Marcos River. .. Beyond it our road approached closely the hill-range, which is made up of spurs coming down from mountains North. They are well wooded with cedar and live oak. ...

> We pitched our tent at night in a live-oak grove. .. Behind us were the continuous wooded heights, with a thick screen of cedars; before us, very beautiful prairies, rolling off far to the southward, with the smooth grassed surface, varied here and there by herds of cattle, and little belts, mottes and groups of live oak.

Near Currie Creek, a branch of the Guadalupe River, he observed:

> Going on next day, we gradually mounted the ridge which sheds the water of the creek. The whole upper valley now lay before us, with those of the two Sister creeks and a wild array of tumbled hills to the north. The valleys appeared densely wooded, with here and there a green and fertile prairie. ... A dwarf live-oak reached even these summits, with the cactus and the aloes. A coarse, thin grass covered all the soils. ... As we descended, we found thicker grass, and abundant springs. ..

Major George Kendall, while searching for a place to raise sheep in 1853, described an area near New Braunfels (Brown 1959):

> . . . A search began which took him on horseback over a wide area, along the lower Guadalupe and the lower Cibolo and the streams which fed it. Still he found nothing to his liking. Then in the hilly region above New Braunfels, a flourishing little German settlement, he found what he was looking for. "This section," he wrote later, "high, dry, coated with short grass. ..

E. B. Keng (1969) wrote of interviews with settlers in the vicinity of the Sonora Research Station:

> Early settlers describe the country as open grassland with occasional liveoak clumps or large liveoak trees. Shin oak, redbud, kidneywood, bush honeysuckle, and other palatable shrubs were found on the hillsides and in the small canyons. Sacahuiste was abundant over the area, particularly on the shallow divides and gently sloping hillsides. The ranchman who formerly owned the Station land points out two liveoak trees from which, as a boy, he could spot a band of horses anywhere in the 16 square mile pasture.
>
> "Stirrup high" grass covered the area - sideoats grama, feathery bluestem, Texas wintergrass, curlymesquite and many other grasses.

If you are familiar with the Sonora Station you are aware that it would be difficult to see a band of horses more than a few hundred yards from the headquarters today.

In the 1880's Krueger (1976) relates:

> Pivedayslater we reached the Colorado River near Austin. .. Above Austin the country became very brushy. ..

> Leaving Austin, I followed the path along the Colorado River and often was near enough to see its red waters. This red color which gave the river its name (Rio Colorado-Red River) is caused by deposits of dark red clay through which the river has to traverse for a long way. Continuing my journey, I passed from the level prairie into the hill country, great stretches of which were covered with a growth of mountain cedar. These cedar forests, being almost impassable, were a safe retreat for many beasts of prey. ..

He continued on across the central granite region:

> I now left the granite country behind and continued my way in the direction of San Saba. To the northwest of Lampasas I found small prairies alternating with large cedar forests. ..

Some years later on his ranch in Blanco County he found:

> . . . In the southern part of my Twin Sisters Ranch there was a cedar forest extending for several miles. It was practically impenetrable and especially hard to get through on horseback. It was in these forests that the most ferocious of my steers would remain in hiding. They simply could not be caught by ordinary means, so we trained two large shepherd dogs by using tame steers, one to seize the tail of the hunted animal and the other to grasp its muzzle. In the thick underbrush the steers could not move about fast enough to defend themselves. ..

Smith (1899) evaluated the vegetation of the Texas ranges and recognized the results of many years of overgrazing:

> The disappearance of the buffalo was nearly coincident with that of the Indian and there was a period of fully ten years after the destruction of the buffalo herds before the number of cattle and sheep on any portion of the ranges equaled the great herds of game. These years, from 1874 to 1884, may be called the "golden period" of the Southwestern stockman, or at least a golden one for those whose flocks and herds were already on the ranges. During this intermediate decade there were few head of stock, wild or domestic, than at any previous period. There were also abundant rains and the seasons were mild and favorable to the full development of the grasses. Grasses and forage plants, ungrazed, grew and thrived, reseeded themselves, and increased to a wonderful degree of luxuriance, so that the stockmen on entering this pastoral paradise thought that it was not possible to put enough cattle and sheep on the land to eat down all of the rank growth of vegetation. It is the common testimony of the older stockmen that in the early eighties the grass was often as high as a cow's back, not only along the river bottoms, but also on the uplands far from the creeks and rivers.
>
> . . . With the building of the railroad the stock industry underwent a very rapid development. Newcomers who had not seen the land when it was possessed by the Indian, the buffalo and mustang, at the time when the herhage was eaten down, or kept in

check by fires or drought, naturally thought that this rich profusion of vegetation was the normal condition and that the saying that it was impossible to put enough cows on the land to eat all the grass was literally true. The result was a rapid and exhausting overstocking of every available square mile of rangeland. The best grasses were eaten down to their very roots, the roots were trampled into the earth, and every green thing was cut down so that it could neither ripen seed, and thus perpetuate its kind, nor recover from the trampling and exposure of its roots to the air and sun. . . . So also the mesquite bean and the cactus, both of which may be destroyed by fire, grew in numbers and commenced to crowd out the grasses.

Bray (1904) analyzed vegetation changes on the Edwards Plateau:

> It is of fundamental importance to note that the type of' vegetation in this region is undergoing a change. This change, broadly indicated, consists in a transition from grass to woody growth. This transition is very apparent even to the casual observer. Everyone has observed how the mesquite captures the open pastures and many have watched the scrub oak timber occupy uplands that formerly were open prairies.
>
> Some of the causes of this are reasonably evident. In the first place, dissection of the old plateau surface by the process of erosion has favored the establishment of forests in the rougher parts. Progress due to this cause, however, is too slow to be apparent. The presence of trees upward of 500 years old in some of the canyons is an index to the length of time forestation has been in progress. As one passes from the canyons and hills to the level plateau divides, the timber gives place more and more to open prairie, which, until within recent years, was free from woody growth of any kind.

A summary of conditions that existed early in the 20th century is provided by Foster (1917):

> A remarkable transformation of grasslands into forest areas is now taking place from isolated patches of original woodland on rough lands to the rolling uplands in general and across intervening prairies. Capture by tree growth is still more remarkable in sections far removed from forest belts as in the western portion of the Edwards Plateau, the denuded region and elsewhere. It is safe to say that fully 50 percent of the grassy uplands of the Edwards Plateau is now occupied by some form of woody growth. The mountain cedar is not only maintaining itself, but is spreading to new areas on steep slopes where no other species except perhaps sumac has succeeded in gaining a foothold. Sumac (*Rhus virens*) seems to be a forerunner to the spread of cedar and other important trees; at least under certain conditions where its seed germinates and furnishes temporary protection to other species which follow. Mountain oak thickets are spreading downward from the ridges and mesa tops to the youngest marking the lower limit of tree growth can be seen in many points of central Texas. The shinneries now

occupy many square miles in compact areas, crowding out the grass over low divides and on uplands where the grass cover was formerly complete. An open stand of mixed cedar, mesquite, mountain oak, and live oak, with a ground cover of prickly pear, occupies vast areas of rolling upland which, within the memory of men now living in the region, was covered only with grass. Within the last 25 or 30 years the change has been so marked as to become a matter of common discussion and of considerable apprehension on the part of stockmen. Every old resident can point out thickets of oak, mesquite areas or scattered cedars, live oak, and mesquite growing on his ranch which in the years gone by did not exist.

To conclude it appears that prior to about 1850 the vegetation of the Plateau consisted of essentially the same species that exist today. The woody vegetation was, in many places, more open than today, however, extensive areas of cedar brakes and oak Savannah and oak thickets occurred, particularly on shallow soils, on rocky slopes and in canyons and river valleys. Cactus was commonly encountered and mesquite occurred on deeper upland soils and in river valleys. Grasslands were apparently more extensive than today and the vegetation was of a taller stature, however, shortgrass areas, probably dominated by curly mesquite and buffalograss, were not uncommon.

After 1850 the woody vegetation became more abundant and widespread, and grassland acreage was correspondingly reduced. The stature of the grass vegetation became generally shorter. By the turn of the century reliable observers document the radical change from prairie to wooded vegetation types (Smith 1899; Bray 1904; Foster 1917). Similar changes are documented for the Rio Grande Plain (Bogusch 1952; Johnston 1963), the Cross Timbers (Gregg 1844; Dyksterhuis 1948), the High Plains (Box 1967) and the Coastal Prairie (Lehmann 1965).

Many of the accounts quoted above also describe the wildlife of the area. They mention the presence of buffalo and antelope in the hill country and on the Rio Grande Plain as well as to the north and west into the plains country. As indicated by Krueger (1976):

> The buffalo never liked country obstructed by bushes. The grand, open prairies ... were their favorite haunts.

Occurrence of these open grassland animals on the Plateau, though large herds are seldom described, also suggest that the vegetation was less densely wooded than today.

Occurrence, Extent and Frequency of Fires

There is little doubt from the literature that fires were a common phenomenon at the time of settlement. The earliest records (1528) of the use of fire by Indians in Texas is reported by Cabeza de Vaca (Nunez 1905):

> The Indians go about with a firebrand, setting fire to the plains and timber so as to drive off the mosquitoes, and also to get lizards and similar things that they eat, to come out of the soil.

Parker (1836) wrote:

> . . . the prairies near the coast were. .. all burnt over twice a year - in mid-summer and about the first of winter.

Roemer (1935) witnessed fires during his travels. On February 6, 1847 he recalls:

> I left Fredericksburg toward evening and found my companions camped about four miles northwest of the city. Since the grass had been burned everywhere in the vicinity of Fredericksburg, they had hurried to the place to find some for their horses.

The next day he observed:

> Later we came to a stony infertile plateau, which on account of the stunted oaks and exposed limestone visible in many places, did not present a very cheerful view and it seemed all the more cheerless since all the grass had been burned as far as the eye could see.

On January 22, 1847 John Meusebach was travelling north out of Fredericksburg (King 1967):

> A prairie fire raged at the second camp for thirty-six hours, destroying all forage for the horses for many miles.

During the winter of 1855 George Kendall had problems with fire (Brown 1959):

> He decided to begin grazing sheep on his lands thirty miles to the west, near Boerne. A prairie fire swept over the new range and a careless shepherd let his charges get caught in it. Between 300 and 400 sheep died as a result of burns.

In 1860 on the same ranch:

> . . . a gentleman came rushing up with the gratifying intelligence that my sheep estancia near Boerne was burnt up! . . . On questioning the man, he told a perfectly plausible and straight story: said that he was in Boerne two days before, saw a heavy smoke, asked where the fire was, and was told that it was at Major Kendall's sheep place. The next morning while on his way to San Antonio, he saw the same fire burning exactly in the direction of the estancia - saw all this with his own eyes, mind you.

In Kerr County during the 1850's Bennett (1956) explains:

> The ranges of the country were far less brushy than they now are. This is accounted for by the fact that the roving Indian tribes burned off the grass; and for many years the white settlers burned off the ranges in spring, killing the underbrush and keeping the country open.

> . . . Probably the burning of the grassy ranges by Indians and pioneer settlers was one of the reasons that cedar did not become a menace earlier.

The diary of Sam P. Newcomb (1958) contains the daily log of a horse-back trip from the Clear Fork of the Brazos in Stephens County, Texas, to the San Saba River and return:

> On March 30, 1864 the party encountered many buffalo on grazed off range, and from 3:00 p.m. to 9:00 p.m. the men travelled on burned-off range searching for grass for their horses.

George Kendall (1966) travelling near the Bosque River on July 14, 1841 witnessed his first prairie fire:

> . . . for the first time, I saw the magnificent spectacle of a prairie on fire. It was purely accidental, and caused us little damage. .. The dry grass flashed up like powder, and the fire spread over the prairie with alarming speed.
>
> . . . All night the long and bright line of fire, which was sweeping across the prairie to our left, was plainly seen, and the next morning it was climbing the narrow chain of low hills which divided the prairie from the bottoms of the Brazos.

Rickard (1934) discusses some of the hazards of ranching on the plains country:

> One of the most dreaded of all was the prairie fire. .. Nevertheless, prairie fires occurred with astonishing frequency and caused much destruction and loss. Aided by the dry climate and the high winds. .. these fires came to be one of the ranchman's worst enemies. They occurred in almost every season of the year. ..

Smith (1899) attributed woody plant encroachment largely to reduction in fires:

> In the early days, when the central prairies were sparsely settled, they were burned over each year, and the young seedlings of this and other trees were killed to the ground. Twenty years ago it was hard to find a mesquite bean on the open prairies that was larger than a small shrub. The only places where they occurred of any size were in the valleys and the "timber islands" -- small scattered groves at intervals on the prairies, usually about some swale or along a ravine or a rocky knoll. Since the more complete settlement of the country, fires are not allowed to sweep the prairies, on account of the possible loss of crops and improvements. There is nothing to check the growth of the mesquite bean, and they have grown to the size of small trees, at the same time largely augmenting in number.

Likewise, Bray (1904) implicates elimination of fire as a factor but points out the interaction of fire with grazing:

> Though the encroachment of timber on the prairie is gradual and insidious, to those whose observation covers a space of twenty-five years the change is truly startling. Where at the beginning of that period the prairie held undisputed sway, the observer now finds himself shut in by miles of oak scrub on every side. Men who drove cattle in the earlier days say that they rode across an open country from above Georgetown to the Colorado breaks, in Williamson County. This same region is now all heavily timbered. A great deal of the shinnery country undoubtedly represents a recent gain of timber growth on prairie divides.
>
> This struggle of the timberlands to capture the grass lands is an old warfare. For years the grass, unweakened by overgrazing of stock, and with the fire for an ally, held victorious possession. Now the timber has the advantage. It spreads like infection. From the edge of the brush each year new sprouts or seedlings are pushed out a few feet farther, or, under the protection of some isolated live oak or accidental briar or shrub, a seedling gets its start, and presently offers shelter for others. This has been going on all along, but in former days these members of the vanguard and the scattered skirmishers were killed by the prairie fires, and the timber front was held in check or driven back into the hills.

A succinct analysis of the situation is provided by Foster (1917):

> The causes which have resulted in the spread of timbered areas are traceable directly to the interference of man. Before the white man established his ranch home in these hills the Indians burned over the country repeatedly and thus prevented any extension of forest areas. With the settlement of the country grazing became the only important industry. Large ranches in time were divided into smaller ranches and farms with a consequent fencing of ranges and pastures. Overgrazing has greatly reduced the density of grass vegetation. The practice of burning has during recent years, disappeared. The few fires which start are usually caused by carelessness, and with alternating wooded and open spaces and the close-cropped grass, they burn only small areas. These conditions have operated to bring about a rapid extension of woody growth. Almost unquestionably the spread of timbered areas received its impetus with the gradual disappearance of grassland fires.

Fires were common at the time of settlement and continued to be for some time thereafter. They tended to occur at almost any time of the year but were most prevalent during dry seasons whenever they occurred. Descriptions suggest that fires often covered large expanses of territory, although topographic breaks, rivers and other barriers tended to restrict their advance. The terms annually, often, periodically and repeatedly, are used to describe the frequency of fires when reference is made to a particular area. This suggests that the same area may have been burned at a high frequency, however, it is almost certain that some areas escaped fire for long periods or that the fire frequency was very low due to lack of fuel, topographic limitations or just random chance.

Lightning is given as the ignition source in some accounts in the literature, however, it appears that the Indians and later the settlers were the primary perpetrators of fire. They certainly increased the frequency and probably the extent of areas that burned.

The impact of fire has been previously discussed. It along with other influences, particularly grazing, contributed to produce the land-scape viewed by early settlers. Change in fire occurrence, frequency and extent, and in the grazing pattern and intensity of the area created a situation that resulted in a profoundly different community today than existed 150 to 200 years ago.

We must recognize, however, that while fire may have acted to prevent excessive invasion of grasslands by woody plants, it may not be effective in reducing woody plants once they are established. This is the problem that faces us today. I will defer to the other members on the program for them to unravel this dilemma. Fire alone can seldom be the cure-all for our modern day brush problems. History strongly suggests that it has long been a factor of the Edwards Plateau environment and it deserves more consideration as part of a total management program for many ranchers.

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LIVESTOCK RESPONSE ON BURNED RANGE

J. E. Huston

Burning is not a new range practice nor has it been only recently recognized as a tool to increase animal productivity. Early settlers routinely burned rangeland to remove old top growth and excess litter, thereby exposing and encouraging lush, new growth. During a more recent period, burning was considered detrimental to rangeland. However, it has been a common observation that livestock and game ruminants concentrate on burned areas. To a large extent, it was this concentration on the burned areas, rather than the fire itself, that proved detrimental. Many recent studies document the value of burning as a range improvement practice under certain conditions (Wright 1974). An extra bonus is the increased livestock production which occurs after a burn, as a result of improved diet quality (McGinty 1979, Woolfolk et al 1975).

Effect of burning on nutrient content of range forage

Nutrients most likely to be low in range forages and thereby limit animal productivity are protein and energy. Results of several studies indicate that new plant growth or regrowth following a late winter-early spring burn is higher in these critical nutrients than in forage on comparable, unburned range (Table 1). However, not all vegetation types react the same to burning. The bluestem prairies of the Kansas Flint hills did not increase or increased only slightly in protein content following burning (Smith et al 1960, Allen et al 1976), whereas a weeping lovegrass pasture in North Texas (Klett et al 1971) and mixed grass ranges in the Edwards Plateau (Landers 1980) increased substantially in protein content following burning. This difference is likely more a result of contamination of the unburned samples with old growth than of actual differences in nutrient content of new growth. Oefinger and Scifres (1977) noted that large differences in nutrient content were apparent for only a few months following burning, and thereafter, differences disappeared. Therefore, average differences for year-round samples were small.

Sampled forage vs. sampled diet on unburned and burned rangeland

While there are definite differences between animal species, all animals are selective in their grazing habits, and generally consume diets that are higher in nutrient content than the average of the vegetation. In a study on a honey mesquite-tobosagrass community in the southern rolling plains, esophageally fistulated sheep were grazed on either unburned or burned stands of tobosagrass. Diets from both areas were higher in nutrients than the available forage (Table 2). The differences in nutrient contents between diet and available forage were much greater in the unburned area because of the large amount of old growth, which was discriminated against. However, several fragments of old growth were observed in the diets of sheep grazing the unburned area, indicating their inability or failure to select perfectly for new growth. No old growth was detected in diets of sheep grazing the burned area, although substantial amounts of ash material and soil were consumed, especially during early spring.

Table 1. Effects of range burning on protein content and digestibility of forage.

Location and dominant plant species	Nutrient Concentration (%) Control	Burned	Reference
Protein			
Texas, weeping lovegrass	3.6	7.6	Klett, et al (1971)
Louisiana, bluestem	7.4	7.8	Grelen and Epps (1967)
Kansas, bluestem	10.2	9.4	Smith, et al (1960)
Texas, gulf cordgrass	4.9	5.4	Oefinger and Scifres (1977)
Kansas, bluestem	5.3	5.9	Allen, et al (1976)
Texas, mixed grasses	9.7	13.2	Landers (1980)
mean difference	1.4		
Digestibility			
Kansas, bluestem	59.1	64.5	Smith, et al (1960)
Texas, gulf cordgrass	37.9	41.4	Oefinger and Scifres (1977)
mean difference	4.4		

Table 2. Effects of range burning of tobosagrass on crude protein (CP) and digestible organic matter (DOM) of available forage and selected diet.[1]

	CP (%)		DOM (%)	
	Control	Burned	Control	Burned
Available Forage	8.4	13.7	38.9	55.6
Selected Diet	14.3	17.1	57.1	62.1

[1]Huston and Ueckert (1980)

Changes in the nutrient contents of animal diets following burniiof rangeland

Results of several research studies indicate that increased quality of forages following burning is short-term (Aldous 1934, Christensen 1977, Oelfinger and Scifres 1977, McGinty 1979). The increased digestible organic matter in diets of sheep grazing burned tobosagrass, compared with those grazing unburned tobosagrass, reached a maximum of approximately two months, following a March burn (Table 3). The smaller early differences, especially at the May 4 sampling date, resulted from a larger forb component in diets selected from the unburned area. The decline in the difference in digestible organic matter in diets between the two areas which occurred after the May 17 sampling date appeared to be the result of maturing of the burned tobosagrass. The increased digestible organic matter in diets from both areas at the June 15 sampling date occurred following a rain in early June. These results are consistent with those of Oelfinger and Scifres (1977) and McGinty (1979), who suggested 4 to 5 and 3 to 4 months, respectively, as the period of improved diet quality following a burn.

Effect of range burning on livestock response

Livestock grazing burned rangeland under good moisture conditions will respond for a short period of time following a burn (3 to 6 months) with increased growth rate, conception rate, or milk production. Results of three studies with growing cattle are summarized in Table 4. Livestock that are in a non-productive state (e.g., dry, open cow) may not be benefited by grazing burned range. The expected improvement in productivity is likely a result of one or a combination of the following factors. (1) Burning under good moisture conditions during late winter stimulates early emergence of new growth. (2) Removal of old growth and excess litter prevents partial consumption of low quality material which replaces higher quality forage. (3) Removal of old growth and excess litter makes new growth more accessible and encourages greater foraging efficiency.

SUMMARY

1) Regrowth on recently burned rangeland is higher in protein and digestible organic matter than vegetation on comparable unburned rangeland.

2) Diets of animals range from slightly to greatly increased in nutrients following burning.

3) Burning of range forages which have excessive amounts of old growth (e.g., tobosagrass and weeping lovegrass) gives the greatest net benefit in diet quality.

4) Benefits of improved diet quality and increased animal productivity are relatively short-term (3 to 6 months).

5) The greatest livestock response to burning is in animals in a high productive state (young growing or lactating).

Table 3. Digestible organic matter contents of sheep diet on burned and unburned tobosagrass at periods following burning.[1]

Sampling Date	Digestible Organic Matter (% of diet)	
	Unburned	Burned
April 19	56	64
May 4	64	65
May 17	50	60
May 31	52	58
June 15	62	64

[1]Huston and Ueckert (1980)

Table 4. Effect of range burning on steer gains.

Location and dominant plant species	Liveweight Gain/Acre (lb)		Reference
	Control	Burned	
Texas, curly mesquitegrass	6	35	McGinty (1979)
Kansas, bluestem	49	57	Owensby and Smith (1979)
Kansas, bluestem	46	61	Woolfolk, et al (1975)
mean difference	17		

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Impact of Prescribed Burning on Wildlife

W. E. Armstrong

Highlight

Prescribed burning when applied to ranges that are properly managed for both domestic livestock and white-tailed deer can increase available deer food production which in turn controls antler size, body weight and reproduction. Conversely, prescribed burns applied to ranges improperly stocked with domestic livestock and deer can expect deer range destruction, resulting in poor deer body weights, poor antler development and poor reproduction.

Introduction

Over the past decade there has been an increasing interest in the use of fire as a brush management tool. In the Edwards Plateau region of Texas, research has been primarily concerned with the control of regrowth cedar (ashe juniper, Juniperus ashei). There has been little research on the effects of prescribed burning on wildlife[1] in this region. The Kerr Wildlife Management Area initiated a prescribed burn program in 1978 to control regrowth cedar. In conjunction with this program, a series of studies dealing with the effects of prescribed burns on white-tailed deer were initiated. They consist of (1) quantitatively measuring vegetative responses of liveoak (Quercus virginiana), shinoak (Q. spp), and ashe juniper to various burn treatments, (2) measuring deer use of burned areas versus unburned areas, and (3) measuring nutritional differences between burned and unburned ranges with emphasis on deer foods.

At this time most of the effects of fire on deer populations are drawn from vegetative observations following fire and a general knowledge of deer management. Some research on the effect of fire on white-tailed deer has been conducted on the Piloncillo Ranch in South Texas (Steuter 1980), the Aransas National Wildlife Refuge (Springer 1976) and the Welder Wildlife Area near Sinton, Texas (Box 1969). The effects of burn programs on livestock also provide some clues as to the effect of controlled fires on deer.

Fire and Deer Management

There are some basic facts about fire and deer that must be clearly understood in order to understand the role of fire in deer population dynamics.

The first basic fact is that fire is a management tool. Its effect on deer populations can be either positive or negative depending on how it is used in conjunction with a total ranch management program.

The second basic fact is that deer management consists of two simple principles. They are (1) providing food and cover and (2) genetic selection.

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[1] Economically in the Hill Country of Texas, the term wildlife refers to deer and turkey. This paper deals only with deer.

If you can grow deer foods and provide suitable cover, you can grow deer. By genetically selecting for the better deer, a herd can be improved.

Fire affects the production of both food and cover. Knowing how to manipulate a fire, a deer herd, a livestock herd and a range in order to produce more deer food is the key to raising deer. All the above factors are interrelated; no one factor by itself is a "cure all" for deer management. Research has demonstrated that deer produced on ranges properly managed for deer foods have heavier body weights, better antler growth and better fawn production than on unmanaged ranges (Armstrong and Harmel, 1978)

Deer Foods

An understanding of deer food habits and the response of deer food plants to fire is essential prior to initiating burn programs. Research has shown that deer are primarily forb consumers (McMahn 1964). Forbs are generally high protein plants (Fraps 1940). Most are seasonal plants, with the greatest abundance being in the late winter and spring period. Most forbs are annual plants. Once the top is removed from the plant, it does not grow back. Fire, therefore, should be conducted as early in the year as possible, preferably prior to the mid-January period. This is the time when many cool season forbs begin to germinate, forming winter rosettes. Burning later than this period of time will reduce many of these rosettes. For a period of time following a burn, there will be a reduction of deer forbs in a burn area. This reduction is usually followed by increased forb production as warmer season forbs begin to germinate. As forbs begin to decrease in the July-August period, deer begin to shift their diet to browse. Browse plants are usually lower in protein content than forbs; however, they are deeper rooted, more drought resistant perennial plants. Browse, therefore, is considered the more stable food in the deer diet.

For practical management purposes, deer are not grass eaters, as only a small portion of a deer's diet is grass.

Forbs are extremely difficult to measure and make intelligent, long-term management decisions by because they are annual, seasonal plants. For this reason, most deer management is based on browse production. The theory being that if you can release grazing pressure on key browse species, you can assume deer are getting adequate amounts of forbs in their diet. Some key cool season deer forbs would be the plantains (tallow weed, Plantago spp.), wild chervil (Chaerophyllum tainturieri), Texas filaree (Erodium texanum), and prairie bishop (Bifora americana).

Browse can be divided into three major categories. They are the preferred browse such as Texas oak (Spanish oak, Q. shumardii var. texana) and hackberry (Celtis spp.), the moderately preferred browse such as shinoak, redbud (Cercis canadensis), and gum elastic (Bumelia lanuginosa), (also in this category but of less summer preference is liveoak and green briar (Smilax spp.)), and the low preference browse such as mesquite (Prosopis glandulosa), cedar (Juniperus spp.), persimmon (Diospyros texana), and whitebrush (Aloysia lycioides). The following is a list of common deer foods and their response to fire.

(1) Liveoak - It is a reasonably fire tolerant plant when burned with humidities above 45 percent. This plant root sprouts following top removal. Liveoak is considered important as winter grazing for deer. As a general rule, little grazing should be noted on liveoak during the summer months.

(2) Hackberry - This plant is fairly fire tolerant. It will basal sprout following top removal. It is a preferred deer browse and should be protected from overgrazing.

(3) Shinoak - This plant also root sprouts well after burning. It is an excellent plant to judge deer range usage. Heavy grazing on this plant in the July-August periods is a good indicator of an overbrowsed deer range.

(4) Texas oak (Spanish oak) - This plant will root sprout if topkilled. It is an excellent deer browse. Root sprouts should be protected from overgrazing.

(5) Flameleaf sumac (Rhus copallina) - Germination is stimulated by fire, the hotter burn areas seem to have the more vigorous germination. This plant is considered a moderate deer browse.

(6) Red bud - A moderate deer food that is relatively fire tolerant. It will resprout if topkilled.

(7) Gum elastic (Bumelia, chittum) - This plant is relatively fire tolerant and will resprout when topkilled. It is a moderate deer food.

(8) Ashe juniper, cedar - Small (less than one inch in basal diameter) regrowth is easily killed by fire. Slow moving fires which hold the heat more uniformly around the cambium layer seems to give more uniform kills. This plant does not root sprout following topkill. It is considered a poor deer food. Removal of this plant will allow for more deer foods to be grown. Mature cedar breaks are fairly immune to controlled burns.

(9) Agarito (Berberis trifoliolata) - This plant is easily topkilled by fire, but will root sprout. It is not uncommon for the more desirable deer foods to grow under its canopy. These are released following fire. Agarito is an undesirable deer food.

(10) Persimmon - This plant is considered a poor deer food. It will also resprout following fire.

(11) Mesquite - It is a poor deer food, which will resprout following fire.

(12) Smilax, greenbriar - This plant is considered as winter forage for deer. It is relatively fire tolerant. It comes back well in hot burn areas, such as brush piles.

Nutrition

Research by various persons seems to indicate increased nutritional value of forage following burning. In Texas this has been demonstrated on the Edwards Plateau near Sonora through increased steer weights on burned ranges

(McGinty 1980) and on the Aransas National Wildlife Refuge (Springer 1976) through vegetative analysis of deer foods and increased deer weights on burned ranges. On the Kerr Wildlife Management Area, observation indicates a preference for deer foods growing in hot burn areas such as brush piles. spot grazing will occur on small burn acreages unless deer populations are controlled prior to burning.

Pre-Burn Considerations

There are some basic management principles that must be considered before utilizing fire. The most important is deer herd control. Prior to any burn program, the deer herd should be heavily reduced. A 50 percent reduction in deer in most places in the Hill Country would not be excessive, since the objective of controlled burning for deer management is to stimulate deer food production. A hot controlled burn that removes canopy cover of preferred deer browse will stimulate root sprouting. Vegetation at this time is vulnerable to overgrazing. If too many deer are on the range, the deer will remove and possibly kill regrowth vegetation, leaving a depleted deer range. However, when a deer herd has been properly harvested prior to a controlled burn, an increase in available browse for grazing can be expected.

Rotational grazing systems, coupled with proper livestock numbers, should be used in conjunction with reduced deer numbers. A watchful eye must be kept on key deer foods to prevent overgrazing.

Another important factor which must be considered prior to burning is brush patterning. During daytime hours deer usually seek out dense cover. They usually come out of dense cover to feed on forbs and browse in the evening and morning periods. A hot fire which removes all cover over large acreages is not desirable as deer tend to avoid these areas. A mosaic pattern of brush to openings is the best deer habitat. Plan for leaving strips or areas of mature brush to act as cover.

Frequency of use of fire is another factor to be considered. Too frequent use of fire over a period of time can effectively control browse plant numbers and deplete deer range. At this time it is recommended that treatments with fire should not be more frequent than seven to ten years apart.

Conclusions

In summary, fire when properly used in conjunction with proper stocking rates, proper grazing practices, and proper deer numbers, can increase deer food production through control of regrowth cedar and stimulation of preferred forbs and browse. Conversely, fire when used in conjunction with uncontrolled deer numbers, overstocked ranges, and poor grazing practices can cause deer range deterioration and loss of deer habitat.

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MANIPULATING RANGE VEGETATION WITH PRESCRIBED FIRE

Darrell N. Ueckert

Highlight

Fire suppression, overgrazing and periodic droughts within the last 100 years have resulted in serious deterioration of native grassland vegetation over much of West Texas. Researchers and resource managers have recently learned to differentiate between wildfires and prescribed burning, and are developing and using prescribed burning for restoring productivity of deteriorated rangelands. Grasses, forbs, succulents and woody plants in various range types in Texas can be successfully manipulated to meet specific management objectives with prescribed fire. Knowledge of the modes of action of fire on plant communities facilitates more intelligent use of fires as a management tool. Although fire can be successfully utilized as a "single treatment" for range improvement in some situations, it holds more potential as a component in range improvement systems where the effects of fire are utilized to complement grazing management, various brush and weed control techniques, and other range improvement practices.

Introduction

Fire, both lightning-caused and man-caused, has been a natural selective force in the development of many of the world's grasslands and is an important factor in their continuance (Daubenmire 1968, Vogl 1974). Early human populations were concentrated in grasslands or grassland-forest ecotones hunting, gathering food, domesticating grassland animals, and cultivating grassland plants (Komarek 1965, 1967, Wedel 1961). Early man apparently found savannahs and other grasslands, and the herbivores and other organisms they supported, more suitable to their needs than the forests, and learned to use fire to create, maintain and expand grasslands (Vogl 1974). Early man used grassland fires to flush game from dense cover, screen the hunter and his scent, concentrate game, maintain productivity of game herds, improve grazing for domesticated livestock, clear areas for cultivation, create fertilizing ash on fields, stimulate production of edible fruit and seed, facilitate harvest of certain crops, for communication, to increase visibility and mobility, reduce or repel insects, minimize attack by predators and enemies, minimize the threat of accidental and warfare fires, and for rain-making (Vogl 1974).

Early settlers learned to use fire in the tall grass prairies of the central Great Plains and continue to use fire as a management practice today (Owensby and Smith 1972). However, experiences with disastrous wildfires in other regions and an attitude of "good conservation" at about the turn of the century caused condemnation of fire by ranchers as well as the general public (Daubenmire 1968). Overgrazing, fire suppression and periodic droughts have led to extensive deterioration of native grassland vegetation and concomitant encroachment of undesirable weeds and brush. Studies within recent years have shown that fire, coupled with good grazing management and other range improvement practices, can restore the productivity of many deteriorated rangelands (Scifres 1980). Ranchers and resource management agencies have become keenly interested in fire as a range improvement tool in the last decade, largely because they have learned that prescribed fires, planned to meet specific objectives, are not detrimental to the range ecosystem as wildfires frequently are.

Wildfires, usually caused by lightning or accidentally, normally occur in dry years, whereas burning for range improvement is applied when the soil is wet or moist. Wildfires usually magnify drought conditions and may kill or seriously damage desirable forage species, but planned burning usually results in immediate initiation of plant growth. Wildfires generally occur where excessive accumulations of highly combustible material have accumulated and often occur during the growing season when desirable range plants are susceptible to fire damage, thus wildfires are often detrimental to the range ecosystem. Burning for range improvement is scheduled when desirable species are dormant, to remove old, rough top growth which is of little value to grazing animals. Wildfires are often unpredictable and very difficult to control, whereas technology is presently available to permit the safe, controlled use of fire in many types of rangeland (Scifres 1980, Wright 1974). In addition, wildfires often result in range deterioration because grazing cannot be controlled after the burn, whereas pre-burn and post-burn grazing management are carefully planned prior to prescribed burning (Hamilton 1979).

The purpose of this paper is to present information on how ranchers and other resource managers can use fire for manipulating rangeland vegetation. Rangelands usually consist of complex mixtures of various grasses, forbs, shrubs and trees which react differently to fire, just as they react differently to grazing. The benefits of prescribed burning of rangeland will be presented later in this paper, but it is pertinent to point out that research results and results from rancher application of prescribed burning will be divergent due to the variable nature of fire and the environments in which it is used. No two fires, or the conditions under which they occur, are alike. Many other variables can influence the results from prescribed burning, including: past history of use, post-burn grazing management, post-burn weather conditions, differences in accumulation of fuel, soil differences, and ecotypic variations within plant species (Vogl 1974). Research results and experiences of neighbors are certainly useful for predicting results from prescribed burning, but we must be mindful that results will vary for different burns, even on the same ranch.

Prescribed burning can be intelligently used only if the modes of action of fire on the plant community are clearly understood. The primary effects of fire on plant communities include: (1) the direct action of heat on plants and soils; (2) the removal of mulch and standing crop of herbage; and (3) the redistribution of nutrients. These involve the effects of fire on organic compounds, stimulation of dormant plant organs, physical, chemical and biotic properties of the soil, microclimate, losses of volatile plant nutrients in the smoke, and deposition of nutrients in the ash.

The quantity of heat required to raise the temperature of living vegetation to the lethal temperature is directly proportional to the difference between the lethal temperature and the initial vegetation temperature. A temperature of about 140°F(60°C) is usually lethal to shoot tissues of terrestrial plants. Hence, plants with an initial temperature of 50°F (10°C) can endure twice as much heat as those at 95°F (32°C). Initial temperature of live aboveground plant parts is governed by ambient air temperature and radiant energy, both of which vary among seasons and even considerably among days within a season. This explains why woody species may be damaged more by burning in summer or on warm winter days compared to cold days. However, heat damage to live plants is also a function of duration of exposure to heat as well as temperature, thus other parameters that determine the characteristics of the fire, such as wind speed and amount and nature of the fine fuel, will also dictate the damage of fire to live plants (Byram 1948, Daubenmire 1968, Hare 1961).

The physiological condition of the protoplasm of live, aboveground plant tissue also influences the effects of heat. As the moisture content of plant tissue increases its tolerance to heat decreases (Hare 1961). Thus succulent plants may be more susceptible to fire than plants containing smaller amounts of water and actively growing plants are more susceptible to fire than dormant plants.

Certain woody plants may be more resistant to fire than others because of differences in thickness, composition, structure, density and moisture content of the bark (Hare 1961). The position of the perennating buds at the time of burning, as related to protection from heat, is also critical in the response of plants to heat. Non-sprouting brush species, such as ashe juniper (*Juniperus ashei*) may be readily killed by fires (Wink and Wright 1973), whereas sprouting species such as honey mesquite (*Prosopis glandulosa* Torr. var. *glandulosa*) and live oak (*Quercus virginiana*) may be top-killed by fire, but sprout profusely from belowground stem buds (mesquite) or lateral roots (live oak) (Scifres and Kelley 1979, Wright *et al.* 1976). Some woody plants are susceptible to fire while young, but are tolerant after the perennating buds have been buried by accumulations of soil around the plant base. Honey mesquite seedlings are easily killed by fire up to 1.5 years of age, severely harmed at 2.5 years of age, but very tolerant at 3.5 years of age (Wright *et al.* 1976). Fire has effectively controlled one-seeded juniper (*Juniperus monosperma*) less than 4 ft. (1.2 m) in height in Arizona (Jameson 1962) and ashe juniper less than 6 ft. (1.8 m) in height in Texas (Wink and Wright 1976), whereas fewer older trees were damaged or killed.

Annual grasses and forbs may be killed by fire after they have emerged (Wright 1972a;Ueckert and Whisenant 1980) but may be promoted if fire occurs prior to germination (Vogl 1974). Grassland fires often kill seeds of annual plants still in the inflorescences or in the upper part of the mulch, but seeds on the soil surface or in the upper soil usually survive (Daubenmire 1968). Annual species that depend on the microclimate provided by mulch for germination are usually hurt by fire (Heady 1956, Smith 1970).

Perennial grasses and other plants whose perennating buds are located below or near the soil surface during the dormant season are usually fairly well protected from the effects of fire, depending on the amount of mulch, soil water content, and intensity of fire exposure. However, some bunchgrasses with compact crowns and a high density of dead plant material near the crown may be damaged by fire (Conrad and Poulton 1966, Wright 1971).

Burning under proper conditions usually has minimal effect on grassland soils. Although maximum temperatures at the soil surface may occasionally reach 1000oF (538oC) during some grassland fires, the duration of exposure is usually brief (Scifres 1975, Stinson and Wright 1969). The soil temperature is usually not changed to depths greater than 2 in. (5 cm) and the greatest changes usually are restricted to the upper 0.13 in. (0.3 cm) of the soil (Daubenmire 1968; Scotter 1979). However, removal of the insulating layer of mulch and standing vegetation by fire and blackening of the soil surface by ash deposition results in warmer soil temperatures during the growing season after burning, which accelerate microbial activity (Black 1968, Daubenmire 1968), stimulate nitrate ion production, rapid vegetative growth, and concommitant soil water and nitrate uptake by plants (Sharrow and Wright 1977). Sharrow and Wright (1977) reported that soil water and nitrate contents declined more rapidly on burned than on unburned areas even though more nitrate was produced on the burned areas in tobosagrass (Hilaria mutica) communities.

In summary, prescription burning under proper conditions does not normally affect grassland soils adversely (Hole and Watterston 1972, Lloyd 1971, Ueckert et al. 1978). Sediment loss in overland flow may increase on some soils following burning, but this loss can be minimized by burning when soil water contents are high (Ueckert et al. 1978, Wink and Wright 1973). Healthy green colors, larger sizes and higher water content of plants recovering from fire often reflect improved soil conditions (Vogl 1974).

Removal of mulch and dormant standing plant material often stimulates plant growth as well as is accomplished by burning. Heavy mulch accumulations often stifle growth by depriving plants of space and light (Scifres and Kelly 1979, Vogl 1974), by maintaining cooler soil temperatures (Sharrow and Wright 1977), and in some cases leachate of chemical substances from mulch may inhibit plant growth (Rice 1974). Removal of aboveground plant parts by burning or mowing triggers latent primordial regions which stimulate new growth in some species (Lewis 1964).

In many grasslands, culms, stems and leaves of plants remain erect when dormant and are very slow to decompose, Fire can be a primary nutrient recycling agent in these grasslands. Even though sulfur and nitrogen in mulch and standing dead plant material is volatilized by fire, all other nutrients are changed to water soluble forms and are deposited in the ash (Vogl 1974) where it can be used for plant growth or displaced by wind or water (Daubenmire 1968). About 70% of the nitrogen in mulch and standing dead material is lost, but there is no evidence that nitrogen stress is imposed on the vegetation by burning (Christensen 1977, Daubenmire 1968, Lloyd 1971, Oefinger and Scifres 1977, Sharrow and Wright 1977, Vlamis and Gowans 1961). Most studies have reported that the nutrient gain from ash is of no detectable significance, and that increases in production following burning result from litter removal (Adams and Anderson 1978, Hulbert 1969, Lloyd 1971, Old 1969).

Benefits of Prescribed Burning

Some of the benefits of prescribed burning of grasslands include: (1) increased production of forage and browse; (2) increased utilization of unpalatable plants; (3) reduction of woody plant canopies and control of certain species; (4) control of annual weeds and grasses; (5) improved species composition of herbaceous stands; (6) improved grazing distribution of livestock and wildlife; (7) increased availability of unavailable browse plants; (8) removal of excessive mulch; (9) removal of dead wood from rangelands; (10) improved upland game bird habitat; (11) partial control of certain parasites; and (12) control of insects (Chamrad and Dodd 1973, DeWitt and Derby 1955, Dix 1960, Gordon and Scifres 1977, Glover 1967, Heirman and Wright 1973, Hulbert 1969, Komarek 1969, Lay 1967, Leman 1968, Lewis 1964, McKell et al. 1962, Oefinger and Scifres 1977, Old 1969, Owensby and Launchbaugh 1977, Scifres 1980, Smith 1970, Stoddard 1935, Ueckert and Whisenant 1980, Wright 1974, Wright et al. 1976). Indeed, fire has proven useful in many rangeland and forest types for accomplishing, or aiding in accomplishing, a multitude of management objectives. Prescribed burning implies the design and application of fire to accomplish specific goals without detrimental consequences and to maximize the benefits of other management practices, such as the grazing system and brush control methods, in an overall long-range management plan (Scifres 1980). The decision to burn may be based on the need for land reclamation or for the maintenance of improved range. "Reclamation burns" are used to reclaim brush-infested areas or to change vegetative composition of herbaceous stands, and are characterized as "hot" fires. Several such burns may be necessary to accomplish the objectives of burning. "Maintenance" burns are "cool" fires used to maintain a desirable balance in the vegetation, to suppress brush regrowth, remove excessive litter and to rejuvenate grass stands (Scifres 1980).

Burning for Manipulating Herbaceous Vegetation

Where prescribed fire is an applicable tool, herbaceous vegetation can be manipulated to meet several specific objectives, including, increased herbage production, rejuvenation of decadent stands, increased availability, palatability, nutritional value and utilization of forage, removal of excessive litter accumulations, shifting species composition, and control of annual weeds and grasses.

Tobosagrass (Hilaria mutica), a highly productive, climax grass on adobe soils in the Southern Desert Plains of North America, is a coarse plant, generally unpalatable to livestock which tends to accumulate large amounts of litter that reduces soil temperatures and stifles annual production. Wright (1969, 1972a, 1974b) reported that burning during wet years increased tobosagrass production 200 to 300% compared to unburned rangeland. However, tobosagrass burned during dry years produced slightly less than that on unburned rangeland. Tobosagrass is apparently well-adapted to fire and produces more forage than unburned tobosagrass for 3 to 4 years after a burn. Burning mixed-grass rangeland near San Angelo during late winter with good soil moisture increased tobosagrass production 71%, while burning during late winter with low soil moisture did not affect tobosagrass production, compared to unburned rangeland (Ueckert and Whisenant 1980). In the Edwards Plateau, burning tobosagrass during winters with good soil moisture has significantly increased forage production and utilization in studies near Barnhart, Big Lake (Ueckert, unpublished data) and Eldorado (R.Q. Landers, Jr., personal communication). Heirman and Wright (1973) reported that tobosagrass was preferred by cattle after burning because the unpalatable, old growth was removed and the new growth was tender, succulent and palatable. Cattle selected tobosagrass on burned areas in the spring and fall, consuming 2,388 lb/acre (2,677 kg/ha) on burned rangeland, compared to 371 lb/acre (416 kg/ha) on unburned rangeland. Grazing pressure was shifted from buffalograss (Buchloe dactyloides) to tobosagrass during spring and fall; thus more buffalograss was available for summer and winter grazing (Heir-man and Wright 1973).

Gulf cordgrass (Spartina spartinae), a highly productive species, forms almost solid stands over large areas of the Coastal Prairie of Texas. Mature gulf cordgrass is coarse and unpalatable to livestock. Oefinger and Scifres (1977) reported that winter burning effectively removed old growth and litter from gulf cordgrass stands and that cattle heavily utilized regrowth following burning. Burning followed by grazing stimulated production of over 19,182 lb/acre (21,500 kg/ha) of gulf cordgrass, compared to 1,218 lb/acre (1,365 kg/ha) on adjacent unburned rangeland. Utilization of gulf cordgrass on unburned rangeland was negligible. Grazing maintained gulf cordgrass in a young, tender state throughout the winter on burned areas. New growth of gulf cordgrass following burning was higher in protein, phosphorus, and digestible energy content than mature growth on unburned areas (Oefinger and Scifres 1977).

Wink and Wright (1973) reported that burning in a wet spring increased yield of herbaceous plants in an ashe juniper community in Callahan County, Texas by 41%, compared to unburned rangeland, while burning in a dry spring reduced production 13%. Burning during a wet spring increased production of little bluestem (Schizachyrium scoparium) 81% and meadow dropseed (Sporobolus asper var. Hookeri) 53%, but did not affect production of sideoats grama (Bouteloua curtipendula), tall grama (Bouteloua pectinata), or vine-mesquite (Panicum obtusum). Burning during a dry spring decreased yields of little bluestem, sideoats grama and tall grama by about 50%, but yields of vine-mesquite increased 112% and yields of meadow dropseed increased 24%.

Wright (1974b) concluded from several studies that sideoats grama and Texas wintergrass were harmed by fire in West Texas, even when precipitation was above normal. He reported that buffalograss, blue grama (Bouteloua gracilis), and sand dropseed (Sporobolus cryptandrus) were neither favored nor harmed by fire. Grass species that seemed to thrive for one to three growing seasons after fire included Arizona cottontop (Digitaria californica), little bluestem, vine-mesquite, tobosagrass, plains bristlegrass (Setaria leucopila), and Texas cupgrass (Eriochloa sericea).

Trlica and Schuster (1969) reported that fall, spring and summer burning significantly reduced total forage production on shortgrass rangeland in the Texas High Plains. Vigor of blue grama was benefited by burning while that of two less desirable grasses, red threeawn (Aristida longiseta) and sand dropseed was harmed.

In studies near San Angelo, in Tom Green County, we found that late-winter burning with good soil moisture did not affect production of sideoats grama, red threeawn, Texas wintergrass, buffalograss or forbs. Burning during late-winter with low soil moisture also did not affect production of these species when May-June rainfall was normal (Ueckert and Whisenant 1980).

In studies on Texas wintergrass-dominated rangeland in Coleman County we found that burning during late-winter 1978 with good soil moisture increased production of perennial grasses 96% during the first growing season after burning and by 41% during the second growing season. Production of Texas wintergrass was increased 94% during the first growing season after burning and 50% in the second growing season. Production of low-value, cool-season annual grasses, including Japanese brome (*Bromus japonicus*) rescue grass (*Bromus unioloides*) and little barley (*Hordeum pusillum*), was decreased 74% the first spring after burning, but there was a trend toward somewhat more annual grasses on burned rangeland, compared to unburned rangeland, during the second spring after burning, Production of forbs was decreased 56% the first growing season after burning, but there was no difference in forb production on burned and unburned rangeland in the second growing season (Ueckert and Whisenant 1980; also Ueckert and Whisenant, *unpublished data*). Subsequent burning studies in Coleman County have indicated that production and vigor of sideoats grama, vine-mesquite, meadow dropseed, Texas wintergrass, western wheatgrass (*Agropyron smithii*), and Arizona cottontop were improved by late winter burning with good soil moisture (Ueckert and Whisenant, *unpublished data*).

Hamilton and Scifres (1980) reported that prescribed burning increased production of buffelgrass (*Cenchrus ciliaris*) by 93% for 4 months following a February burn in the Rio Grande Plains. Buffelgrass on unburned areas produced slightly more than that on burned areas during the following 12 months, which was an extremely dry period. However, when good growing conditions returned, the burned area produced 67% more forage than the unburned area for the next 5 months. Utilization of buffelgrass by cattle was 88% on the burned area, compared to 69% on the unburned area, for 17 months following burning.

Several researchers have reported that prescribed burning controlled undesirable herbaceous weeds or resulted in other desirable shifts in herbaceous species composition. Scifres and Kelley (1979) reported that burning live oak-dominated vegetation in thicketized uplands on the Texas Coastal Prairie increased herbaceous species diversity for two growing seasons after burning. Burning in fall increased herbaceous species diversity more than burning in spring. Burning decreased the proportion of grass species of poor grazing value in the stand and increased the proportion of grass species of good-to-excellent forage value by the second growing season after the fires. Gulfdune paspalum (*Paspalum monostachyum*) and Heller panicum (*Panicum oligosanthes* var. *helleri*) increased the first growing season after burning but began to decline as the proportion of little bluestem (*S. scoparium* var. *frequens*) increased during the second growing season on burned areas. Forb standing crop on uplands burned in the fall was five times that of unburned areas and twice that of areas burned in the spring.

Wright (1978) reported that spring burning in tobosagrass communities effectively controlled annual broomweed (*Xanthocephalum dracunculoides*) and reduced Carolina canarygrass (*Phalaris caroliniana*) and little barley. Neuenschwander et *al*. (1978) reported that the response of herbaceous plants to burning in tobosagrass-mesquite communities was characterized by the response of tobosagrass, and the response of associated herbaceous species to tobosagrass.

Burning decreased the importance of forbs during the first growing season after burning, but if soil moisture was adequate forbs were more important on burned rangeland than on unburned rangeland during the second, third and fourth growing seasons after burning.

An important objective for our studies on prescribed burning in Texas wintergrass-dominated rangeland in Coleman County was to determine if fire could be used to decrease the proportion of Texas wintergrass and annual, cool-season grasses and to increase the proportion of warm-season, perennial grasses in the stands in order to provide a more desirable, yearlong forage base. We found that prescribed burning effectively reduced Japanese brome, little barley, rescuegrass and forbs, thus making soil moisture readily available for production of warm-season, perennial grasses. Production of warm-season, perennial grasses doubled following burning. The relative proportion of Texas wintergrass to herbaceous production was successfully reduced, even though its absolute production increased or was not affected by burning (Ueckert and Whisenant 1980; also Ueckert and Whisenant, unpublished data).

Camphorweed (Heterotheca subaxillaris), common goldenweed (Isocoma coronopifolia), and rayless goldenrod (Isocoma wrightii) have become serious problems on rangeland in South and West Texas in recent years. Mutz and Scifres (1980) reported that sparse infestations of camphorweed were effectively controlled for 1 to 2 years by prescribed winter burning, if conditions were conducive to a relatively hot fire at ground level. Camphorweeds did not regenerate vegetatively following heat damage to the winter rosette growth stage. Hamilton and Mayeaux (1980) reported that winter burning killed over 40% of the common goldenweeds on Rio Grande Plains rangeland near Laredo, Texas. At 10 months after winter burns, canopy cover of common goldenweed was reduced 83 to 91% and average plant height on burned areas was 15 in. (38 cm) compared to 35 in. (89 cm) on unburned areas. Ueckert et al. (1980) reported that winter burning did not effectively control rayless goldenrod in dense stands along the Pecos River in West Texas. Only 35% of the plants were killed by burning. Growth and seed production were stimulated on rayless goldenrod plants that were not killed by the fire.

Some grasses, such as threeawns (Aristida spp.) are objectionable to sheep and goat producers in Texas because the seeds become entangled in wool and mohair fleeces, reducing wool and mohair values, and because the sharp calluses of the fruit penetrate the skin and flesh, causing weight loss, decreased carcass quality, and occasionally death losses (Maurice Shelton, personal communication). In Kansas, prairie threeawn (Aristida oligantha) was effectively controlled by fall burning (Owensby and Launchbaugh 1977). Burning on dates later than early December did not control prairie threeawn. Mulch removal by burning was cited as the causal factor associated with control of prairie threeawn, Late winter and early spring burning has not harmed red threeawn (A. longiseta) in our studies near San Angelo (Ueckert and Whisenant 1980).

Burning in a relatively dry fall and winter near Brady stimulated growth and seed production of purple threeawn (A. purpurea) in a Texas wintergrass-mesquite community (Steve Whisenant, personal communication). Trlica and Schuster (1969) reported that basal diameters of red threeawn decreased on Texas High Plains rangeland burned 2 years in succession, but red threeawn plants either maintained or increased in basal diameters on areas burned once. Fire had little effect on numbers of flowering culms of red threeawn the first growing season after burning, but production of flowering culms was stimulated during the second growing season after burning.

Burning for Manipulating Woody Vegetation and Succulents

Woody vegetation and various species of cacti (Opuntia spp.) can also be manipulated with prescribed fire in many instances for achieving specific management objectives, including reduction of undesirable plant canopies, control of certain undesirable species, increased production and availability of browse, and removal of dead wood.

In mesquite-tobosagrass communities in West Texas, fire has proven useful for (1) reducing mesquite canopies to acceptable levels, (2) top-killing mesquite and leaving the stems susceptible to woodboring insects, and (3) killing 40 to 80% of three species of cactus (Wright 1974a).

Wright et al. (1976) reported that seedlings of honey mesquite were easily killed with moderate fires until they were 1.5 years old, severely harmed by fire at 2.5 years of age, and very tolerant of fires after 3.5 years of age.

Mesquite is very difficult to control with fire on the High Plains and along river bottoms in the Rolling Plains. However, on upland range sites in the Rolling Plains, an average of 27% (range 4% to 52%) of the mesquite trees that had been previously top-killed with aerial sprays of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] died within 3 to 5 years after burning with headfires where fine fuel loads of tobosagrass were 4,200 to 7,000 lb/acre (4,708 to 7,847 kg/ha). Mesquite mortality was independent of fine fuel load within this range, and was more directly related to wind speed, relative humidity, air temperature, fine fuel moisture, and water content of the mesquite stems (Wright et al. 1976). Mesquite mortality increased over a 3 to 5-year period after burning and mortality was attributed to the combined effects of fire, insect and rodent damage, droughts, and competition from grasses.

Large mesquite trees are easier to burn down than small trees (Britton and Wright 1971). Relative humidity, wind speed, and total fine fuel load accounted for 80% of the variation in ignition of standing mesquite stems that had been top-killed with aerial sprays of 2,4,5-T. Ignition of mesquite stems varied from 34 to 95%. Burndown of mesquite stems varied from 14 to 89%. Relative humidity, wind speed, and total fine fuel load accounted for 86% of the variation in burndown of mesquite stems. Conditions recommended for achieving burndown of mesquite that has been top-killed by herbicides are: winds of 6 to 10 mph (10 to 16 km/hr), air temperatures of 70 to 750F (21 to 24°C), and relative humidities of 25 to 35%. Britton and Wright (1971) reported that mortality of mesquite stems following prescribed burning increased as basal diameters increased. Only about 4% of the trees 2 in. (5 cm) or less in basal diameter died following burning, compared to about 10% of those 2 to 5 in. (5 to 13 cm) in diameter and 30% in the 5 in. (13 cm) size class. Mesquite mortality averaged 12% in their study, and ranged from 0 to 24%. Heir-man and Wright (1973) have presented additional data on burndown and mortality of mesquite. Living, green mesquite trees are rarely killed by fire (Wright 1972b).

Prescribed burning in a mesquite-mixed grass community that had been chained two-ways, 5 years before burning, in Tom Green County only killed about 2% of the mesquite resprouts, but over 90% of the resprouts were top-killed (Ueckert and Whisenant 1980). At 2 to 3 years after burning, canopy cover and height of mesquite was reduced about 40%, compared to adjacent, unburned rangeland. In Coleman County late-winter burning killed 10% of the mesquite trees that had been chained one-way about 1 year prior to the burn, and over 95% of the resprouts were top-killed by the fire. Increased mortality of mesquite resprouts on areas chained one-way compared to that on areas chained two-ways was attributed to the fact that some of the large trees were not completely uprooted by chaining one-way and the bud zone of some of these trees was exposed to lethal temperatures during the burn. The bud zones of resprouts that originate from stumps broken off below the soil surface by chaining are well protected from heat during prescribed burning (Ueckert and Whisenant 1980; also Ueckert and Whisenant, unpublished data). We feel that burning at 5 to 6 years after chaining will effectively suppress regrowth of mesquite for about 5 to 10 years. Neuenschwander et al. (1978) reported that prescribed burning of tobosagrass-mesquite communities in the southern Rolling Plains effectively suppressed mesquite regrowth on areas previously sprayed with 2,4,5-T for 6 years.

Lotebush (*Ziziphus obtusifolia*) is very tolerant of fire. Although 100% top-kill may be achieved with prescribed burning, usually very little root-kill has been observed (Neuenschwander et al. 1978, Ueckert and Whisenant 1980). Lotebush sprouts from roots as well as the crown (Wright 1972b). Neuenschwander et al. (1978) reported that lotebush regained about 36% of its pre-burn height and 40% of its pre-burn canopy area by the middle of the first growing season after burning. Lotebush had regained over 70% of its pre-burn canopy height and area by 6 years after burning. Lotebush canopy height was reduced 32% at 3 years after prescribed burning in a mixed grass-mesquite community near San Angelo (Ueckert and Whisenant, unpublished data).

Algerita (*Berberis trifoliolata*), catclaw (*Acacia* sp.), littleleaf sumac (*Rhus microphylla*), whitebrush (*Aloysia lycioides*), ephedra (*Ephedra* sp.), and hackberry (*Celtis* sp.) are also very resistant to fire (Ueckert and Whisenant 1980). These species were readily top-killed by prescribed burning in Tom Green County, but very few plants were root-killed.

Resprouts of hackberry, lotebush, ephedra and littleleaf sumac were heavily utilized by Spanish goats during the first growing season after prescribed burning. Goats browsed very little on resprouts of algerita, catclaw and honey mesquite and only a moderate amount on whitebrush resprouts. Percentage of twigs browsed for several brush species are shown in the following table.

Average percentage of twigs of several brush species browsed by Spanish goats during the first growing season following a prescribed burn in February 1978 near San Angelo, Texas.1/

Species	Percentage of Twigs Browsed
Algerita	1
Catclaw	20
Honey mesquite	31
Whitebrush	64
Hackberry	84
Lotebush	88
Ephedra	94
Littleleaf sumac	97

1/ 1.35 goats/acre (3.3/ha) for 62 days (July 11 to September 11, 1978).

Browse utilization was especially heavy on resprouts of lotebush and littleleaf sumac where old stems were burned down by the fire, increasing availability of the regrowth to the goats. This example demonstrates (1) how goating may be used in conjunction with prescribed burning for suppressing woody plants, (2) how prescribed burning can be used to increase availability and utilization of browse, and (3) how prescribed burning can be utilized to convert mature old-growth shrubs into a useful browse resource.

Wink and Wright (1973) reported 100% mortality of ashe juniper plants less than 6 ft. (1.8 m) in height and considerable mortality among plants over 6 ft. in height where there was at least 890 lb/acre (1,000 kg/ha) fine fuel for headfires in Callahan County, Texas. They reported good root-kills on all sizes of ashe juniper in areas with at least 2,000 lb/acre (2,240 kg/ha) fine fuel loads. Steuter and Wright (1979) reported 52% mortality of redberry juniper (*Juniperus pinchoti*) seedlings 3 to 12 in. (7 to 30 cm) tall and 25% mortality of seedlings 12.2 to 28 in. (31 to 70 cm) tall following headfiring with 2,300 lb/acre (2,600 kg/ha) fine fuel loads in the Rolling Plains of Texas. They found adult redberry junipers quite tolerant to fire.

Box and White (1969) reported that fall and winter burns reduced woody plant canopies 55% to 57% and burning in two successive years reduced brush canopies 71% on South Texas rangeland where burning was preceeded 2 years earlier by shredding, roller chopping, scalping, root plowing or root plowing + raking. Burning reduced brush canopies only 24% on areas that had not been pretreated with mechanical practices. Huisache (*Acacia farnesiana*), blackbrush acacia (*A. rigidula*), twisted acacia (*A, tortuosa*), and lotebush all increased in relative abundance following burning, whereas agarito (algerita), lycium (*Lycium berlandieri*), tasajillo (*Opuntia leptocaulis*), honey mesquite, and creeping mesquite (*P. reptans* var. *cinerascens*) all declined in relative abundance. Forage production increased following burning. Fall burning tended to reduce forb production and increase grass production the following year, whereas winter burning tended to increase forb production without affecting grass production.

Hamilton and Scifres (1980) evaluated prescribed fire for woody plant suppression in improved buffelgrass pastures in the Rio Grande Plains of Texas.

They concluded *that* although a single maintenance burn would not kill a significent percentage of the mixed-brush sprouts on 8-year old improved buffelgrass pastures, the stature of most woody species would be reduced. Existing mesquite sprouts were not killed by maintenance burns, but the rate of new seedling establishment was decreased compared to unburned areas. Canopy height and cover of mesquite were significantly reduced for 17 months following burning. Numbers of blackbrush acacia, as well as canopy cover and height, were also reduced by maintenance burning. They felt the lower growth form of all woody species, resulting from top-kill from the first maintenance burn, would improve the position of these plants for damage by subsequent burns.

Several investigators have reported efficient use of fire for increasing availability of herbaceous forage to livestock in dense stands of brush. Scifres and Mutz (1980) reported that whitebrush in the South Texas Plains was effectively controlled with pelleted tebuthiuron (N-(5-[1,1-dimethylethyl]-1, 3,4-thiadiazol-2-yl)-N,N'-dimethylurea), but the standing dead plants severely limited grazing distribution of livestock. Prescribed burning with headfires during winter with 6 to 7 mi/hr (10 to 11 km/hr) winds, 550F (13°C) air temperature, and 19% relative humidity eliminated 60 to 66% of the standing woody debris in tebuthiuron-treated plots, compared to less than 2% in untreated whitebrush stands. Fine fuel loads were about 1,600 to 2,100 lb/acre (1,800 to 2,400 kg/ha) on herbicide-treated plots compared to only 840 lb/acre (940 kg/ha) on untreated plots. Gordon and Scifres (1980) reported that dead canes of Macartney rose (Rosa bracteata) remain standing after control with foliar herbicides, seriously reducing livestock movement and handling. They found prescribed burning very useful for eliminating the Macartney rose debris. Livestock distribution was greatly improved, forage utilization was more uniform throughout burned pastures, and livestock handling problems were greatly reduced.

Prescribed burning has also proven useful for reducing excessive debris left by chaining or tree dozing dense stands of brush. In Tom Green County, we eliminated 92% of the mesquite logs remaining from two-way chaining 5 years prior to the burn by headfiring in late winter with 9 mi/hr (14 km/hr) winds, 16% relative humidity, 830F (280C) air temperature, and 3,200 lb/acre (3,587 kg/ha) fine fuel loads. In Coleman County only 17% of the mesquite debris left from chaining one-way, 1 year prior to burning was eliminated by burning with late-winter headfires with 8 to 12 mi/hr (13 to 19 km/hr) winds, 29% relative humidity, 730F (230C) air temperatures and 3,000 lb/acre (3,363 kg/ha) fine fuel loads (Ueckert and Whisenant 1980). In subsequent studies in Coleman County prescribed burning eliminated 80% of the mesquite debris in a pasture that had been chained one-way about 6 years prior to the burn, which was conducted as a headfire with 9 to 14 mi/hr (14 to 23 km/hr) winds, 32 to 59% relative humidity, 64° to 760F (18° to 25°C) air temperatures, and with fine fuel loads averaging 2,850 lb/acre (3,196 kg/ha) (Ueckert, unpublished data). Heirman and Wright (1973) reported 43 to 68% combustion of mesquite logs in tobosagrass fuel averaging 4,306 lb/acre (4,827 kg/ha) and 14 to 52% combustion in buffalograss fuel averaging 1,234 lb/acre (1,383 kg/ha). Their burns were conducted with 12 to 20 mi/hr (19 to 32 mi/hr) winds, 25% relative humidity and 75°F (24°C) air temperature.

Large logs are generally easier to burn with grassland fires than small logs. Also logs with loose bark and those well aeriated by tunnels of wood boring insects ignite more readily than those recently felled. Logs in small or large piles are usually more easily ignited, and combustion is usually more complete, compared to solitary logs, because logs lying in close proximity receive more heat reradiation. Chaining two-ways tends to pile or windrow logs and debris, whereas chaining one-way tends to leave logs and debris scattered.

Wright (1979) has developed prescription techniques for eliminating piles of dozed juniper and debris left by chaining juniper in the mixed prairie of Texas. Areas tree dozed or chained are usually not burned until 3 to 5 years after treatment. Brush piles are burned out of 500 ft (150 m) fire lines on the north and east sides of tree dozed pastures during May or early June while grasses are green, with winds less than 10 mi/hr (16 km/hr) and relative humidities above 45%. The following winter, grasses are burned in the fire lines when winds are less than 8 mi/hr (13 km/hr) and relative humidity is 40 to 60%. In chained juniper, the dead juniper can be burned at the same time as the grass. After firelines are burned out, the rest of the pasture should be burned with an 8 to 15 mi/hr (13 to 24 km/hr) wind from the southwest, when air temperature is 70° to 80°F (21° to 27°C) and relative humidity is 25 to 40%. It is suggested that burning be delayed at least 5 days after a rain. Wink and Wright (1973) reported that 99% of the piles of ashe juniper were consumed by fire where there was at least 890 lb/acre (1,000 kg/ha) of fine fuel.

Several species of cactus have been successfully controlled with prescribed burning in mixed prairies in Texas. Bunting and Wright (1976) reported that only about 30% of the brownspine pricklypear (Opuntia phaeacantha) were killed by one year after burning. However, almost 80% of the pricklypear plants had died by 4 years after burning. They attributed the increasing pricklypear mortality to the combined effects of fire, insects, rodents, rabbits, and drought. They reported 50% mortality of cholla (O. imbricata) following burning. Tasajillo (O. leptocaulis) is severely harmed by fire. Bunting and Wright (1976) reported 68% mortality at 1 year after burning and 87% mortality by 2 years after burning.

Ueckert and Whisenant (unpublished data) recorded 61% to 73% reduction of pricklypear canopy cover at 2 to 3 years after burning mixed grass rangeland near San Angelo and 86% reduction of pricklypear canopy cover at 1 year after burning tobosagrass rangeland on the Texas Range Station near Barnhart. Pricklypear canopy cover increased 27% on adjacent, unburned rangeland in one year at the Barnhart study area. Pricklypear canopy cover was reduced 58% at 1 year after burning and 73% at 2 years after burning on Texas wintergrass-dominated rangeland near Coleman, Texas. Tasajillo mortalities averaged 60% and 86% at 2 years after prescribed burning at San Angelo and Coleman County, respectively (Ueckert and Whisenant, unpublished data). Pricklypear and tasajillo cause serious animal health problems to sheep and goat producers in the Edwards Plateau every year. Prescribed burning, coupled with good grazing management and livestock management can significantly reduce this problem.

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IMPROVING SHINOAK RANGE WITH PRESCRIBED FIRE

Harold Schmidt

When rangeland has been abused to the extent that woody plants are dominant, more than livestock management must be brought to play in the restoration or improvement process. In my case I'm relying heavily on prescribed burning. My ranch, located on the east side of Kimble County, has a brush problem. The biggest problemis shinneryoak (Quercus spp.). That's not to say it won't grow a healthy stand of other oaks; ashe juniper (Juniperus ashei), persimmon (Diospyros texana), prickly pear (Opuntia spp.), yucca (Yucca spp.) and poisonous plants if managed in that direction. It was past management that allowed this brush invasion, and I have to take part of the credit (or discredit) since I've been actively engaged in ranching since 1950. I want a balanced range, but on many sites, I don't.

My ranch's history has included sheep, goats, cattle, and white-tail deer -- too many of them! Right now it's a cow/calf, wildlife operation, carrying about one domestic animal unit per 17 acres or almost 37 units per section. My goal is to raise healthy cattle with the minimum use of store-bought groceries, so I'll be constantly fighting this heavy timber.

Since the AAA program of the 1930's, my family has been wrestling with obnoxious plants, with varying degrees of success. In some places we're not totally overrun with woody plants. We used numerous methods: hand cutting, bull dozers, cables and chemicals. And I'm looking forward to adding the hydroaxe to the team. Plus I've used goats. But for me goats remove the more desirable along with or before the shinnery, so that I'm controlling my brush but not improving my range's condition. The brush problem remains.

In 1974 I added prescribed burning to the group. I like it best--maybe because it's new, maybe because it's cheap. All of you know a practice only 5 or 6 years old is neither tried nor true. Prescribed burning and I are still on our honeymoon, still riding the glamour train. Nevertheless it is showing great promise. Just how much credit to give burning is difficult to say because using fire requires a high level of use of all the other management practices. It's easy to go downhill even when you're trying to improve. Fire, prescription fire, is like some doctors' prescriptions--strong medicine similar to a miracle drug and miraculous results are possible. But for me the spectacular thing about prescribed burning (absolutely no relative of wildfire) is the fact that it is not spectacular. Remember, once again, prescribed burns call for cool, wet soils, and for temperature, humidity and wind speed to be within bounds. This is far different from the July-August wildfires we all know about.

Livestock and wildlife manipulation play a big hand in determining what grows on a given range. So too does the stocking rate, the grazing system, the amount of cross fencing and water development. But when browse gets out of reach or is present in unbalanced quantity, you are in trouble. All you can hope for is to bring your interspaces up to their potential. I have discovered that the deeper rooted brush somehow has commandeered the deeper soils and left my more desirable plants -- those that must feed the multitudes -- the shallower sites. The freeloaders may be using only one-third of the surface as shown in an aerial photograph, but close examination shows them to be using more than one-half of the available soil and water; thence the problem is greater.

Past management, which leaves something to be desired, has allowed brush in general and shinnery in particular to become too large a percentage of the total vegetation. And when this critter with its deep roots (or big bank accounts) gets established he is a booger to control. Woody plants with their deeper roots suffer less in drought than do grasses and forbs. Shinnery suffers less from grazing pressure than do the more palatables like hackberry (Celtis spp.), sumac (Rhus spp.), elbowbush (Forestiera pubescens), honeysuckle (Lonicera spp.) and the like. And once again the imbalance remains.

Now where does fire fit into the picture? First, fire does not pick and choose. Wherever it goes, it's an indiscriminate equalizer, conceivably reducing everything in its path to ground level, giving everything an equal chance for regrowth. There are exceptions: the slick barked persimmon is fire resistant. Second, I'm convinced our higher quality plants, the grasses, forbs and woody plants alike, are inherently more fire tolerant than the less desirables. Now that's a program that sounds like a winner to me. After burning, little bluestem (Schizachyrium scoparium) can do a better job of competing; honeysuckle can replace agarito (Berberis trifoliolata); greenbriar (Smilax spp.) can cover a thicket once dominated by shinnery. Let me emphasize the shinnery here is not dead. Fire just set it back, hit it harder than it did the more desirable greenbriar. Hackberry can outperform agarita.

Fire again with exceptions, I've found, stimulates everything. Shinnery can grow two feet or more in one year. But if I can make yearlings out of ten year old plants, or in some way reduce its vigor, while not injuring the desirables, I'm ahead. The exception is ashe juniper. A cool fire can kill it easily. And prickly pear if not too tall is killed.

Fire, I thought, had a fertilizer effect, and it may, but researchers tell me blackening the surface hastens soil temperature rise and microorganism activity which in turn speeds up spring growth. Fire, even a hot one, burns a patchwork mosaic: top kills some, singes some, misses some; proving to me that it is not a one shot remedy or a catastrophy. Burning under the right conditions of temperature, moisture, and wind, rarely sterilizes the soil. Humus is still left in the centers, and Texas wintergrass (Stipa leucotricha), sideoats grama (Bouteloua curtipendula), vine-mesquite (Panicum obtusum)and sida (Sida spp.) grow readily on the edges. Sida, incidentally, is a preferred deer food plant.

My burns have been conservative in that weather conditions have not been extreme and resulted in "dangerous" fires. I am becoming more confident with fire but still feel like a beginner. I have experimented some. My prescriptions are based on work by Dr. Wright. One pasture was set on fire when the ground was muddy and about one-half the litter was wet. It didn't justify the effort; the fire performed poorly.

A burn conducted when the soil was too dry resulted in some severe effects. Weeds grew in the hot spots. You can get the same results with low wind speeds, in brush piles, and up steep slopes. I've got to remember to stick closer to the recipe. Lack of litter allowed only a cool fire to pass through some thickets. Even so, some sunshine got in, some moisture was released by the injured timber, and now it looks better.

Another burn was conducted close to the prescription or recipe and everything went right. I got a good top kill, no apparent damage to the grasses or forbs and a definite set back on the woody plants. The same pasture one year later definitely justified the effort.

Once again, shinnery can be top killed, but with its tremendous root system, it will be back. How many times I don't know. But each time it is reduced to ground level there will be some sunshine and moisture released. And if there are some desirable plants on the perimeter, they will gain in vigor and be better able to compete.

I visualize burning on a regular basis. Right now the plan is to burn 20 percent of the ranch each year, knowing that years will go by without the right conditions for the prescription. So I'll miss some years. For my cow/calf operation and wildlife program I want something like this: an abundance of grasses and forbs with a lesser amount of woody plants. Close examination shows shinnery, wild plum (Prunus spp.), redbud (Cercis spp.), hackberry and all the rest present but in more nearly the correct percentages.

CONTROLLING MATURE CEDAR WITH HEADFIRES[1]

F. C. Bryant and G. K. Launchbaugh

Highlight

Today, most ecologists recognize fires are natural factors that control the long range patterns of vegetation (Blackburn and Bruner 1975). When fire is absent as a natural factor, this also may influence the development of plant communities. For the Edwards Plateau, this absence of fire has been cited as at least one reason for the invasion of Ashe juniper (Juniperus ashei) into the prairie regions. Long ago it was confined to rougher, more dissected topography of the Plateau (Wells 1970).

Introduction

Previous research using fire to control juniper has dealt with areas in Texas where the juniper was pre-treated by chaining (Wink and Wright 1973) and in Oklahoma, where no pre-treatment was necessary (Dalrymple 1969). In both studies, there was enough herbacious fuel on the ground to carry a fire through the juniper infested grassland. With a minimum of 1000 lb/AC (1,123 kg/ha) of herbaceous fuels, Wink and Wright (1973) killed almost all trees that were less than 6 ft (1.8 m) tall. Dalrymple (1969) killed 100% of the trees 2 ft (0.6 m) tall or less and 77% of the trees between 2 ft (0.6 m) and 6 ft (1.8 m) tall. However, few trees taller than 6 ft (1.8 m) were killed by fire in Oklahoma and in New Mexico, Dwyer and Pieper (1967) noted that juniper mortality due to a wildfire decreased as tree size increased.

In our study, we wanted to see how fire might be used in dense juniper stands to kill large, mature trees where there was inadequate herbaceous fuel on the ground to carry a fire.

Study Area and Methods

The study area was located on the YO Ranch near Mt. Home, Texas. After a firebreak was cleared around the study site, some fifty small plots were established on 600 ac (243 ha) of dense Ashe juniper trees. Approximately half the plots were windrowed (that is, trees were uprooted and pushed against the standing live trees) and the other half were simply pushed down and uprooted to leave the plot as a scattered mass of downed trees. The latter treatment was to put 'fuel on the ground' to carry a fire. After allowing at least 60 days for the leaves to dry, the plots were burned in June and October 1979, and March, April, and May 1980. We evaluated the burns in terms of (1) how far the crown

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[1] The technical aspect of this paper is presently being submitted for publication in the Journal of Range Management. The authors are indebted to Charles Schriener IV for his generousity in allowing us to use facilities and land to complete this study.

fire traveled in the live, standing juniper and (2) how many live trees were killed by the fire.

Results

The least effective burns were on those plots where the juniper was just pushed down and uprooted. The most effective burns were windrowed plots that had the following conditions; high wind velocity (715 mph), low relative humidity (20-40%), low moisture content in the leaves of the live trees (37.41%), and crown cover of juniper trees greater than 35%.

The maximum distance the fire moved through crowns of green juniper was approximately 450 ft (137 m) and greatest number of trees killed was 421 (2 ha).

In every case, the crown fire went out by itself when the fire reached areas where the trees were greater than 45 ft (13.7 m) apart (<25% crown canopy).

Summary

The potential for broad application of this technique is limited by two salient factors. First, there were few days during our study when the average wind speed was great enough to carry a good crown fire. Second, areas where canopy cover of juniper exceeds 35% may be isolated.

On the positive side, for brush control, this technique would allow a savings in costs for mechanical treatment where there is inadequate fine fuel to carry a fire, When we were able to ignite crown fires from the windrows, we killed about six trees for every one that was pushed into the live stand. Also, a firebreak would not be necessary if (1) an applicator grazed livestock heavily enough for a short period before the burn to reduce the chance of a grass fire and (2) he selected the area where he wanted the crown fire to stop by burning into less dense stands (that is, where trees are farther apart than 45 ft (14 m)]. As with any brush control, he should rest the entire pasture where the burns occurred for at least one year after the burn.

Further, this technique may have application in habitat management to 'open up' dense, stagnant stands of juniper, especially where live oak or shin oak occur and burning encourages resprouting of nutritious leaves and stems. Where appropriate, windrows could be pushed 0.5 to 1.0 miles (0.8 to 1.6 km) in length in semi-parallel lines every 900 ft (274 m). If a maximum crown fire extended 400 ft (122 m) into the standing juniper, 450 ft (137 m) would be left as a strip for wildlife cover between the burns.

The ultimate evaluation of this technique of burning standing green juniper will be answered over the next three to five years. We must know how long it will take for the scar to 'heal' after such a drastic burning treatment.

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Techniques and Procedures for Safe Use of Prescribed Fire

Henry A. Wright

We know a lot about the effect of fire on western rangelands and its value as a tool, but information necessary to conduct specific prescribed burns is generally inadequate or non-existent. Thus, the use of fire is frightening, and many undesirable prescribed burns just do not get started. Few land managers have the training or courage to conduct a burn. Most have been exposed only to catastrophic fires, which are untimely, have undesirable effects, and scare everyone in their path.

There are other fears which inhibit prescribed burning. One is a fear of the liability consequences if a fire gets away. This fear affects individual landowners and also influences government agencies. Another fear, which has been important in the past but may be less so now, is a concern about one's career if he lets a fire get away.

Fire is not as dangerous as most people think. It is just dangerous to be inexperienced. It is very dangerous to be half-experienced, for this is the person who becomes over-confidence and could do the most damage.

When I arrived at Texas Tech 13 years ago, I had very little experience in burning plots or large acreages. My students and I learned as we went. Despite our inexperience, we have not had any serious escapes, although we have had little "slop-over" from time to time, particularly during the first few years. This should provide each of you with encouragement that you can learn to do prescribed burns without serious consequences, if you try to be reasonably careful and follow some basic guidelines.

During the past 13 years that I have been at Texas Tech, I have conducted or supervised about 135 fires under a wide range of fuel and weather conditions. Firewhirls caused two escapes in 1969. One burned 10 acres (4 ha) and the other burned 500 acres (200 ha) in honey mesquite (Prosopis glandulosa)-tobosagrass (Hilaria mutica) communities. Neither of these escapes were serious and they occurred before we knew anything about firewhirls. Firebrands from high volatile fuels (e.g. Ashe juniper (Juniperus ashei)) have caused numerous spot fires, particularly in dozed Ashe juniper and shin oak (Quercus sp.) in the Edwards Plateau. Again, however, most of these occurred while we were developing prescriptions, and we were prepared for their occurrence (D-7 caterpillar, pumper, and crew of 12 people to conduct burn). Only one of the spot fires burned as much as 0.5 acre (0.2 ha).

My point is that although fires need to be planned and we need to be careful, the training period for prescribed burning is not necessarily one of high risk. Keep in mind that we have never had more than 12 to 14 men, a D-7 caterpillar tractor, and a 100 gallon slip-on pumper on any fire.

In this paper, I intend to give you some basic background on firing techniques and how you can apply them to accomplish various management objectives in the Edwards Plateau.

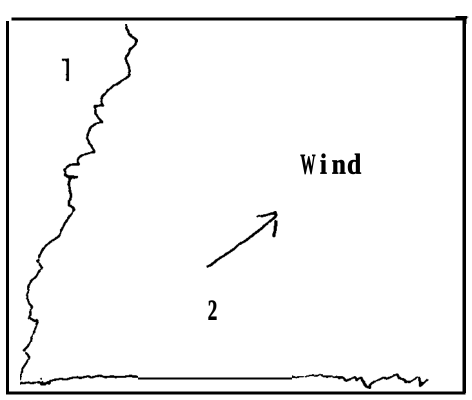
Firing Techniques

Headfires, backfires, strip-headfires, flank fires, center ignition, and area ignition are all methods to ignite fires (Fig. 1) (Davis 1959, Dixon 1965, Southwest Interagency Fire Council 1968, Sando and Dobbs 1970, Mobley et al. 1973). Since these methods have been thoroughly discussed in the above references, they will only be briefly discussed here, although their use will be more fully illustrated for the Edwards Plateau in sections that follow.

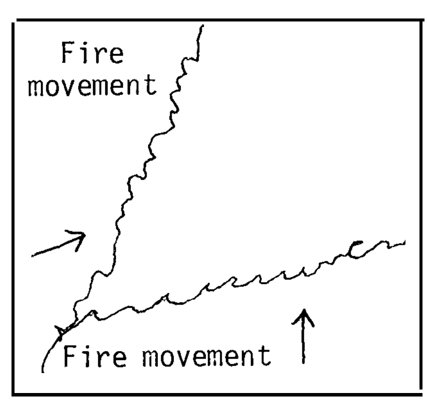
Headfires (fires that move with the wind) are most effective for killing shrubs and trees (Fahnestock and Hare 1964, Gartner and Thompson 1972) and in getting an effective burndown of standing dead trees (Britton and Wright 1971). They are also effective in using low quantities of fine fuel [600 to 1,000 lb/acre (674 to 1,124 kg/ha)] to efficiently clean up debris and brush (Heirman and Wright 1973, Wink and Wright 1973). Backfires (fires that back into the wind) work well (1) when the fine fuel (less than 1/8-inch in diameter) exceeds several thousand pounds per acre, (2) when you wish to maintain good control in high volatile fuels (e.g. dozed juniper), (3) when you wish to reduce heat damage to overstory conifers (Biswell et al. 1973, Mobley et al. 1973), and (4) when the weather is more risky than is desirable.

Strip-headfires and flank fires are variations in between the speed with which headfires and backfires move. They are usually used when backfires move too slowly but a headfire would be undesirable or too dangerous. Area ignition (Fenner et al. 1955, Schimke et al. 1969) is used to set the entire area on fire at once and cause a fire to suck into the middle. We do not recommend using this technique in the Edwards Plateau. Center ignition (Beaufait et al. 1966) is similar to area ignition although the center is lit first, and the intensity of the fire increases more slowly over time than area ignition. These latter two fire techniques usually burn very intensely and can cause firewhirls to start. Center ignition and sometimes area ignition are generally used for slash burning when winds are light. They are of little value for prescribed burning in the Edwards Plateau.

The way that a fire is lit can affect fire behavior as much as anything. Fires in one location can be used to draw fire from another even though the prevailing wind may be blowing against the latter. Two diagrams below illustrate this point:



First sequence



Second sequence

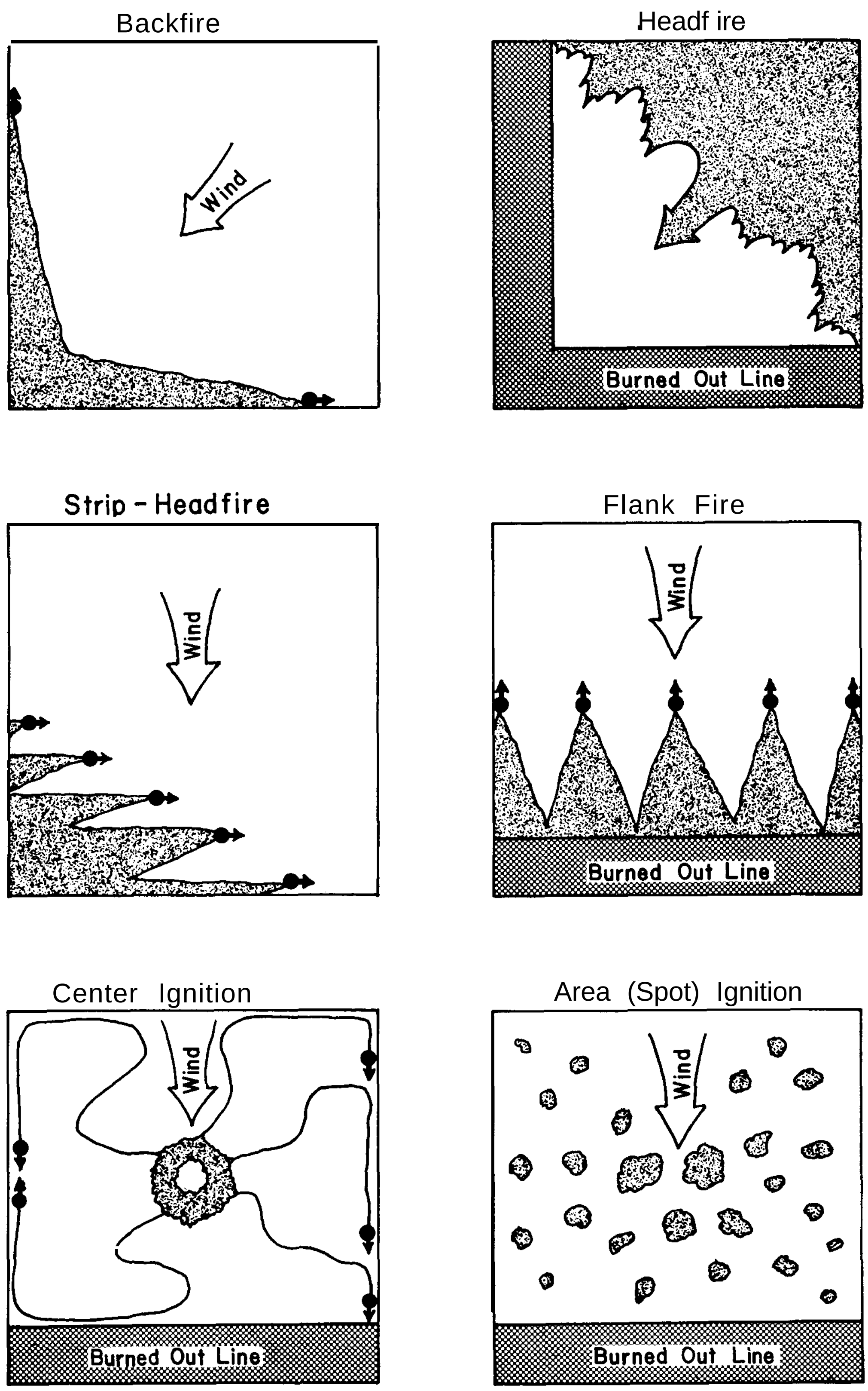


Fig. 1. Firing techniques used for prescribed burning.

Also, canyons will serve to pull fires. Fires move at twice the speed up a canyon as adjacent areas, and this intense burning will pull fire from adjacent areas.

Prescriptions for High Volatile Fuels

High volatile fuels (dead Ashe juniper is a prime example) require more preparation before burning than other fuel types (e.g. grassland and mesquite). Firelines on the leeward sides should be about 500 ft (150 m) wide and the trees and shrubs in the firelines need to be crushed, chained or dozed before being burned. These firelines with a 10 ft (3 m) dozed strip on each side (Fig. 2) need to be burned when relative humidity is within the range of 40 to 60%, air temperature is within the range of 40" to 60°F (4" to 16°C), and wind speed is less than 10 mi/h (16 km/h). When air temperature drops to 40°F (4°C) and relative humidity rises to 60% it is very hard to ignite anything. However, as long as the relative humidity does not drop below 40% and wind speeds are light, there will be little risk from volatile firebrands (Bunting and Wright 1974, Green 1977).

After the firelines have been prepared, crushed strips in brush or grass will be needed to ignite the headfire. For headfires, we recommend air temperatures of 70" to 80°F (21" to 27°C), relative humidity of 25 to 40%, and wind speeds of 8 to 15 mi/h (13 to 24 km/h), provided you have a 500 ft (150 m) fireline to burn into.

Dozed Juniper in Mixed Prairie (Texas)

This is a high volatile fuel that gives off firebrands which ignite cow dung easily. Generally dozed or chained areas are not burned until 3 to 5 years after treatment. This allows time for native grasses to recover, time for juniper seeds to germinate, and time for most leaves to fall off the dead trees. The primary objective of burning is to remove dead piles and to kill young juniper trees.

A 500 ft (150 m) fireline is prepared on the north and east sides of a pasture (Fig. 2). Dead piles of brush (4 to 5 years old) are burned out of this line in May or early June when the grass is green, wind speed is less than 10 mi/h (16 km/h), and the relative humidity is above 45%. Later (January or February), where little bluestem (*Schizachyrium scoparium*) is the primary fine fuel, the 500 ft (150 m) firelines are burned out when the relative humidity is 40 to 60%, and the wind speed is less than 8 mi/h 13 km/h) using the strip-headfire technique (Fig. 3). Where buffalograss (*Buchloe dactyloides*) occurs, a higher wind speed and lower relative humidity are required.

After the fireline has been burned out, the rest of the area is burned with a southwest wind when the relative humidity is 25 to 40%, wind speed is 8 to 15 mi/h (13 to 24 km/h), and air temperature is 70" to 80°F (21° to 27°C) (Fig. 2). After a rain, wait at least 5 days to burn.

For safety, avoid burning backfires into headfires and avoid burning across ridges. Firewhirls can easily develop under these situations. When

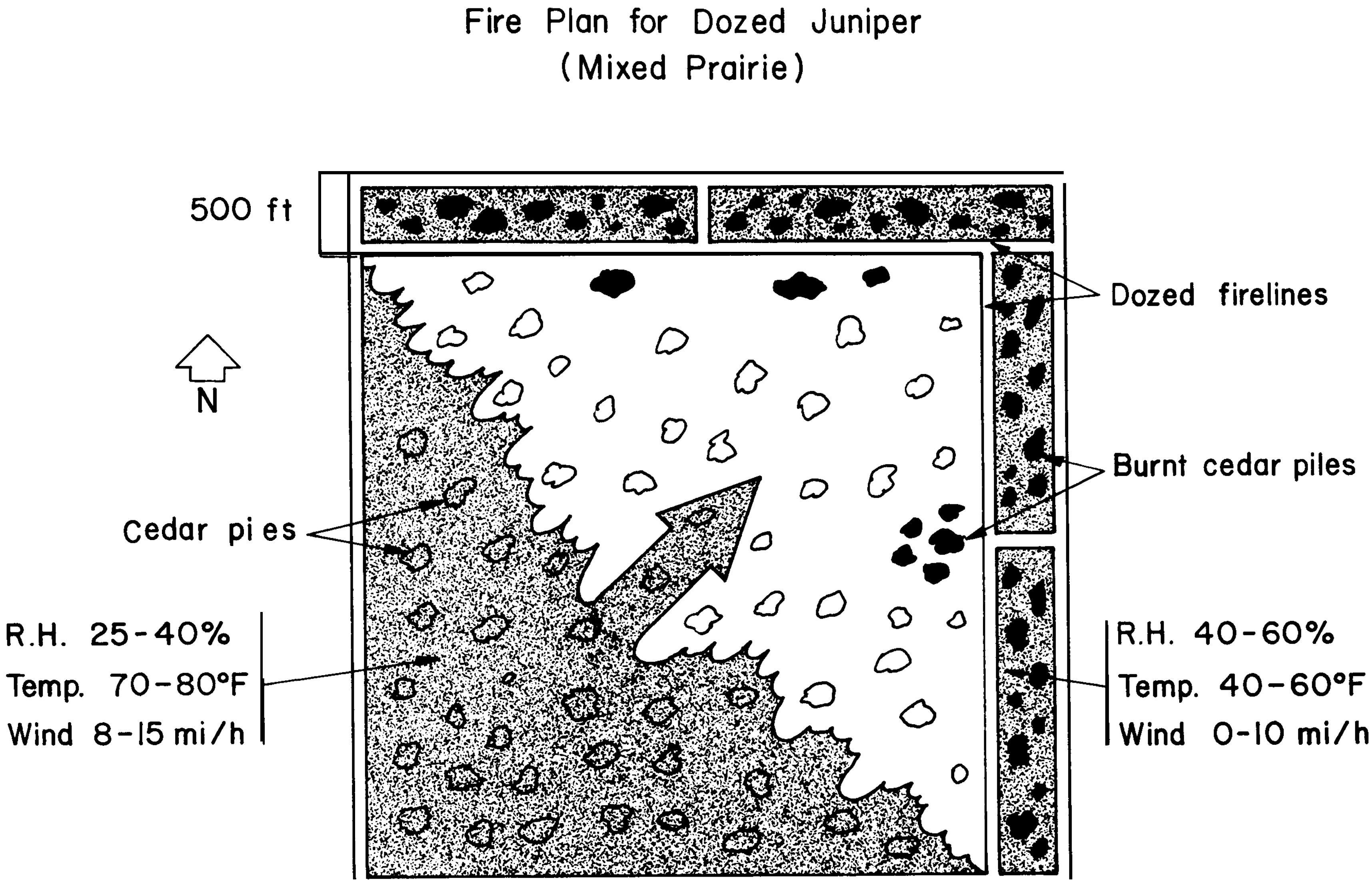


Fig. 2. When the grass is green, juniper piles in the 500 ft (150 m) strip (black splotches) on the downwind sides (north and east) are burned with wind velocities less than 10 mi/h (16 km/h) and relative humidity above 45%. Eight months later (when grass is dormant), the grass in the 500 ft (150 m) strip is burned (strip-headfire technique) when the wind speed is less than 10 mi/h (16 km/h) and relative humidity is between 40 and 60%. Lower relative humidities may be used if the grass fuel is less than 2,000 lb/acre (2,247 kg/ha). All large concentrations of piles are backfired on the downwind sides of main area to be burned, and then the entire area is burned into the prepared firelines with a wind speed of 8 to 15 mi/h (13 to 24 km/h) and a relative humidity of 25 to 40%.

Strip -Headfire Technique to Prepare Firelines

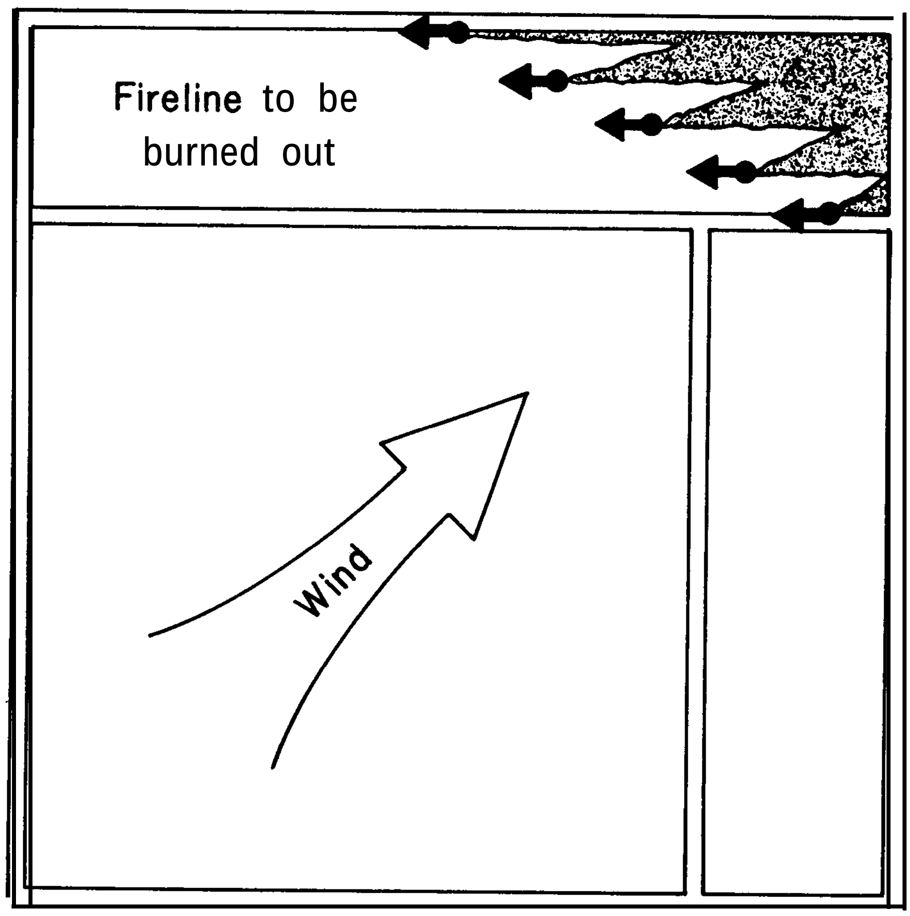


Fig. 3. The strip-headfire technique usually involves the combination of a backfire (lead man) and several staggered strip-headfires. The men are staggered so that the fire will not over-run anyone. Also the line of the second man may only be 10 to 20 ft (3 to 6 m) from the dozed line, whereas the men will usually be spaced progressively farther apart [e.g. 33, 82, 164 ft (10, 25, 50 m)]. This is a very common technique to burn firelines in most vegetation types.

possible, burn into heavily grazed pastures to minimize risk. In this fuel type, one should have at least two seasons of burning experience before assuming responsibility for conducting a burn.

Chained Juniper in Mixed Prairie (Texas)

Chained juniper is less hazardous to burn (Fig. 4) than dozed juniper because the dry juniper fuel is closer to the ground and burning embers are not likely to travel more than 250 ft (75 m), although we use the 500 ft (150 m) fireline in this fuel type for safety until we have more data. Thus, the dead trees in the fireline can be burned at the same time as the grass.

Prescriptions for Low Volatile Fuels

Detailed prescriptions for conducting burns in low volatile grassland fuels (e.g. grasslands that may have been seeded following brush control) have been given by Wright (1974, 1979) and Wright and Bailey (1980). Depending on the objectives and the quantity of fine fuel, a wide variety of prescriptions can be used. Experience is the best teacher. Generally, firebrands (glowing embers) are not a problem in grasslands with low volatile shrubs and trees (e.g. honey mesquite), but chunks of glowing debris will easily roll on the ground when wind gusts above 20 mi/h (32 km/h). Thus, depending whether the objective of a prescribed burn is to remove litter, burn debris, or topkill shrubs and trees, the desired fireline width will vary depending on quantity of fine fuel in adjacent pastures and the wind speed and relative humidity needed to accomplish objectives. Firelines in low volatile fuels may range from the width of a cow trail to 200 ft (60 m).

Firewhirls develop where wind shears occur such as when a headfire runs into a backfire, or a fire goes up slope into a wind. We have seen several firewhirls develop when headfires met backfires while wind speeds were 10 to 15 mi/h (16 to 24 km/h). We have also seen two huge firewhirls develop when wind speeds were light and variable. For these reasons, we prefer to burn with a steady wind and never burn into backfires, unless we have at least a 300 ft (91 m) fireline. Fires should be planned to move with the ridges, not across them.

Decadent Bluestem or Seeded Species

The primary reason for burning areas such as this are to (1) remove litter, (2) increase forage yields, (3) increase palatability of grasses, and (4) suppress undesirable shrubs. Usually, 3,000 to 4,000 lb/acre (3,371 to 4,494 kg/ha) of fine fuel (less than 1/8-inch in diameter) is present. Thus, most burns can be conducted when the relative humidity is 50 to 60%, wind speed is less than 10 mi/h (16 km/h), and air temperature is 40" to 60°F (4" to 16°C). Firelines only need to be 10 to 12 ft (3 to 4 m) wide.

A procedure for conducting such fires (Fig. 5) has been outlined by Launchbaugh and Owensby (1978). They start the fire on the down wind side using two people to light and two pumpers to patrol. After the fire has burned back 50 to 100 ft (15 to 30 m), then the rest of the pasture is headfired. Grasses are relatively safe to burn, using this procedure, unless the

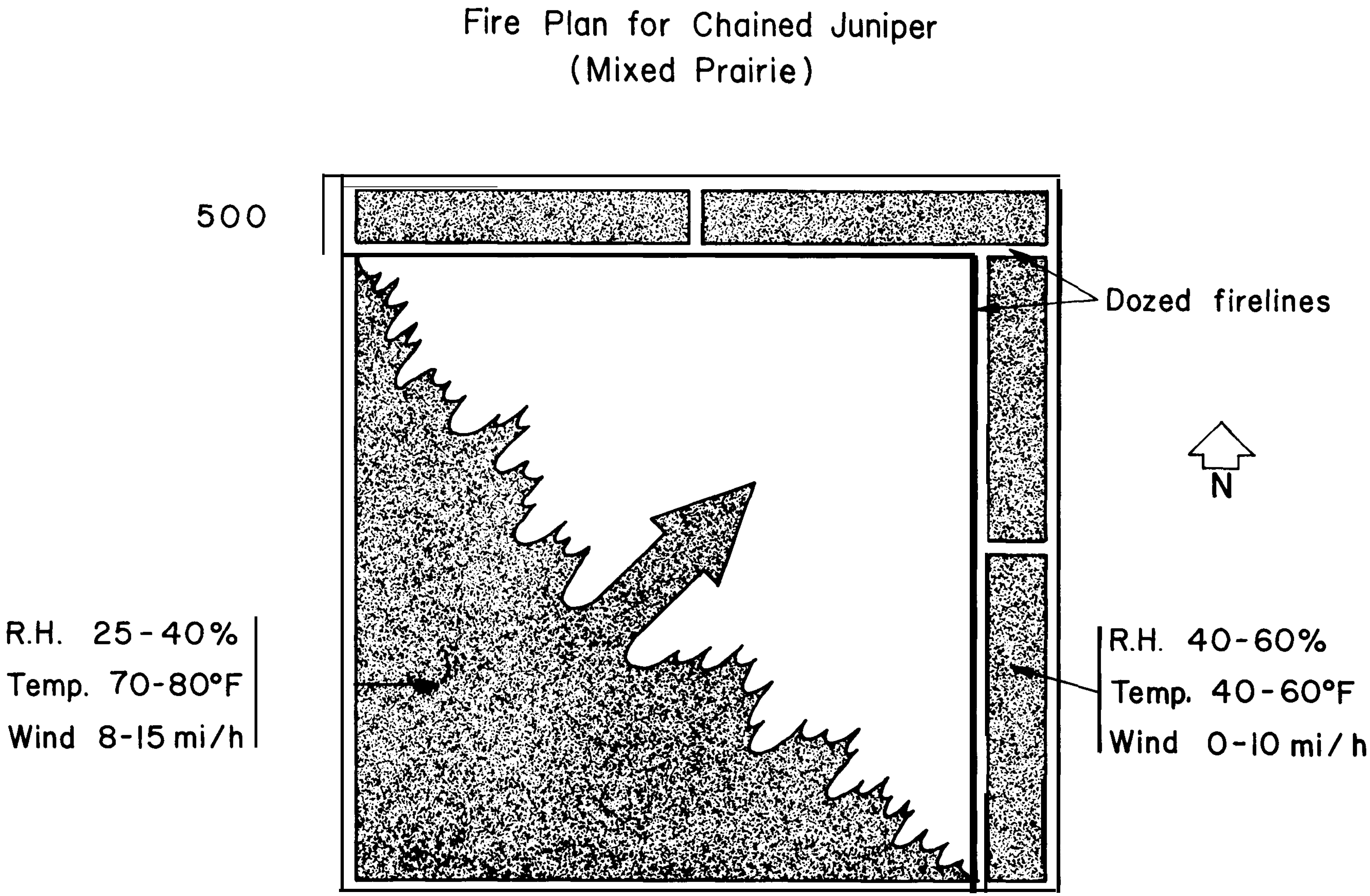


Fig. 4. Fire plan for chained juniper. Using the prescription indicated, dead brush and grass can be burned simultaneously in early spring.

Fife Plan for Tallgrass Prairie

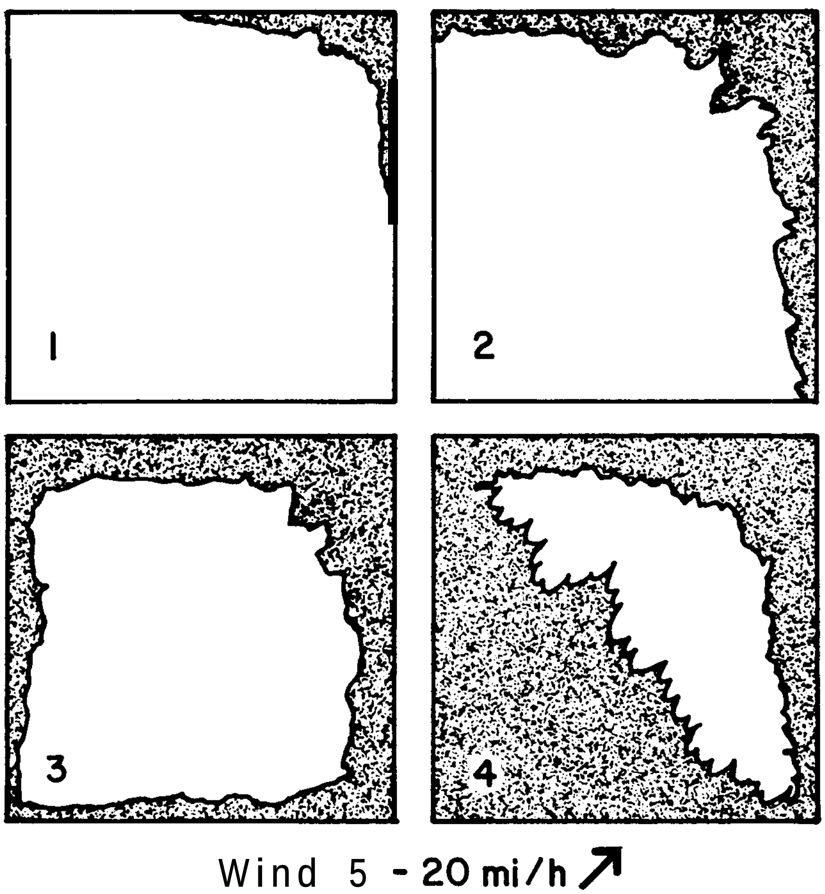


Fig. 5. In tallgrasses natural firebreaks, including roads, trails and fenceline cowpaths, are used to the extent possible. In some cases a wetline may be put down with a sprayer where there is no natural break. A backfire is started on the downwind side (1) and lit simultaneously in each direction on the downwind sides (2). After the backfire has burned 50 to 100 ft (15 to 30 m) on the lee sides, then the remainder of the area is lit (3), and burned with a headfire (4). Wind speeds may vary from 5 to 20 mi/h (8 to 32 km/h) (Launchbaugh and Owensby 1978). Relative humidity is usually above 40%.

winds become gusty and blow burning debris across the fireline. This technique can be especially useful in seeded grasslands where young juniper trees are becoming established, but are less than 4 ft (1.2 m) tall.

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Planning and Conducting Prescribed Fires

Henry A. Wright

For me, fire planning has usually been a simple matter, once I knew the objectives that I wanted to achieve and that the prescription for achieving these objectives had been tried and proven reliable.

My first step is to visit the area that someone wants to burn and look at the fuel type. Is it high volatile fuel (e.g. juniper, Juniperus spp.) or a low volatile fuel (e.g. grass and mesquite, Prosopis spp.)? Assuming that we plan to work with a high volatile fuel, has the area been chained or dozed? I must be extremely careful on dozed sites, but have more leeway on chained sites.

The next step is to look at the lay of the land and decide how it should be burned. Generally we like to use southwest winds (driest and most prevalent winds) for the main headfire. However, if these winds would move across ridges, we may prefer to use southeast winds as a second alternative to minimize the risk of forming firewhirls.

Once we have looked the area over and decided how we want to burn the area, we draw a map with all roads and proposed firelines. On the map we draw in major ridges, hills, etc. and write prescriptions for backfires and main headfire. After thinking the "fireplan" over for a few days, we go back to the ranch and flag all lines that need to be dozed. We draw a map and go over the fireplan and dozed lines with the rancher or person in charge. The ranchers usually take care of all dozing. If an operator is hired to do the dozing we walk the lines while he cuts them.

All of this work may take place in November and December. Meanwhile we encourage the rancher to let his neighbors, local fire department, and local news media know what is going on. PR work is very important. We also encourage the rancher to graze pastures heavily on the lee side of the fire.

In February (or sometimes in January) we begin to look for the appropriate weather conditions to burn out firelines. We want to start burning when maximum air temperature for the day is about 60°F (16°C), minimum relative humidity is 40%, and maximum wind speeds are less than 10 mi/h (16 km/h). We watch the local weather every day until the right day seems to be near. Then we call the U.S. Weather Bureau in Fort Worth, Texas [(817) 334-3451; (817) 334-3401] and ask for the person in charge of giving Fire Weather Forecasts. This is usually done the evening before an anticipated burn. Currently, we usually ask for Dick Lyle or Jeff Brown. If they are not on duty, we ask when they will be on duty and make the best out of the forecast we get. You can usually tell whether the person on duty knows more than you do.

If the preliminary forecast for the next day looks good, we alert all members of our fire crew that we will probably burn tomorrow and give them the approximate time that we plan to leave. Before leaving, we check the local weather and check with Fort Worth again. If their forecast is good then we pass out the final word that we will be burning.

A good rule to remember in this regard is that for every 20°F (11°C) increase in temperature, the relative humidity will drop 50%. Thus, if you get up in the morning and the high predicted for the day is 60°F (16°C), you can quickly measure the relative humidity and current temperature to estimate the low relative humidity for the day. Meanwhile we gather up a crew of 6 to 12 people, 4 radios, 6 shovels, 6 swatters, 2 pickups (one with a slip-on pumper), 5 drip torches, 30 gallons of fuel (70–30% disel-gas mixture), 2 belt-weather kits, and a couple boxes of matches.

When we arrive at the burning site, we check wind direction to see where we should start burning. If weather conditions are on the "high safe" side, we begin burning in buffalograss areas and save the heavier fuels for later. Burning is done using the strip-headfire technique mentioned earlier, with 2 to 3 people with swatters spaced behind the lead torch and a pumper following them. At least four people have FM radios.

If air temperature is 60°F (16°C), relative humdity is 40%, and wind speed is 10 mi/h (16 km/h), we proceed cautiously. However, after the relative humidity rises above 50%, we issue all drip torches and tell everyone to move as fast as they can. Only the pumper patrols the firelines. When air temperature drops to 40°F (4°C) and relative humidity rises to 60%, we usually have to quit burning because only the heaviest stands of grass will burn. The next day we check for smoldering debris and move it 50 ft (15 m) inside the fireline.

We repeat the above procedures until we have all firelines burned out. This usually involves three trips for a 2,000 acre (810 ha) pasture.

After all firelines have been burned, we start looking for suitable weather for the headfire--air temperature 70" to 80°F (21" to 27°C) , relative humidity 25 to 40%, and wind speed 8 to 15 mi/h (13 to 24 km/h) . Again, we follow local weather until a suitable day is approaching and then we ask the U.S. Weather Bureau in Fort Worth for a forecast, Before leaving to burn, the next day, we get an updated forecast.

If everything looks good, we call the rancher and tell him to notify neighbors and the fire departments again. Despite all of his telephone work, his phone will still ring off the hook, but the word eventually gets out. Be sure to tell the fire department not come out unless you tell them that you are in trouble. After the burn is over, plan to spend the next day mopping up to be sure that nothing is burning within 50 ft (15 m) of your firelines. A dozer is highly desired for this work.

At this point the burn is finished but let me give you some precautions. Remember that prescriptions for specific fuel are helpful in the planning of a burn, but they do not protect you against the intangibles--a hill on the side of a pasture that might cause unusual winds, a canyon on the lee side that may aid the formation of an intense firewhirl which will throw firebrands at greater distances than normal, unusual fuel densities that can create intense firewhirls, possibility of a night-time low-level jet wind, or volatile fuel material. This is why experience in fire behavior is stressed before letting people strike out on their own.

Lastly, do not tell people how to burn a piece of property over the telephone. Your information based on many years of experience does not mean much to most people, and they will most likely burn on Thursday regardless of the weather. On the other hand, when people ask for help, we should do all we can to help them. Otherwise, many of them will proceed without help and burn several thousand acres of their neighbor's land and many miles of fence, as we have already witnessed more than once.

Environmental Considerations and Regulations Associated with Range Burning

Gary I. Wallin

In 1975 the Texas Air Control Board's regulations were changed allowing outdoor burning for specified purposes when certain conditions are met. Prior to this time the regulations did not contain any rules allowing outdoor burning for crop or range management purposes. Prior to changing the regulation the Board held several meetings, a public hearing, received many written comments concerning outdoor burning and studied other state's regulations.

As you know, the burning of vegetable matter produces air contaminants. Through research, emission rate factors have been developed for different types of burning operations (Table 1). The factors given for grasses is probably representative of range burning emissions. The major contaminants are particulate matter, carbon monoxide and hydrocarbons. The general publics primary concern with outdoor burning is visible degradation.

Even though emissions from outdoor burning of vegetable matter for forest, range and crop management purposes can put large amounts of contaminants into the atmosphere, the Board decided to allow this outdoor burning when there is no practical alternative to burning and when the burning will not cause or contribute to a violation of any Federal primary or secondary ambient air standard.

The portion of Regulation I pertaining to this type of outdoor burning reads:

Outdoor burning is authorized in each of the following instances:

Outdoor burning in a rural area of trees, brush, grass and other dry vegetable matter at the site where it occurs and only when no practical alternative to burning exists for right-of-way maintenance, land-clearing operations, and for those forest, crop, and range management purposes not specifically governed by orders issued pursuant to Rule 131.03.01.002(a) of this Regulation if all the following conditions are met:

(1) Any burning conducted for salt marsh grass management purposes in the following counties may be conducted only after verbal or written notification to the Texas Air Control Board Regional Office having jurisdiction: Orange, Jefferson, Chambers, Galveston, Harris, Brazoria, Matagorda, Jackson, Calhoun, Aransas, Refugio, San Patricio, Nueces and Kleberg. Burning of salt marsh grass in these counties shall not be conducted during periods of actual or predicted persistent (12 hours or more) low-level atmospheric temperature inversions (non-surface based) or in areas covered by a current National Weather Service (NWS) Air Stagnation Advisory. This meteorological data will be available from the Texas Air Control Board Regional Office having jurisdiction.

Table 1. Emission factors and fuel loading factors for open burning of agricultural materials

Emission Factor Rating: B

Refuse category	Emission factors: Particulate lb/ton	kg/MT	Carbon monoxide lb/ton	kg/MT	Organics (as C_6H_{14}) lb/ton	kg/MT	Fuel loading factors (waste production) ton/acre	MT/hectare
Field crops								
Unspecified	21	11	117	58	23	12	2.0	4.5
Grasses	16	8	101	50	19	10		
Headfire burning								
Alfalfa	45	23	106	53	36	18	0.8	1.8
Bean (red)	43	22	186	93	46	23	2.5	5.6
Hay (wild)	32	16	139	70	22	11	1.0	2.2
Oats	44	22	137	68	33	16	1.6	3.6
Pea	31	16	147	74	38	19	2.5	5.6
Wheat	22	11	128	64	17	9	1.9	4.3
Backfire burning								
Alfalfa	29	14	119	60	37	18	0.8	1.8
Bean (red), pea	14	7	148	72	25	12	2.5	5.6
Hay (wild)	17	8	150	75	17	8	1.0	2.2
Oats	21	11	136	68	18	9	1.6	3.6
Wheat	13	6	108	54	11	6	1.9	4.3
Vine crops	5	3	51	26	7	4	2.5	5.6
Weeds								
Unspecified	15	8	85	42	12	6	3.2	7.2
Russian thistle (tumbleweed)	22	11	309	154	2	1	0.1	0.2
Tules (wild reeds)	5	3	34	17	27	14		

(Adapted from Lahre, T. and P. Canova. 1978)

(2) Prior to prescribed or controlled burning for forest management purposes, the Texas Forest Service shall be notified.

(3) The burning must be outside the corporate limits of a city or town except when it is necessary to eliminate a naturally occurring fire hazard.

(4) Burning shall be commenced only when the wind direction is such as to carry smoke and other pollutants away from any city, town, residential, recreational, commercial or industrial area, navigable water, public road or

landing strip which may be affected by the smoke. Burning shall not be conducted when a significant shift in wind direction is predicted which could produce adverse effects to persons, animals, or property during the burning period. If at any time the burning causes or may tend to cause smoke to blow onto or across a road or highway, it is the responsibility of the person initiating the burning to post flagpersons on affected road in accordance with the requirements of the Department of Public Safety.

(5) The burning must be at least three hundred feet (ninety meters) from any residential, recreational, commercial or industrial area except those located on the property where the burning is to take place, except when it is necessary to eliminate a naturally occurring fire hazard.

(6) Heavy oils, asphaltic materials, items containing natural or synthetic rubber or any material other than dry plant growth which may produce unreasonable amounts of smoke must not be burned.

(7) The hours for burning shall comply with the following:

(A) The initiation of burning for land-clearing and right-of-way maintenance purposes shall commence after 9:00 a.m. Material which will not be completely consumed before 5:00 p.m. shall not be added to the fire.

(B) The initiation of burning for crop and range management purposes shall commence after 9:00 a.m. The acreage to be burned should be adjusted to provide that the burning is completed by 5:00 p.m. on the same day or as soon as reasonably practical.

(8) Burning shall not be commenced when surface wind speed is predicted to be less than 6 mph (5 knots) or greater than 23 mph (20 knots) during the burn period.

As you can see, the burning of salt marsh grass in specified coastal counties gets special treatment in the regulation. The reasons for this rule are due to the past problems we have encountered with this type of burning. Numerous accidents have been caused by smoke blowing across highways and severe visible degradation created when burns were conducted during atmospheric inversions. The worst problems have occurred in the more populated counties. Please contact our nearest regional office prior to burning any salt marsh grass. Our regional office will be able to advise you about any air stagnation advisories.

With any burning always watch the weather. The wind direction, wind speed, time of day, and humidity play a big part in minimizing the effects of your emissions. Always think of your neighbors and try to burn under the conditions that will least likely bother them. For those with close neighbors, you may want to notify them prior to burning.

There are numerous burning procedures that tend to improve the effectiveness of your burns as well as keep your emissions to a minimum. Burning when your combustible material is dry, when the wind speed is not too high or too low and burning against the wind are such conditions. Emission factors for open burning of agricultural materials indicate backfiring will substantially reduce the quantity of particulate matter produced but will slightly increase emissions of carbon monoxide and organics (Table 1). An effective burn and low emissions compliment each other.

So, in summary, the Board has recognized the need for outdoor burning for range, crop and forest management purposes. However, we require that certain precautions are taken to minimize the effects of these burns. If everyone does their best to comply, the right to practice outdoor burning will continue to be allowed by the Board,

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Lahre, T. and P. Canova. 1978. Supplement No, 8 for compilation of air pollutant emission factors, third edition (including supplements l-7). U.S. Environmental Protection Agency, AP-42 Supplement 8, Section 2:4, 5 pp.

COSTS OF USING PRESCRIBED FIRE

Robert E. Whitson

Introduction

The use of prescribed fire for grassland management has been determined to be a very effective tool when properly utilized (Scifres 1980). A ranch manager must have information relating to his costs of using fire if he is to make valid comparisons to potential benefits and make a rational economic decision. The purpose of this paper is to identify major costs associated with using prescribed fire in the Edwards Plateau in order to improve the decision making environment for ranch managers in the region.

Considerable information is available concerning technical aspects of fire, potential benefits, methods of using fire, and environmental conditions which affect the successful application of fire. However, little information is available regarding costs associated with using prescribed fire. The costs of using fire will vary with the size of the bum, availability of equipment and labor and the value of forage that is burned.

A recent study in California indicated that total costs per acre ranged from $33.51/acre to $5.95/acre for bums ranging from 40 ac to 2,560 ac, respectively (Univ. of Calif. Ext. Serv. 1979). Other studies by the Forest Service have indicated that burning costs associated with controlling big sagebrush were about $4.00/acre (Nielsen and Hinckley 1973).

No two ranch firms will likely have the same costs. Therefore, less emphasis should be placed on the magnitude of the costs identified in this paper, while more emphasis should be placed on the identification of the categories of costs. Each ranch manager who utilizes burning as a range improvement tool should plan to develop and keep accurate records of what it costs his operation to conduct a prescribed burn.

Cost estimates described in this paper are developed for a manager who is considering an initial burn. Follow-up bums could perhaps be carried out at less cost. Further, cost estimates illustrated in this paper do not include interest charges associated with the total length of time the burn is effective. Cost estimates are illustrated for completing a bum through a 90-day deferment period post burn. Cost estimates are developed for 160, 320, 640 and 1280 acre burns.

Cost Categories

Within each general category, cost items will be discussed and specific requirements for personnel, equipment, services, supplies and indirect costs associated with the loss of forage will be itemized. Major cost categories of a burn for this paper include the following (Univ. of California, Extension Service 1979):

A. Planning/organizing
B. Fire lane construction
C. Burning
D. Post burn control
E. Loss of forage

Planning/organizing

This cost component is somewhat difficult to specify because generally ranch operators do not "pay" themselves for being a manager. Thus, a manager who has never used fire as a tool will likely need to spend several days learning proper techniques of how to safely manage a prescribed fire. Once he has mastered the required technology, time must be spent in development of the proper burning design. In a previous study it was determined that about as much planning and organizing goes into making a small burn (160 ac or less) as is required for a relatively large burn (perhaps 1,280 acres).

Utilizing estimates from previous studies, assuming adequate technical understanding, planning a bum is assumed to require approximately 16 man hours and approximately 8 vehicle hours. Using a cost of $5.00/man hour and $9.00/vehicle hour, organizing and planning a burn is estimated to cost $152. This cost on an acre basis is as follows:

Acres	$/acre
160	.95
320	.48
640	.24
1280	.12

Fire lane construction

The cost of fire lanes will vary depending upon whether they follow existing roads or right-of-ways or whether they will be constructed across pastures which may have moderate to dense brush infestations. Along existing roads or right-of-ways it is possible to use a farm type tractor and a heavy disc plow or a road maintainer to construct fire lanes. For purposes of this paper, it is assumed that 3/4 of the fire lanes will be constructed with a maintainer and 1/4 will require a dozer. Contract costs of $35/hour and $45/hour are assumed for maintainer and dozer services, respectively. Utilizing estimates developed by Hamilton (1980a) it is estimated that an 18 foot wide fire lane, constructed by a 12' maintainer, will require .77 hours per mile. It is assumed that a dozer constructed fire lane will require approximately 4 hours per mile. Using the assumed ratio of maintainer/dozer requirements, a mile of fire lane is estimated to cost $65.00/ mile. Fire lane costs per acre will depend upon the acreage of the burn and the configuration of the area to be burned. Using a square mile as an assumed configuration, the cost of fire lanes/acre is described in Table 1 for four sizes of a burn.

Table 1. Cost per acre for fire lane construction.

Acres	Miles of fire lane required (mi)	Total [a/] fire lane cost ($)	Cost/acre ($/ac)
160	2.0	130.	.81
320	3.0	195.	.61
640	4.0	260.	.41
1280	7.0	455.	.36

[a/] An average of $65./mile was multiplied by the total miles required.

As noted in Table 1, costs per acre decrease as the size of the burn increases. The difference in costs per acre diminishes as the burn size becomes 650 acres or larger. However, fire lane costs began to increase rapidly as the size of the burn is 160 acres or less (Table 1).

Burning

This cost category is expected to vary because of the possibility of "trading" labor with neighbors or other equipment savings which could result from local fire fighting equipment being available, etc. It is anticipated that most of the equipment needed for conducting a burn will be available at the ranch. However, necessary standby equipment such as a dozer or maintainer are not likely to be part of the ranch equipment and will consequently result in one of the major equipment costs (Hamilton 1980b).

Labor for carrying out a burn will vary depending upon specific conditions. However, it is estimated that a burn of from 160 acres to 640 acres will require 4-6 men. Between 640 and 1280 acres, it is estimated that 8-10 men will be required for an 8-10 hour period.

Expendable supplies, such as torch fuel, are estimated to require 5 gal. of a diesel/gas mixture per mile. For planning purposes, it is estimated that 50% of the fire lanes can be used to estimate burning fuel requirements. One or two pick-ups are estimated to be required during the actual bum for an 8-10 hour period.

Costs associated with burning are summarized in Table 2. Burning costs are estimated to range from $.63 to $2.43/acre depending upon the size of the burn. The higher cost associated with the smaller bum is due to the inefficiencies associated with utilizing men and equipment. The ranch with adequate family labor or which has access to lower cost standby equipment could expect to conduct the burn at less costs.

Table 2. Costs per acre for burning.

Acres	Fire crew [a/] ($)	Standby equipment [b/] ($)	Vechicles/ expendables ($)	Total cost ($)	Cost/acre ($/ac)
160	160	168	60	388	2.43
320	200	224	80	504	1.58
640	240	280	190	710	1.11
1280	320	280	200	800	.63

a/ Assume $40./day/man which includes meals and transportation.

b/ Assume 80% of contract price/hr. over 6-10 hour period for a maintainer.

Post burn patrol

This cost category will depend upon the individual ranch situation. A manager who could potentially lose his headquarters, might want to spend more time with post-burn patrol than a manager who had an isolated situation. An estimate of the patrol cost is based upon an assumed requirement of 2-4 men with 1-2 pick-ups and sprayers for a 4-6 hour period following the burn (Hamilton 1980a). Post burn patrol is estimated to cost as follows:

acres	total cost	$/acre
160	68	.43
320	105	.33
640	150	.23
1280	204	.16

Forage losses

This item will vary depending upon the type of grazing system being used and how the forage is being used. A manager who is using continuous grazing may need a pre-bum deferment of 4-6 months (or longer) in order to build fuel. Following the burn, another deferment period will be required of 60 to 90 days (or more) depending upon soil moisture conditions (Scifres 1980). In some situations, adequate fuel cannot be produced regardless of the deferment period because of poor range conditions, dense brush canopy, etc. In these situations, an initial treatment may be required, such as use of herbicide, prior to the pre-bum deferment. For this paper, cost estimates were developed for a post-burn deferment of 90 days. The cost of this deferment period was valued at $5.00 per animal unit month (AUM). It is assumed that an acre of range produces .6 AUM/acre for this study. Costs associated with loss of forage are assumed not to be affected by the size of the burn. Further, burning was assumed to be accomplished on an entire pasture basis. Therefore, no added costs were estimated for fencing which would be required if part of a pasture was burned. Using the above considerations, the value of deferred/ burned forage, was estimated to be $.75/acre.

Cost Summary

Total costs per acre of burning ranged from $2.02/acre to $5.37/acre and are summarized in Table 3.

Table 3. Summary 0 total costs per acre for burning in the Edwards Plateau.[a]

Acres	Planning/ organizing	Firelane construction	Burning	Post burn patrol	Forage loses	Total cost
160	.95	.81	2.43	.43	.75	5.37
320	.48	.61	1.58	.33	.75	3.75
640	.24	.41	1.11	.23	.75	2.74
1280	.12	.36	.63	.16	.75	2.02

a/ See each section for more specific details on development of individual cost categories.

Most of the economies associated with burn size are obtained when the size of the burn was 640 acres or more. For example, estimates indicate that it costs twice as much per acre to burn a 160 acre pasture as compared to a 640 acre pasture. Costs are 1.36 times greater when a 640 acre bum is compared to a 1280 acre bum.

It is emphasized that these costs represent "best estimates" of a typical ranch situation in the Edwards Plateau. Many specific situations will likely produce different estimates. Therefore, managers should plan to maintain cost records of their bums in order to accurately determine their specific costs.

The magnitude of burning costs should not be used as a criteria for adoption by managers. The decision to adopt fire should be done after considering the potential economic benefits associated with burning. The magnitude of these burning costs estimated in this paper appear to make fire an improvement alternative which should be considered by managers. However, further evaluation of the economic benefits of using fire by ranch managers must be accomplished before the economic feasibility question can be fully answered.

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