

PRIVATE-PUBLIC COLLABORATION TO REINTRODUCE FIRE INTO THE CHANGING ECOSYSTEMS OF THE SOUTHWESTERN BORDERLANDS REGION

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ABSTRACT

Fires caused by lightning or Native Americans were the major ecological factor in the borderlands region of Arizona, New Mexico, and Mexico prior to European settlement. Historical overgrazing and aggressive fire suppression have led to the encroachment of woody vegetation and accumulations of woody fuels in these grasslands. Ranchers associated with the Malpai Borderlands Group, state and federal land managers, and the staff of The Nature Conservancy agreed that re-introducing fire could improve landscape productivity and biological diversity. The ranching community was concerned that continued encroachment of woody plants would eventually affect its economic viability and result in the subdivision of ranches and the loss of its way of life. The parties in the borderlands group worked together to develop prescribed fire plans that have resulted in four landscape-level prescribed fires since 1995. They also developed a monitoring plan using established photo points, ground transects, aerial surveys, and remote sensing techniques to ascertain fire effects and to determine if modified procedures could be beneficial. The prescribed fires and results from the monitoring spurred research on wildlife habitat re-

quirements, fire histories, fire behavior, the effects of cool or warm season burning on multiple resources, and interactions of livestock and wildlife grazing and fire. Information from prescribed fires such as those conducted by the borderlands group will become more important as anticipated changes in the region's climate and vegetation produce new challenges to ranchers and agency land managers.

Keywords: Arizona, grasslands, New Mexico, private-public collaboration, reintroduction of fire, savannas, southwestern borderlands

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INTRODUCTION

Fires caused by lightning or Native Americans were the major ecological factor in the borderlands region of Arizona, New Mexico, and Mexico prior to European settlement. Periodic fires maintained grasslands and reduced the encroachment of woody vegetation and accumulations of woody fuels. However, historical overgrazing, which resulted in the decline of grass cover, and aggressive fire suppression reduced fire's influence. Concerns about natural fire management and the land management agencies' policies of suppressing all fires, even if they were producing beneficial results, were the catalyst for the formation of the Malpai Borderlands Group near Douglas, Arizona, USA. Ranchers associated with the Malpai Borderlands Group, state and federal land managers, and staff from The Nature Conservancy agreed that re-introducing fire could improve landscape productivity and biological diversity. They worked together with the Coronado National Forest to develop and implement the Peloncillo Programmatic Fire Plan for prescribed and managed fires. Under their direction, at least four landscape level prescribed fires have been ignited since 1995, the largest of which was a 19285 ha area in 2003. In support of the efforts to understand the ecology of the region's ecosystems and the impacts of re-introducing fire, a number of re-

search studies involving agency, university, and non-governmental organization scientists, are being conducted. Monitoring and scientific research are important components of these collaborative efforts and will become even more important in the future if projected changes in the region's climate occur, potentially changing vegetation characteristics that will affect land management and fire use strategies for stewardship of the land. Outreach to neighbors and to interested groups from throughout the west and the world is also an important component of the private-public collaboration.

THE SOUTHWESTERN BORDERLANDS

The southwestern borderlands of Arizona and New Mexico are within the Madrean Archipelago or Sky Islands region. The borderlands are part of the Basin and Range Physiogeographic Province between the Rocky Mountains and the Sierra Madre Occidental of northeastern Sonora and northwestern Chihuahua, Mexico. The area is characterized by mountains, occasionally exceeding 2745 m in elevation, that support mixed conifer or subalpine forests, surrounded by valleys supporting grasslands or deserts. The region is noted for its beauty and exceptional biological diversity. The Peloncillo Mountains, which are located

along the border between Arizona and New Mexico and contain at least 879 species of plants and 318 species of birds (Bodner *et al.* 2005), are an example of the diversity of habitats found in the area.

Precipitation varies by elevation and physiography; annual precipitation averages about 455 mm in the oak woodlands, which occurs in mid-elevation locations. Streams are intermittent or ephemeral and carry water generated from winter mountain snowpacks and summer thunderstorms during the monsoon period. Some streams support riparian habitats and are locally important for ranches and wildlife.

Cattle ranching has been the primary agricultural industry in the region since the 1870s and 1880s (Hadley *et al.* 1999). Use of the land for ecotourism (which is often related to the variety of bird species in the border region), camping, hiking, and hunting are increasing as the southwest's urban populations continue to grow and as people seek escape from the summer's heat. A relatively new situation, landscape fragmentation, threatens the area as large ranches are being subdivided for economic reasons into small parcels for exurban development (McDonald 1995, Hadley 2005).

FIRE IN THE BORDERLANDS

Extensive fires were frequent in the grasslands and woodlands of the borderlands prior to the 1880s (McPherson and Weltzin 2000). Fires were ignited by lightning storms in the pre-monsoon period or set purposely or accidentally by the indigenous peoples of the region. Approximately 80% of the fires attributed to the Apache Indians occurred during periods of warfare (Kaib *et al.* 1999). Climate and fire reconstructions have shown that large fires often occurred when dry conditions followed wet periods when fine fuels accumulated (Kaib *et al.* 1999, McPherson and Weltzin 2000). Mean fire intervals during a 230 yr record,

from 1650 to 1880, ranged from 4 yr to 8 yr for desert grasslands, 3 yr to 7 yr for canyon pine-oak stands, and 4 yr to 9 yr for mixed-conifer forests (Kaib *et al.* 1999).

Much of the alteration of natural fire regimes has been related to severe range deterioration linked to drought and overgrazing by large herds of cattle in the 1880s and 1890s (Hadley *et al.* 1999). As a result, when fires were ignited, they were not able to spread because of the lack of continuous ground cover. Woody species, such as mesquite (*Prosopis* spp.), increased their dominance on the range because fire no longer controlled their establishment and growth (McPherson and Weltzin 2000). Cattle also contributed to the spread of woody species by consuming and transporting edible tree seeds throughout the grasslands. Concurrently, species of oaks (*Quercus* spp.) and junipers (*Juniperus* spp.) expanded and became denser in the higher elevations (McPherson and Weltzin 2000).

A decline in fire frequency has been recorded in the tree ring records from seven mountain sites in Arizona and Mexico (Kaib *et al.* 1999). The record indicates that the occurrence of fires essentially ceased at about the beginning of the 20th century in the United States but continued uninterrupted in Mexican forests (Kaib *et al.* 1999). This reduction in fire frequency has been related to more aggressive fire suppression by the land management agencies in the United States as grazing impacts began to moderate.

In recent years, the occurrence of wildfires has increased along the border, probably because of increased illegal immigration and smuggling. The National Interagency Fire Center website (<http://gacc.nifc.gov/swcc/>) reports that more than 62% of the wildfires on the Coronado National Forest in 2007 were human caused. The number of human caused fires was slightly greater (67%) on the Coronado National Forest's three border ranger districts (Douglas, Sierra Vista, and Nogales) in

2007-2008 (C.H. Stetson, Forest Service, personal communication). It is difficult to differentiate between fires caused by undocumented aliens or smugglers and careless recreationists unless arrests are made. However, nearly 50% to 75% of the human-caused fires on the Coronado National Forest in 2008 occurred in areas known to be utilized by people engaged in illegal activities and not generally associated with developed or dispersed recreation (P.A. Gordon, Forest Service, personal communication).

These fluctuations in fire regimes, combined with climatic changes that include increased cycles of drought and abundant precipitation, have caused alterations in the region's vegetation (McPherson and Weltzin 2000). Drought has killed grasses and damaged or killed trees and shrubs, thereby adding to the fuel load. Subsequent wet periods have encouraged tree establishment in open areas created by drought. The shift from predominant summer precipitation to predominant winter precipitation has favored the establishment of C_3 woody species (McPherson and Weltzin 2000).

FIRE AND LAND MANAGEMENT

The Malpai Borderlands Group started as an informal discussion group of landowners and environmentalists. They were concerned about fragmentation of the landscape by subdivisions and the decline in productivity and biological diversity of the grasslands because of the encroachment of woody species onto grasslands (McDonald 1996). They believed that the lack of natural fires was a major factor in the shift in vegetation. The group was galvanized into action in 1992 following the active suppression of a beneficial fire in a grass-creosote brush (*Larrea* spp.) area where escape was unlikely. The Malpai Borderlands Group was formalized soon afterwards as a non-profit organization with the immediate goals to establish a fire management plan that included

ranchers and land management agencies, and to create a fire map that indicated how the private landowners wanted fire starts to be handled. Unfortunately, the map was not always used by the agencies suppressing fires. In 1994, a lightning fire ignited in Sycamore Canyon east of Douglas and the Bureau of Land Management (BLM) initiated aggressive suppression. The fire was actually reducing natural fuels, shrubs, and tree cover, and was creating a mosaic of vegetation types. It took a major effort by the landowner and the local Forest Service representative to halt the costly suppression activities.

The goals of the Malpai Borderlands Group are: "To restore and maintain the natural processes that create and protect an unfragmented, healthy landscape, to support a diverse, flourishing community of human, plant, and animal life in our borderlands region." (McDonald 1995:485). The group felt that it could achieve its goals by encouraging landowners to base management on sound science, a strong conservation ethic, and economic feasibility.

The members of the Malpai Borderlands Group believed that their efforts should be led by the private sector, with land management agencies and environmental groups as partners. Discussions between the group and the Forest Service and other federal and state agencies indicated common agreement about the benefits of the reintroduction of fire into the region's ecosystems and the desire to maintain open, unfragmented landscapes. The Natural Resources Conservation Service (NRCS) appointed a coordinator to work with the group. This is a unique position because the coordinator is not restricted by state borders and can work in both Arizona and New Mexico. The private landowners and the federal agencies continue to cooperate on specific projects and meet at an annual agency meeting.

Close cooperation amongst all parties is necessary because of the number and intermix-

ing of ownerships in the 323 755 ha region of interest. Approximately 53% of the land is in private ownership, 23% is administered by Arizona or New Mexico, 23% is administered by the Coronado National Forest or the BLM, and 1% is administered by the US Fish and Wildlife Service. Because the biological, physical, and cultural components of the Borderlands Project Area are representative of much of the land along both sides of the border between the United States and Mexico, the lessons learned from the project have wide application throughout the region.

THE PELONCILLO PROGRAMMATIC FIRE PLAN

The Peloncillo Programmatic Fire Plan was developed as a vehicle to reintroduce landscape level prescribed and managed fire into the Peloncillo Mountains (Allen 1999). It was written by an interagency, interdisciplinary team led by the Coronado National Forest in collaboration with the BLM, which administers parts of the mountain range. Approximately 48 565 ha of federal land within the Malpai area are included in the mountain planning area. The idea was to have a plan that covered the entire mountain range within federal administration and to address all of the environmental issues in one document.

The impacts of fire on the Arizona protected Palmer agave (*Agave palmeri*), the federally endangered lesser long-nosed bat (*Leptonycteris curasoae*), and the federally threatened New Mexico ridge-nosed rattlesnake (*Crotalus willardii obscurus*) prompted consultation with the state of Arizona and the US Fish and Wildlife Service. Palmer agave is particularly important because it provides nectar for the lesser long-nosed bat. However, research by Slauson *et al.* (1999) indicated that a prescribed fire did not result in differences in agave fruit set and overall resources for bats between burned and unburned sites.

Low intensity surface fires appear to enhance short-term population dynamics of the New Mexico ridge-nosed rattlesnake (Davis 2008). Holycross *et al.* (1999) used telemetry to study New Mexico ridge-nosed rattlesnake populations before and after a prescribed burn. The burn did not result in any mortality to ridge-nosed rattlesnakes. However, there was concern that prescribed fires in wooded canyons, which are preferred snake habitats and often contain high fuel accumulations, would adversely affect the limited snake population.

Prescribed burning protocols were developed to lessen potential impacts on the three species. The revised plans would involve conducting cooler burns in critical snake habitats, limiting ignitions after rains when the snakes are most active, and developing protocols on handling snakes that were found during burning operations. An allowable level of mortality was established for the agave that would not negatively impact the bats.

The plan, with four alternatives, was distributed to individuals and organizations for public comment (Allen 1999). The alternative that was chosen included actions that combined wildland fire, prescribed fire, and appropriate suppression with suitable consultations with affected landowners and grazing permittees. The final plan was included in the Coronado National Forest Land and Resources Management Plan. Although each action still required documentation and consultation, managers did not have to develop a completely new plan and enter into intense consultation for each prescribed burn. The development of the plan set a framework for future consultations between the US Fish and Wildlife Service and other agencies, and the Coronado National Forest.

LANDSCAPE PRESCRIBED BURNS

Since 1995, the Coronado National Forest, BLM, private landowners, and other federal

and state agencies have conducted four large landscape prescribed fires designed to begin ecological restoration in the southern Peloncillo Mountains. The project areas generally are at elevations above 1524 m that support mixtures of oak, juniper, shrubs, and herbaceous species. The general goals for the four landscape prescribed fires were to (1) restore historic biological diversity by reducing the density of woody species; (2) restore habitats for wildlife; (3) improve watershed stability, hydrologic function, and herbaceous cover; and (4) create a fuel mosaic that would allow fire to resume a more natural role in ecosystem function (G. Helbing, Forest Service, unpublished report). The specific objectives for the fires were to create a mosaic with 65% of the area burned, kill about 60% of the burroweed (*Isocoma tenuisecta*), reduce the number of smaller mesquite and junipers by 40% to 50%, and protect larger oak groves and riparian areas.

The first burn was in Baker Canyon and covered about 2430 ha near the international border. The second fire was the Maverick Fire in 1997, which covered an area north of the Baker burn. This was followed by the Baker II in 2003, which was planned for about 19285 ha of federal, state, and private lands, but final surveys indicated that 14365 ha were actually burned. Still, it was the largest successful prescribed burn ever conducted within the United States at that time. In 2007, a fourth landscape burn was conducted on about 2185 ha in Cottonwood Canyon, west and north of the Maverick Fire area.

Planning and conducting prescribed burns, especially large ones, require intensive coordination among many partners to meet objectives and to ensure the safety of personnel. The Baker II burn, for example, was conducted by personnel from the Coronado National Forest, other national forests, BLM, US Fish and Wildlife Service, National Park Service, and the Animas Foundation, which operates the Diamond A Ranch in New Mexico. The Dia-

mond A Ranch conducts an independent prescribed burning program on its private lands. The NRCS and Forest Service's Rocky Mountain Research Station assisted with planning, and the Mexican government sent observers and offered the use of a helicopter. Ignitions were done on the ground from prepared blacklines and from a helicopter in some inaccessible areas. The prescribed burns created a mosaic of grass and wooded areas and were generally successful in achieving the objectives.

MONITORING

Monitoring was an important part of the prescribed burning program. Scott (1999), for example, evaluated the effects of the Baker burn on agave and found that the damage to the agave population was small enough that bats dependent on the agave would not be impacted.

One problem in the case of prescribed fire is that the fire may not burn where plots are located. A choice must be made to either let the fire move normally through the area or to force ignitions near the plots, and possibly measure unnatural conditions. The deliberate burning of plots would defeat their purpose since the hope is that they would be representative of the actual treatment.

The Douglas Ranger District wildlife biologist and a Nature Conservancy scientist conducted a helicopter survey to assess the effects of the Baker II burn with special emphasis on critical snake habitat areas. They found that although some critical areas were impacted by the fire, most escaped severe damage. Yool (1999) and his associates used satellite images and other resources to evaluate the Maverick burn (Clark 1999) and to study landscape fragmentation related to wildfire, prescribed burning, and livestock grazing in the Peloncillo Mountains (Rogan *et al.* 2005). Such information provided managers with a better understanding of landscape changes and conditions.

CLIMATE CHANGE AND THE BORDERLANDS

Past grazing practices and changes in climate have directly impacted the productivity of the land and its ability to support healthy and diverse biological ecosystems today. The southwest has witnessed numerous cycles of wet and dry conditions over the centuries. These conditions are recorded in tree ring records (Swetnam and Betancourt 1998). The 1950s drought caused large-scale changes in the woodlands of the southwest and northern Mexico. Presently, the southwest has been in a drought situation since about 2000. Droughts are linked to increased fire occurrences (Swetnam and Betancourt 1998), and to declines in native grass cover and productivity that mimic the impacts of overgrazing (McPherson and Weltzin 2000).

Whether the drought cycles are normal or are the result of climate changes, ranchers and other managers are acutely aware of them. The Malpai Borderlands Group currently is encouraging its members to implement a system to monitor precipitation and vegetation by locating standard rain gauges and inventory transects on their home ranges. This system would alert ranchers to changes on the land that could be linked to precipitation as well as to management strategies. Such a system could also alert them to shifts in the climate.

Managers are aware of the possibility of climate change and are already concerned by observations that annual precipitation appears to have shifted from predominately summer moisture to predominately winter moisture. Such a shift, which could be accentuated by an increase in atmospheric carbon dioxide, would favor C_3 woody species over C_4 native perennial grass species (McPherson and Weltzin 2000). However, Bahre and Shelton (1993) reported that, at present, there is no evidence for a single, directional trend in annual or seasonal precipitation in the region since 1870,

and that all identified long-term changes in woody vegetation, except for mesquite, appear to be of anthropogenic origins.

Climate models are predicting that the arid southwest will become drier during this century, and that this transition is already occurring (Seager *et al.* 2007, Archer and Predick 2008). The models predict that temperatures will continue to rise, as would water demands by plants and animals, and that there will be an increase in extreme weather conditions. Precipitation may increase in some areas and decline in other areas of the desert southwest.

McPherson and Weltzin (2000) conducted a review of the impacts of fire and climate change on the borderlands. They indicated that an increase in atmospheric carbon dioxide and surface temperatures has been predicted to affect annual and seasonal precipitation amounts, with summer precipitation declining by 15% to 20%. Soil moisture needed for grass establishment and growth during the summer would decline. Such declines could affect tree regeneration as well. The increase in CO_2 would also favor the photosynthetic pathway of C_3 plants and, thus, the increased productivity of woody species over that of C_4 native perennial grasses. The result could be denser stands of woody species on grassland sites and possibly the expansion of woodlands. However, soil nutrient conditions could moderate some of these effects. Drought and low soil water that caused increased tree mortality, as observed during the 1950s, could provide more woody fuels for potentially stand-replacing fires. Climate change would impact species composition as less drought-tolerant species are eliminated or decline in importance from the landscape and are possibly replaced by undesirable exotic herbaceous species that are better adapted to more arid conditions (Archer and Predick 2008).

The potential of climate change raises many questions. Climate change will affect ranchers and others living in the region, but

how? While there appears to be general agreement that the climate will change, there are different theories on the outcome. Will a shift to drier and warmer conditions result in increases in the cover of woody species in spite of management, or will all species decline? Will prescribed and managed fires be harder to control, making prescribed fire a less desirable tool? Will more frequent wildfires destroy critical habitats for listed and common wildlife species? Will the native perennial grass species be able to regenerate and occupy available niches if soil water is too low and temperatures too great? Will the availability of water for livestock become a greater problem requiring deeper wells or costly transport of water over considerable distances? Will ranchers be able to adjust stocking rates to accommodate changing climatic conditions? Will extended droughts make it uneconomical to continue ranching?

The current interest in carbon accounting presents additional questions. Can ranchers profit from carbon offset management on private lands as suggested by de Steiguer (2008)? Because trees and forest and woodland ecosystems are relatively large sinks for carbon sequestration (Malmsheimer *et al.* 2008), will there be a financial benefit to ranchers for retaining more trees on their lands? What balance between trees and herbaceous vegetation for livestock would be most profitable? Will carbon offsets become a consideration for management of public lands, and how will this affect management? Less carbon is released by prescribed burning because of policies requiring acceptable atmospheric conditions during burns. In addition, less fuel is burned in prescribed fires relative to wildfires (Malmsheimer *et al.* 2008). Would this become another rationale for pursuing the prescribed fire program in the borderlands?

RESEARCH ON FIRE EFFECTS

Malpai Borderlands Group

Science is a key component of the Malpai Borderlands Group's approach to land management. The group and its members provide some financial and logistic support to scientists. Monitoring of landscape fire effects and studies such as the McKinney Flats Herbivory and Fire Study, designed to test the impacts of livestock, natural herbivory, and fire on the landscape in arid environments (Curtin 2003, 2005), are examples of supported activities. The group maintains a science committee that evaluates existing and proposed scientific projects and their relevance to the region. The science committee consists of ranchers, private natural resource consultants, university faculty, and independent researchers. Scientists from The Nature Conservancy, and active or retired federal employees from the US Forest Service, US Geological Survey, NRCS, US Fish and Wildlife Service, and the Agricultural Research Service are members and advisors. The committee is led by the Malpai Borderlands Group's Science Coordinator. The current coordinator has both an academic and practical ranching background.

Southwestern Borderlands Ecosystem Management Unit

In 1993, the Research and Development Branch of the US Forest Service selected the Southwestern Borderlands Ecosystem Management Unit (EMU) as one of the service's 19 national units. The unit is part of the Rocky Mountain Research Station. The proposal for the EMU, which was prepared by Leonard DeBano of the Rocky Mountain Research Station and Larry Allen of the Coronado National Forest, was supported by the Malpai Borderlands Group, Animas Foundation, The Nature Con-

servancy, Arizona universities, and federal and state land management agencies.

The Southwestern Borderlands EMU's goal is to provide scientific information to support local private and public land managers in the region. The unit's mission statement is: "Contribute to the scientific basis for developing and implementing a comprehensive ecosystem management plan to restore natural processes; improve the productivity and biological diversity of grasslands and woodlands; and sustain an open landscape with a viable rural economy and social structure in the region." (Gottfried and Edminster 2005:237). The mission is divided into three focus areas:

1. summarize and synthesize existing knowledge about the borderlands region
2. conduct comprehensive landscape inventories and monitoring
3. conduct research to fill gaps in the existing knowledge base

The focus areas and the studies associated with each are described in Gottfried *et al.* (1999b) and Gottfried and Edminster (2005). Because the unit has only had two scientists, most of the research has been conducted by collaborating university faculty and students, scientists from public agencies, or private scientific organizations supported by the Rocky Mountain Research Station.

Fire-related research fits into the third focus area. Much of the EMU's active research is aimed at providing knowledge about the use and effects of fire as a land management tool on the ecosystems in the borderlands. The unit has supported research about the effects of fire on the New Mexico ridge-nosed rattlesnake and Palmer agave. It has also supported research on the effects of different fire frequencies on soil nutrients at Fort Huachuca (Biggs *et al.* 2005) and some of the research related to remote sensing of fire effects (Yool 1999). The

EMU is a partner in the McKinney Flats study (Curtin 2003, 2005).

The Southwestern Borderlands Unit has conducted two main research studies. One study, in cooperation with the NRCS, was a range restoration study in mesquite dominated semidesert grasslands (Gottfried *et al.* 1999a). Normally, perennial grasses provide fuel for periodic burning that will help keep mesquite sprouts in a sub-dominant position on the land. The study consisted of three treatments: one was crushing the shrubs with a Marden Crusher drawn by a bulldozer, seeding with native perennial grasses, and then burning; the second involved crushing and burning without seeding; and the third was the control. The grass species mixtures used for seeding were individualized to site conditions. Prescribed burning was delayed until 2005 because the drought affected the condition and coverage of herbaceous species. The Douglas Ranger District conducted the burns. The study was conducted in cooperation with the Malpai Ranch in Arizona and the Roos Ranch and Diamond A Ranch in New Mexico, Arizona Lands Department, and the Whitewater and Hidalgo Conservation Districts. Data are currently being analyzed.

The second study addressed the effects of cool-season (November-April) and warm-season (May-October) prescribed burning on the resources within the common encinal oak savanna ecosystem. This region of the southwest usually has wildfires in the pre-monsoon period in the late spring. The Southwestern Borderlands Unit placed instruments in 12 small watersheds at Cascabel on the east side of the Peloncillo Mountains (Gottfried *et al.* 2007a). The study was designed to burn four watersheds in the cool season, four in the warm season, and retain four as controls. The cool-season watersheds were burned in early March 2008 and three of the warm-season watersheds were burned in May 2008. However, the study had to be modified after a wildfire burned

across the controls and one of the designated warm-season watersheds during the May fire. We are currently evaluating the effects of the cool-season and warm-season prescribed fires and the warm-season wildfire.

This study was designed as an ecosystem study and included research on the effects of burning period on hydrology, erosion and sedimentation, vegetation, fuels, birds, mammals, reptiles, and soil nutrients. Ecological and hydrologic research studies on the watersheds have produced baseline information about the recently unburned southwestern oak savannas, which is valuable to managers because so little is known about them.

Gottfried and others (2006, 2007b) reported on the precipitation, runoff, and sediment relationships on the watersheds. Although most storms do not produce large runoff events, a storm in August 2005 was noteworthy because it produced rainfall intensities of greater than 84 mm hr^{-1} and peak runoffs as high as 2175 L s^{-1} (Gottfried *et al.* 2006). Kauffman *et al.* (2007) found relatively large differences in hillslope erosion rates between years with $48.2 \pm 1.03 \text{ t ha}^{-1}$ in 2005 and $13.1 \pm 0.58 \text{ t ha}^{-1}$ in 2006. The differences may be related to storm intensities and durations during the two monsoon seasons. Information from an extreme event like this is particularly important for planning purposes, and hydrologists and other land managers have requested this information so that they can have a better understanding of the ecosystem to aid their planning efforts.

Ffolliott *et al.* (2008a) reported that tree transpiration in Emory oak (*Quercus emoryi*) dominated savannas is 60% of that in denser oak woodland stands with similar age and size class distributions. Another recent study quantified differences in vegetation and fuels between the oak savannas and woodlands, which provided valuable insights for management planning (Ffolliott *et al.* 2008b). Other studies have quantified avian populations and seasons

of use (Jones *et al.* 2005), and described the snake and lizard populations.

Fire behavior in the savannas is also being investigated. Koestner *et al.* (2008) studied burn intensity and severity of the cool-season burn in March 2008. They determined that combustion temperatures were high and varied by fuel type (e.g., litter, grass, juniper, oak). The average burn temperatures ranged from 463°C for light grass to 638°C for heavy grass. Burn severities for both the March and May burns were low to moderate and water repellency in soils was mostly non-existent, although high levels of water repellency were noted under woody debris and bear grass (*Nolina microcarpa*) clumps (Neary *et al.* 2008).

OUTREACH ACTIVITIES

A central belief of the Malpai Borderlands Group is that outreach is important in management and science. The group has found that field demonstrations and public meetings provide new information that could be useful to private and public practitioners and could possibly be applied rapidly if needed. Attendees can also suggest improvements or factors that initially were not considered and, thus, improve practical methods or research activities. An open process helps provide trust among local private and agency neighbors. The Malpai Borderlands Group has had an outstanding record of maintaining contacts with ranching organizations throughout the west and internationally, for example, with managers from Mexico, Kenya, and Mongolia. The Malpai Borderlands Group interacts with other private-public land management collaborative groups in the southwest such as the Quivira Coalition in New Mexico, the Altar Valley Association in southern Arizona, and the Diablo Trust in northern Arizona. These groups also support efforts by ranchers, federal and state land managers, and other interested individuals to be good stewards of the land by restor-

ing healthy, open landscapes based on good science and, thus, preserving a viable ranching lifestyle and economy. However, to our knowledge, the Malpai Borderlands Group is the only collaborative group in the region to accomplish multiple landscape level burns.

Research results are disseminated by publications and conferences. Forest Service scientists, university faculty and students, and non-governmental organization scientists have produced 190 scientific publications and research reports and 18 M.S. theses or Ph.D. dissertations since 1995. In addition to research conducted at Cascabel, studies have covered a wide range of topics including, but not limited to, archeology, regional hydrology, historical vegetation changes, the ecology of mesquite and listed species, fire behavior, use of remote sensing, and soil nutrient dynamics in the Malpai borderlands and adjacent areas. The recent development of a stereo photo series for quantifying natural fuels in the oak-juniper types of southern Arizona and New Mexico (Ottmar *et al.* 2007) filled a large knowledge gap in these fuel types. Research projects are also located at Fort Huachuca and at the Santa Rita Experimental Range, which are outside of the Malpai area.

The Southwestern Borderlands Unit has supported or co-sponsored several major conferences including the 1994 (DeBano *et al.* 1995) and 2005 Madrean Archipelago (Gottfried *et al.* 2005) conferences, the 1999 conference on integrated research and management in the borderlands (Gottfried *et al.* 1999b), and the 1996 symposium on the effects of fire on Madrean Province ecosystems (Ffolliott *et al.* 1996). The EMU cooperates closely with ranchers, other federal and state agencies, several universities in the southwest, and conservation organizations to achieve its objectives of providing and integrating scientific informa-

tion with management expertise to achieve sound land stewardship.

CONCLUSION

Success usually can be achieved when diverse groups work together toward common goals. The Malpai Borderlands Group, other landowners, and The Nature Conservancy understand that fire has a natural role in the landscape and that it is important to reintroduce this force to increase productivity and biological diversity of the land. The management and use of fire is important for sound stewardship. The Forest Service, BLM, and other federal and state land managers arrived at the same conclusions and questioned the existing immediate fire suppression model used for all situations. The agencies and private landowners have cooperated in the four landscape level prescribed fires including the Baker II prescribed burn. The large number of private groups and agencies is a partial indication of the level of collaboration in the southwestern borderlands. The ranchers recognized that their efforts should be based on sound scientific knowledge in order to be successful and defensible. They independently supported scientific investigations and cooperated with the Forest Service's Southwestern Borderlands EMU. The combined efforts of private landowners, conservation organizations, and federal and state land management agencies have successfully reintroduced fire into the southwestern borderlands of Arizona and New Mexico. The partnerships provide a valuable platform from which to address research and management issues across varying land ownerships and in the face of future challenges such as projected climate changes.

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