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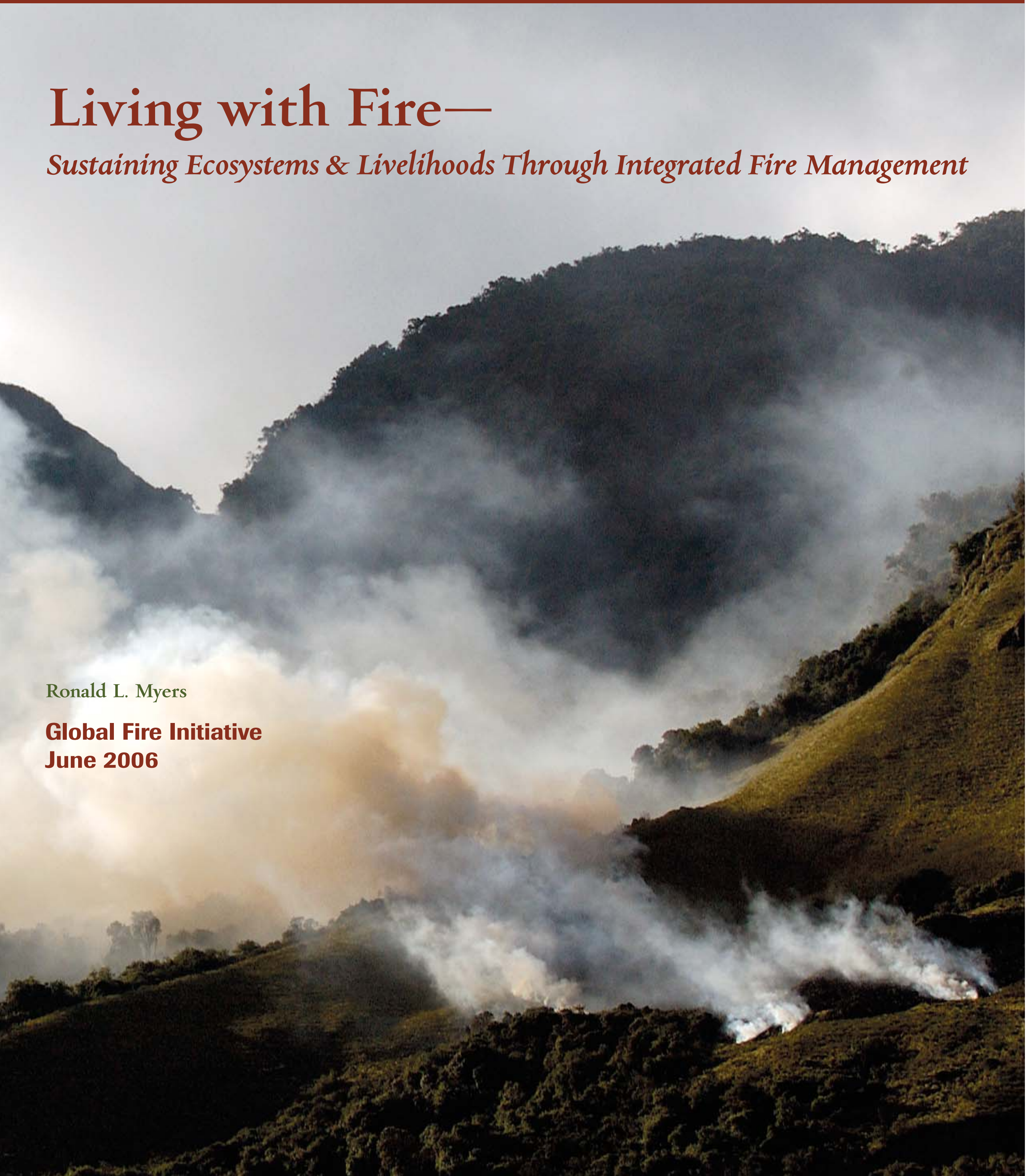
Living with Fire—

Sustaining Ecosystems & Livelihoods Through Integrated Fire Management



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Photos:

Cover Image: Fires set by chagras (Andean cowboys) to renew forage grasses are favoring páramo grasslands in Ecuador at the expense of *Polylepis* species that dominate Andean dwarf forests. © Pete Oxford/Minden Pictures

Top Back Cover: The Brazilian Cerrado, once covering 22 percent of the country or 2 million sq. km, is a mosaic of savanna and shrubland molded by a diversity of fire regimes. © Tui De Roy/Minden Pictures

Middle Back Cover: Traditional agriculture (tavy) in Madagascar. © Frans Lanting/Minden Pictures

Bottom Back Cover: Burning to help herd cattle during the annual cattle round-up in northern Andes páramo grassland in Ecuador. Páramo is a fire-dependent ecosystem but the ecologically appropriate fire regime is poorly understood. © Pete Oxford/Minden Pictures

Inside Front Cover: Slash-and-burn agriculture in eastern Bolivia. © Carlos Pinto

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Executive Summary

The notion that fire can be a useful tool became known to early humans when they first took advantage of fire's effects on the African savannas several million years ago to manipulate vegetation and wildlife. The threat that fire posed to their security and livelihoods was likely obvious to these early people too. As humankind spread throughout the world, they created new fire regimes that continued to shape and modify landscapes. There also continued to be fires that destroyed homes, crops, livestock and other resources. There has always been these "two faces of fire"—beneficial fire and detrimental fire.

In the twentieth century, fire became viewed as primarily a threat to people and natural resources, and many countries have developed sophisticated fire prevention programs and fire suppression organizations to protect people and natural resources. Some have been so effective and pervasive in preventing and suppressing fires that society lost the notion of fire as a useful tool and as an important process in shaping landscapes. The result was changed vegetation that fueled more intense fires during unusually dry years, coupled with the loss of species that had thrived in more open landscapes that previously burned more frequently and less intensely. Compounding the problem, people in ever increasing numbers built, and continue to build, their homes in areas where suppression had long prevented fires, but where flammable vegetation continues to persist and accumulate. The overall result of "successful" fire exclusion has been fires more damaging to forests, soils and watersheds, and an increasing economic cost both in lost property and in fighting these fires.

In many other places around the world, people have continued to use fire in traditional ways, but population pressures are causing land use changes, migrations into new areas and increasing ignitions worldwide. Fire-prone vegetation such as savannas and woodlands now burn annually, decreasing tree density. In forested areas, anthropogenic savannas and grasslands are spreading at the expense of forests even in climates where fire was historically a rare event.

Fire has become a conservation issue because many areas around the world depend on fire to maintain native species, habitats and landscapes. These are ***fire-dependent ecosystems.*** Conversely, there are other areas where fire can lead to the destruction or loss of native species and habitats. These areas are called ***fire-sensitive ecosystems***. Services provided by ecosystems such as clean air, clean water and healthy and productive soils can be affected negatively or positively by fire depending on the adaptations of the species and other characteristics of the environment, and on how often and how intensely an area burns. These facts are just beginning to come to light in the relatively new science of fire ecology.

Still, the role of fire in many ecosystems around the world is poorly understood by scientists, and generally not recognized at all by society. Where the benefits of fire are recognized, the ecologically appropriate fire regime may be unknown.

The fact that fire has two faces—beneficial roles and detrimental impacts depending on the circumstances—has largely gone unrecognized by societies and governments that have demanded or developed ever more sophisticated fire suppression technologies and fire prevention campaigns. Only within the past 15 years have some governments begun to recognize the unintended consequences of excluding fire from some landscapes and the fact that the increased cost of more fire exclusion is resulting in diminishing returns. Governments and urban societies have also not recognized or understood the need of many rural societies to use fire. Policies and programs have been designed around the belief that rural people are the cause of fire problems. Instead, these policies should look to rural communities as part of the solution and provide them with incentives and technologies that build on their traditional knowledge of fire use so that they can more effectively manage fires that are needed or that occur.

Fire management is the range of possible technical decisions and actions available to prevent, maintain, control or use fire in a given landscape. The primary premise of this paper is that more sophisticated fire management technologies are not likely to solve the problem of destructive wildfires, nor are they going to be effective in re-establishing ecologically appropriate fire regimes in places that need to burn. There is a need to ***integrate*** socio-cultural realities and ecological imperatives

with technological approaches to managing fires. This paper sets forth a framework that we are calling ***Integrated Fire Management*** which leads to ecologically and socially appropriate approaches to managing fires and addressing fire-related threats on conservation lands.

Integral to the concept is that fires can be both beneficial and detrimental depending how, where, when and why they are burning. Any single fire can have both beneficial and damaging aspects. Decisions made while managing a fire can take advantage of the potential benefits while striving to minimize potential damages.

Also integral is the recognition that in many societies, burning is an essential tool for people in securing their livelihoods. Understanding the ecology of fire in a particular landscape informs assessments as to whether people are burning too much, too little or inappropriately to meet both conservation goals and to maintain the ecosystems on which they depend. Identifying and understanding society's needs as well as the ecological constraints of an area will lead to the design and application of more effective fire management programs. It makes little sense to have a strict fire prevention campaign in a region that ecologically needs to burn, and where the inhabitants routinely use fire. Simple, but more appropriate messages beyond "Prevent Forest Fires" need to be developed, such as "the two faces of fire: good fire versus bad fire."

Key to successfully integrating ecology, society and fire management technologies is effective analysis of the situation. What is the ecological role and impact of fire in a given area? What is the social, cultural and economic context in which fires are occurring? Who is doing the burning and why? How are they burning? What are the characteristics of the fuels in the area and how does fire behave in them under different burning conditions? What other factors or threats are exacerbating the fire problem, such as land tenure issues, illegal logging, invasive species or climate change?

Effective analysis is followed by identifying ***desired future condition*** and establishing fire ***management goals*** that will facilitate maintaining or reaching that condition. What role should fire be allowed to play in the landscape? Are there land uses or other constraints that limit fire from playing an ecologically appropriate role? How and where should fires be constrained? Should some fires be purposely ignited and who should do that? What mix of fire use, prevention and suppression strategies should be utilized? How will local communities be involved? Having the answers to these questions will lead to better fire management planning, community programs and decisions on individual fires.

To implement appropriate strategies, there need to be supportive laws and policies along with an institutional framework that embraces the concept of Integrated Fire Management. Ecological and social information must also be incorporated into fire management curricula at universities, technical schools and professional training programs.

Fire management invariably involves preparedness and response capability to deal with fire emergencies. By integrating information about past fires, ignition sources and the need and propensity of certain vegetation types to burn, agencies and communities can better anticipate fire events and make better decisions when fires occur.

Post-fire recovery and restoration efforts are frequently poorly designed, ineffective and costly. They can be better designed by incorporating ecological knowledge of the burned vegetation and its recovery potential. Efforts might best be directed toward preventing subsequent fires in a burned area, rather than intensive seeding and planting efforts.

Many Integrated Fire Management decisions will be made with incomplete knowledge and limited experience, so it should be embedded within an ***adaptive management framework***. Current plans and actions should be based on existing knowledge and inferences derived from the initial situation analysis. The effects of those decisions must be monitored, and it is those monitored trends that will inform future management actions along with the incorporation of new knowledge. Effective mechanisms, such as ***fire learning networks,*** need to be in place to facilitate review of implementation strategies, and translation and dissemination of technology, information and new knowledge.

Contents

Acknowledgements

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Fire as a Conservation & Social Issue

There has been a growing consensus that the incidence and severity of wildland fires (i.e. all vegetation fires) are on the increase worldwide, although this common wisdom is difficult to tease out of existing records on forest fires (FAO 2005). In some countries, including the United States, the instances of very severe and damaging fires are increasing because decades of successful fire prevention and suppression in some fire-prone ecosystems have led to changes in fuel loads and forest composition that feed more intense fires (USDA Forest Service 2000; National Commission on Wildfire Disasters 1995). These fires are difficult and expensive to control. The progression from a vegetation cover that was maintained by frequent, low-intensity, non-lethal surface fires to vegetation that now fuels lethal, forest stand-destroying fires is made all the more problematic by a huge influx of people building their homes within these altered forests and other naturally fire-prone forests and shrublands. The result is the now frequent headlines of homes being lost to flames during the fire season in the United States, Australia and Canada. The long-term vegetation changes caused by successful fire exclusion, coupled with the novel fire regimes that these fuels create, are a threat to both biodiversity and society.

In some vegetation types, notably Mediterranean-type shrublands in western North America (chaparral) and Australia, the boreal forests of Canada and the subalpine vegetation in the western United States, rising costs of suppression and damage to property are largely due to people moving into these naturally fire-prone environments and not so much a result of fire suppression (Bridge *et al.* 2005; Keeley & Fotheringham 2003; Johnson *et al.* 2001), although suppression may at times exacerbate these problems (Minnich & Chou 1997). In fact, ignitions have increased over what was probably the historical range of variability in Mediterranean shrublands, subalpine forests, and boreal forests due to increasing human populations and access. In some instances, suppression may actually be preventing shifts from these vegetation types to more fire prone vegetation, e.g. to non-native grasslands (Keeley 2001). Fire regime characteristics and fuels are strong determinants of whether fire suppression efforts are effective in excluding or reducing the incidence and impact of fire, even in countries like the United States, Canada, Australia and Spain that have developed sophisticated fire suppression organizations and policies. These countries are finding that they are approaching diminishing returns in terms of costs and fire suppression effectiveness (Sheldon 2006).

The experience of the United States and a few other countries is in marked contrast to other regions of the world, particularly, but not exclusively, in the tropics. *The Global Review of Forest Fires 2000* (Rowell & Moore 2000) reports:

> "New evidence from the Amazon has concluded that fire causes a positive feedback cycle in which the more tropical forests burn, the more susceptible to future burning they become. This raises the possibility of large wildfire episodes happening more frequently and on such a scale that tropical forest ecosystems will not endure. The scientists believe the whole Amazon itself is threatened, which has global consequences for biodiversity and climate change."

The United Nations Environmental Programme's report *Spreading Like Wildfire—Tropical Forest Fires in Latin America & the Caribbean: Prevention, Assessment & Early Warning* (Cochrane 2002) states:

> "The fire situation is severe in many tropical evergreen forests in Latin America and the Caribbean…Through logging, burning, and natural events, the once near-fire-proof forest is becoming fire-vulnerable and fire-prone…Fire has a momentum in tropical evergreen forests…Each year's forest degradation is carried into the future…This process is under-appreciated by resident populations, policy makers, fire managers and scientists."

In many places, fire prevention campaigns and suppression capabilities are only beginning to take hold, if they exist at all. For example, in the Zambezia province of Mozambique, fire-degraded Miombo woodlands burn annually. Thousands of houses and 15 percent of crops in the province are destroyed each year and fatalities are common (M. Jurvelius FAO, *personal communication*). Similar situations exist in many other parts of Africa; they just rarely attract the attention of the international media.

In other regions, such as the Mediterranean countries, fires are increasing because changes in land use, such as the abandonment of traditional grazing practices and farming, are creating fuels in new landscape contexts that may have never existed before (Vélez 2005).

Widespread fires throughout Latin America, the Caribbean, Africa, Southeast Asia, the Mediterranean, China and Siberia increasingly threaten a wide variety of vegetation types and ecosystems, alter regional and global climate, and foster spread of undesirable invasive species concomitant with forest and biodiversity loss. Furthermore, fire-induced damages are increasingly affecting human livelihoods, human health, and local and national economies.

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This Paper

There are disconnects between fire prevention programs, suppression responses to wildfires, fire use, conservation of biodiversity, and the needs and aspirations of people who use and are affected by fire. This paper sets forth a framework called ***Integrated Fire Management***, which incorporates the ecological, socio-economic and technical aspects of fire in a holistic fashion, (1) to address the social and conservation problems and issues that result from the burning of vegetation, and (2) to meet the goal of sustainable ecosystems and human livelihoods in fire-prone environments.

The focus of the paper is on fire as an element affecting the conservation of biodiversity and maintaining sustainable resources and ecosystem services for people. Thusly, emphasis is placed on the management of fire at places identified for their conservation value. Effective fire management requires an integration of bottom-up approaches—involving local ecology and fire science, decisions and actions by on-the-ground managers, and the activities, needs and perceptions of rural people living in conservation areas and their environs—with top-down approaches that provide supporting policies, laws, educational programs, training, resources and emergency response. The audience of this paper is conservation scientists, conservation practitioners, land managers and decision-makers working with governmental agencies, non-governmental organizations (NGO's), private lands and communities who have an interest in the conservation of natural resources and in providing sustainable livelihoods for people.

Integrated Fire Management is not a new term, as a quick internet search will attest. It has been previously used to narrowly define the integration of fire suppression actions such as early warning, detection, initial attack and recovery. The term "Integrated Fire Management" has also been used to describe fire management approaches in less developed regions involving communities, rural land users, government agencies and non-governmental organizations (FAO 2003). In the latter case, it has at times been inappropriately synonymous with *Community-based Fire Management* (Goldammer *et al.* 2002).

The term "integrated" has been used a number of times in the past not only in relation to fire but also to describe other approaches to managing natural resources such as "integrated forest management" or "integrated community development." So while the term might seem hackneyed to some, "integrated" is used in this paper because it concisely describes the state of bringing together diverse concepts and issues synergistically to produce effective outcomes that cannot be attained by technology alone. It also readily translates into the languages of target audiences.

The meaning of ***Integrated Fire Management*** in this paper is the integration of science and society with fire management technologies at multiple levels. It implies a holistic or seamlessly-woven comprehensive approach to address fire issues that considers biological, environmental, cultural, social, economic and political interactions (Kaufmann *et al.* 2003). The concepts can be applied to all regions of the world irrespective of development status.

The goals of this paper are to (1) succinctly define the role of fire in ecosystems, (2) discuss how too much, too little, or the wrong kind of fire can be a threat to biodiversity, (3) define the concept of fire regime and the role of fire regimes in maintaining ecosystems, (4) illustrate the need of many rural communities to use fire and how some of the current approaches to fire prevention are out of step with those needs, (5) define Integrated Fire Management, and (6) present a process for integrated and collaborative approaches to dealing with fire issues.

The Role of Fire in Ecosystems

In discussing and addressing fire as a conservation issue, it is important to recognize and understand the different roles that fire plays in different ecosystems. The Nature Conservancy, in its preliminary global assessment of fire as a conservation threat, identified three broad categories of vegetation responses to fire: ***fire-dependent, fire-sensitive and fire-independent*** (Hardesty *et al.* 2005). That report focused on the predominant fire effect at the level of biome and ecoregion, recognizing that within ecoregions there can be a variety of ecosystems and habitats that have responses different from the predominant effect.

Because this report focuses on potential management actions to fire within conservation areas where multiple responses may be manifested, a fourth category is included: ***fire-influenced***. These ecosystems may be linked hierarchically to fire-dependent and fire-sensitive ecosystems because they are frequently found as transitions between them.

All ecosystems or native vegetation types do not fit perfectly into each of these categories, but the groupings provide a means of illustrating and discussing the threats and conservation needs and opportunities associated with fire in diverse vegetation types and how management actions may vary among them.

Figure 1. A fire-independent cloud forest in Costa Rica. The nearly continuous cloud cover and aseasonal climate combine to make both ignition and fire spread unlikely. Similar cloud forests are increasingly affected by fire either because agricultural encroachment has created adjacent flammable vegetation and altered the local climate, or where the cloud forest is juxtaposed next to or between natural fire-dependent vegetation such as tropical pine forests or tropical alpine páramo. Climatic oscillations periodically allow a drying of the cloud forests and fires enter from either above or below. (Photo by R. Myers)

Fire-Independent Ecosystems

Fire-independent ecosystems are those where fire normally plays little or no role. They are too cold, too wet or too dry to burn. Examples are deserts, tundra and rain forests in aseasonal environments (Figure 1).

Fire becomes a threat only if there are significant changes to these ecosystems brought about by land use activities, species invasions or climate change. The preliminary assessment of fire as a conservation issue, which focused on 200 priority (i.e. based on their biodiversity value) ecoregions worldwide, identified 18 percent by area as dominated by fire-independent ecosystems (Hardesty *et al.* 2005).

Fire-Dependent Ecosystems

Fire-dependent ecosystems (Figure 2) are those where fire is essential and the species have evolved adaptations to respond positively to fire (Figure 3) and to facilitate fire's spread, i.e. the vegetation is fire-prone and flammable. They are often called ***fire-adapted*** or ***fire-maintained*** ecosystems. Fire in these areas is an absolutely essential process. If fire is removed, or if the fire regime is altered beyond its normal range of variability, the ecosystem changes to something else, and habitats and species are lost. Individual species within fire-dependent ecosystems have evolved in response to specific fire regime characteristics such as frequency, intensity and season of burn, and to the variability of those characteristics. Types of fire regimes vary greatly, ranging from frequent, low-intensity, non-lethal surface fires to those characterized by mixed-severity fires (i.e. lethal and non-lethal effects varying across the landscape), to relatively infrequent, high-severity, lethal or stand-replacing fires that arrest or re-set ecological succession creating a diversity of habitats in time and space as the vegetation recovers (Brown 2000). On an area basis, approximately 46 percent of the world's priority ecoregions are dominated by fire-dependent ecosystems (Hardesty *et al.* 2005), meaning they need to burn under an appropriate fire regime if they are to persist in the landscape.

Figure 2. A fire-dependent Caribbean pine (*Pinus caribaea*) savanna in Belize maintained by a regime of frequent, low-intensity surface fires. (Photo by R. Myers)

Examples of fire-dependent ecosystems abound around the world. In Mesoamerica, there is a wide variety of fire-dependent pine forests and pine savannas. Mexico, with its temperate and tropical environments, has the highest pine species diversity in the world—55 species and varieties (Espinosa 2001).

Most species of pine are linked to disturbance, often defined by specific fire regimes (Rodríguez-Trejo & Fulé 2003). Several of these forest types extend into Central America. The same can be said of Mexico's high diversity of oak species—110 species (Zavala Chávez 2003), a large number of which may require fire or are favored by fire-induced disturbances. Elsewhere in Mesoamerica and the Caribbean, fire-dependent *Pinus caribaea* savannas and woodlands range from the Bahamas through Cuba and on to Belize, Honduras and Nicaragua (Myers *et al.* 2004a; Myers *et al.* 2006). The Dominican Republic has forests and savannas of the endemic *Pinus occidentalis*, which are dependent on fire (Horn *et al.* 2000; Myers *et al.* 2004b). Besides *P. caribaea*, Cuba has three species of endemic pines that persist in fire-prone environments.

Fire-adapted pine species also form extensive open forests and woodlands in the tropical and subtropical environments of Southeast and South Asia. Fire plays a key, though poorly understood, role in the maintenance and characteristics of *Pinus kesiya* and/or *P. merkusii* forests ranging from the Assam Hills of India, across Myanmar, Thailand, Southern China, Cambodia, Laos, Vietnam and the Philippines to Sumatra (Kowal 1966; Richardson & Rundel 1998).

Africa has been referred to as the "fire continent" (Komarek 1971) primarily because much of Sub-Saharan Africa, with the exception of the tropical forests of western and central equatorial Africa, once consisted of a vast landscape of tropical and subtropical fire-prone savannas, and fire-influenced woodlands and shrublands that have been shaped by the longest history of human involvement with fire in the world.

South America is just as much a "fire continent" as Africa. A significant proportion of South America lies in the same bioclimatic zone that supports savanna in Africa. The Brazilian Cerrado, once covering 22 percent of the country or 2 million sq. km, is a mosaic of savanna and shrubland molded by a diversity of fire regimes (Miranda *et al.* 2002). Other tropical grassland types in South America are found in the Gran Sabana and Llanos of Venezuela, and in Bolivia, Peru and Paraguay. Temperate South America claims the vast Argentine pampas and other grasslands. Fire's role in other South American temperate ecosystems, such as the *Araucaria* forests, is poorly understood.

Fire-maintained palm forests and palm savannas are common throughout the tropics (Myers 1990), along with a variety of fire-dependent and fire-influenced coastal and freshwater marshlands. Scientists are just beginning to understand that fire is also an integral part of tropical alpine areas such as páramo in the Americas (Horn 1998; 2005) and Afro-alpine vegetation (Bond *et al.* 2004).

Other strongly fire-dependent environments include Mediterranean-type forests, shrublands and savannas located in widely dispersed parts of the world; temperate and boreal coniferous forests and oak-dominated forests and grasslands of North America, Central Asia, China, Russia and Mongolia; and the eucalypt forests, savannas and heathlands of Australia.

Fire-Sensitive Ecosystems

Fire-sensitive ecosystems have not evolved with fire as a significant, recurring process. Species in these areas lack adaptations to respond to fire and mortality is high even when fire intensity is very low (Figure 4). Vegetation structure and composition tend to inhibit ignition and fire spread. In other words, they are not very flammable. Under natural, undisturbed conditions, fire may be such a rare event that these ecosystems could be considered ***fire-independent.*** Only when these ecosystems become fragmented by human activities, fuels are altered and ignitions increase, do fires become a problem. As fires become frequent and widespread, the ecosystem shifts to more fire-prone vegetation. Tropical forests become savannas of introduced grasses (Cochrane 2001; Cochrane & Laurance 2004; D'Antonio 1992) and semi-arid grasslands are invaded by non-native grasses that create a continuous fuel (McPherson 1997). On an area basis, 36 percent of ecoregions are dominated by fire-sensitive ecosystems (Hardesty *et al.* 2005).

Examples of fire-sensitive ecosystems are the wide variety of tropical and subtropical broadleaved forests found along both altitudinal and moisture gradients and temperate zone broadleaved and conifer forests at the wetter end of the moisture gradient. There are a number of ecosystems whose category is uncertain. An example is the Chilean Matorral, a Mediterranean-type shrubland. Although flammable, it appears to lack the regenerative responses to fire of species found in other types of Mediterranean shrublands around the world (Armesto & Gutierrez 1978; Montenegro *et al.* 2004). In some ecosystems the ecological role of fire simply has not been identified.

Fire-Influenced Ecosystems

This category includes vegetation types that frequently lie in the transition zone between fire-dependent ecosystems and fire-sensitive or fire-independent ecosystems (Figure 5), but it may ultimately include broader vegetation types where the responses of species to fire have not been documented and the role of fire in maintaining biodiversity is not recognized. They are ecosystems that generally are either sensitive to fire but contain some species that are able to respond positively to fire disturbances, or they are ecosystems that would persist in the absence of fire but fire disturbances play a role in creating certain habitats, favoring the relative abundance of certain species, and maintaining biodiversity.

a.

b.

Figure 3. Many species in fire-dependent ecosystems have adaptations to not only survive fire but to respond to it reproductively. a. Vegetative state of *Bulbostylus paradoxa* (Cyperaceae), a common ground cover species in the savannas of Central and South America. b. *Bulbostylus paradoxa* blooming within a few days after a fire. It is likely that this species only blooms after it burns. The presence of species with such strong adaptations to fire is an indicator of a long history of frequent fire. Photos taken in the pine savannas of eastern Honduras. (Photos by R. Myers)

In fire-influenced ecosystems, fires generally originate in adjacent fire-dependent vegetation and spread to varying degrees and at varying intervals into the fire-influenced vegetation, although a low level of traditional agricultural clearing and burning may have been important endogenous sources of ignition. Here, fire may be important in creating certain habitats by opening forest or shrub

Figure 4. Fire-sensitive tropical moist forest in the Brazilian Amazon. Fires are typically very low intensity, but because the vegetation lacks adaptations to survive fire, the impacts are high. The fire opens the canopy, allowing drying of the forest floor and the growth of flammable grasses and ferns. (Photo by Mark Cochrane)

canopies, initiating succession and maintaining the transitional vegetation. Fire-influenced ecosystems present challenging management issues because of the subtle role that fire may play. Examples include the transition zone of wet sclerophyll forest between savanna and rain forest that occurs in northeastern Queenslands (Russell-Smith & Stanton 2002), the riparian vegetation or gallery forests along water courses in savanna or grassland vegetation (Kellman & Meave 1997), the "islands" of fire-sensitive vegetation often embedded in a matrix of fire-prone vegetation such as "hammocks" in the Everglades of Florida (Myers 2000) and similar vegetation patterns in the Pantanal of Brazil, and certain types of tropical and subtropical forests like those identified in Mesoamerica where fire has maintained the dominance of mahogany (*Swietenia macrophylla*) and associated species (Snook 1993).

Climate change may cause significant changes in the structure and shifts in location of fire-influenced ecosystems. In other words, it may be in these ecosystems where climate change-induced shifts in vegetation will become most apparent over the short term.

The Source of Fire Threats to Biodiversity

The nature of fire-related threats varies depending on ecosystem responses and the adaptations of species to fire. A wide variety of fire-sensitive ecosystems in the tropics and elsewhere are threatened by land use activities and vegetation conversion efforts that either use fire or increase the probability of ignitions. Forest vegetation that rarely burns and normally resists fire is being modified by human activities such that fire is entering these ecosystems at shorter intervals. An initial fire is usually of very low intensity, but the impacts are severe—killing trees, increasing fuel loads and opening the canopy, allowing fuels to dry and grasses and ferns to grow. Without subsequent ignitions the forests can recover, but the predominant trend is toward increased ignitions leading to repeated fires and rapid changes in vegetation structure and fuel characteristics. Fire creates a positive feedback loop that leads to increasing flammability and drier conditions (Cochrane 2001; 2003) (Figure 6).

These fire-sensitive ecosystems are now being exposed to frequent ignitions and require urgent and aggressive measures to counteract the sources of the threat or to mitigate their impacts. Experience gained from preventing and fighting fires in temperate and boreal ecosystems may not be transferable to tropical environments primarily because of different social and economic contexts and due to the costs associated with high-technology fire suppression. Greater emphasis needs to be placed on the underlying causes of the fires and on developing local and regional solutions that are sustainable (Hoffman *et al.* 2003).

Conversely, as governments, land management entities and scientists attempt to address fire-related threats through policy changes, incentives and community-based prevention and suppression programs, there is a danger that the vital role of, and need for, fire in many ecosystems will be overlooked, as was done in much of the United States over the last century and has occurred in portions of Australia and Canada. There is a misconception (at least by fire professionals and the interested public in temperate climes) that the tropics is a vast fire-sensitive rain forest threatened by rampant logging-induced fire and agricultural burning. In reality, the tropics include some broadleaved forest types where periodic fire is part of the system, i.e. fire-influenced ecosystems, but where excessive burning is clearly a threat. The tropics and subtropics also harbor ecosystems and habitats that require fire.

Figure 5. The transition between a fire-dependent savanna (Cerrado, light-green areas) and fire-sensitive tropical moist/dry forest (dark-green areas). Lightning-ignited fires occur every year in the savanna. Periodically, and to varying degrees, these fires burn downslope and enter the broadleaved forest. These relatively rare fire events may be important in creating regeneration niches for some of the tree species. The transitional vegetation can be considered fire-influenced. Noel Kempff National Park, Bolivia. (Photo by Hermes Justiniano)

There is a distinct possibility that many of these fire-dependent ecosystems may now be burning too much, but there is also a general lack of information about the nature and ecological appropriateness of current fire regimes in many of these ecosystems.

Lack of information about, and failure to understand, the role of fire in these ecosystems, coupled with community-based and national efforts to control or prevent all fires, has the potential to lead many important conservation lands down the same road of ecologically-inappropriate fire exclusion that the United States undertook decades ago with similar results: altered vegetation, destroyed habitats, species loss, destructive wildfires and watershed degradation.

The World Conservation Union (IUCN), in a special fire issue in *Aborvitae* (Stolton & Dudely, eds. 2003), states that:

> "Disturbance is present in all natural ecosystems. Forest management therefore needs to be able to accommodate chance episodes of natural disturbance, including fire. Managers also need to distinguish between harmful and harmless or beneficial fires. Fire is sometimes essential for forest regeneration, or provides tangible benefits for local communities; in other cases it destroys forests and has dire social and economic consequences."

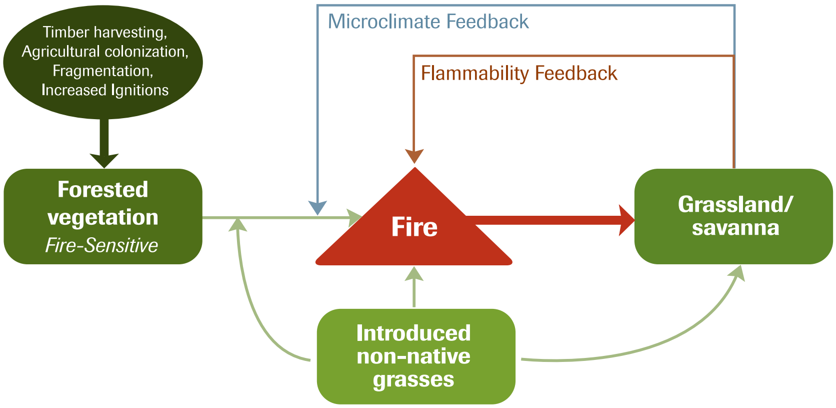


Figure 6. A conceptual model illustrating the rapid change from fire-sensitive forested vegetation to fire-prone grassland or savanna once fire initially burns the forest and ignition sources persist. Inadequately managed timber harvesting and agricultural clearing are the forcing functions that initiate the change. Non-native grasses enter the process as a result of the initial opening of the forest canopy, but their spread and predominance are the result of the feedback that produces drier, more flammable conditions. Although the process could operate in both directions, i.e. a long fire-free period causing a transition back to forests, it is predominately one-way and is occurring worldwide throughout the tropics and subtropics in forests ranging from dry to wet environments. (Adapted from Cochrane 2001)

Altered Fire Regimes: A Conservation, Biodiversity & Social Threat

A fire regime is defined as a set of recurring conditions of fire that characterizes a given ecosystem. A specific range of frequency, fire behavior, severity, timing of burn, size of burn, fire spread pattern and pattern and distribution of burn circumscribe those conditions. Eliminate fire, increase fire, or alter or constrain one or more of the components of the fire regime such that the range of variability for a given ecosystem is no longer appropriate, and that ecosystem will change to something else—habitats and species will be lost.

Virtually all terrestrial ecosystems have a fire regime, a history of fire that has shaped or affected structure and species composition. In tropical broadleaved forests, that regime might consist of very small fires affecting a miniscule portion of the ecosystem in any given year coupled with perhaps a large landscape-scale fire recurring on the order of centuries or millennia from which the forest recovers. These large fires in tropical forests usually occur during protracted droughts associated with El Niño events. Statistically any one spot on the ground may not burn for hundreds, if not thousands of years. Even fire-dependent ecosystems can burn inappropriately from too much or too little fire, or fire that occurs during the wrong season.

An ***ecologically appropriate fire regime*** is one that maintains the viability or desired structure, composition and functioning of the ecosystem. It is not necessarily a ***natural fire regime***. Humans have been affecting fire regimes for millennia. Where people live in fire-prone vegetation, they tend to burn it for a variety of reasons and they tend to burn it frequently. In many areas, human ignitions may have played an important role in creating and extending specific ecosystem types and vegetation structures that have conservation value today. The important conservation questions are: What is the conservation value of a given or desired fire-prone ecosystem type or vegetation structure and what is the fire regime that will maintain these values? The question is not necessarily whether the fires that maintain it or created it have been of human or natural origin.

An ***altered or undesirable fire regime*** is one that has been modified by human activities, such as fire suppression and prevention, excessive burning, inappropriate burning, ecosystem conversion or landscape fragmentation, to the extent that the current fire regime negatively affects the viability of desired ecosystems and the sustainability of products and services that those ecosystems provide. The Nature Conservancy, an international, non-profit conservation organization dedicated to the conservation of biodiversity by protecting and appropriately managing conservation lands around the world, has identified altered fire regimes as one of the key threats to biodiversity (Hardesty *et al.* 2005). The human-derived sources of the threat include:

1. Ignitions for agricultural clearing and site preparation by both rural farmers and by large commercial operations;
2. Other activities related to land clearing or land use that increase fuels and their susceptibility to ignition, e.g. inadequately managed logging or population increase coupled with continued traditional fire uses such as hunting, improving access, controlling pests, signaling and improving forage or fruit production;
3. Ignitions related to vengeance or protest, arson, civil unrest and migration;
4. Grazing or changes in, or abandonment of, grazing practices (which, depending on the environment, may increase or decrease fire frequency or alter season of burning);
5. Invasive species that follow logging disturbance, road building and land clearing, and change fuel characteristics;
6. Landscape fragmentation (which may either limit the spread of fires by breaking fuel continuity or increase the number of ignitions from increasing human populations and the proliferation of flammable forest edges); and
7. Climate change affecting dry/wet seasons, vegetation/fuel shifts and/or vegetation productivity.

Integrated & Collaborative Ecological & Social Approaches to Reducing the Threat of Altered Fire Regimes

Figure 7. Fire Management Triangle. Fire management is the application of appropriate fire prevention, fire suppression and fire use technologies and tools to address wildland fire issues.

***Fire management** is the range of possible technical decisions and actions directed toward preventing, detecting, controlling, containing, manipulating or using fire in a given landscape to meet specific goals and objectives.* Fire management can be thought of as a triangle with the sides being prevention, suppression and fire use (Figure 7).

The importance or priority of any one side depends on the natural and cultural environment in which the fires are occurring, the specific conditions of any given fire and on the management goals for the area.

Fire management is not the sole solution to fire problems. Many countries have developed national-level, top-down technical approaches to reduce fire hazard and improve suppression capabilities modeled after fire organizations in the United States, Canada, Australia, Spain and elsewhere (Moore *et al.* 2003). They have also passed laws prohibiting or restricting the traditional use of fire. Frequently, these government agency efforts have failed to engage the local people, who, in many places, not only need to use fire and are the primary ignition source for most fires but also are the segment of society most affected by fires (Ganz & Moore 2002). Such policies have also failed to consider the important and beneficial role of fire in many ecosystems.

Consequently, addressing the threat of altered fire regimes requires:

1. Understanding the ecological role of fire;
2. Understanding the underlying causes of too much or too little fire, such as why people are burning, why they are burning the way they do, and how they are affected by fires; and
3. Seeking sustainable solutions by developing integrated approaches to managing fires that occur, or are needed, in protected natural areas, in conservation zones and in surrounding, adjacent or embedded communities.

Without first understanding the ecological role of fire, it is impossible to make decisions about whether people are burning too much or not enough.

***Integrated Fire Management** is defined as an approach to addressing the problems and issues posed by both damaging and beneficial fires within the context of the natural environments and socio-economic systems in which they occur, by evaluating and balancing the relative risks posed by fire with the beneficial or necessary ecological and economic roles that it may play in a given conservation area, landscape or region. It facilitates implementing cost-effective approaches to both preventing damaging fires and maintaining desirable fire regimes. When fires do occur, it provides a framework for (1) evaluating whether the effects will be detrimental, beneficial or benign, (2) weighing relative benefits and risks and (3) responding appropriately and effectively based on stated objectives for the area in question. Managing beneficial aspects of fires may involve various forms of fire use* (Myers 2006).

Integrated Fire Management involves integrating (1) the three technical components of fire management: prevention, suppression and use with (2) the key ecological attributes of fire, i.e. the ecologically appropriate fire regime and (3) the socio-economic and cultural necessities of using fire along with the negative impacts that fire can have on society.

These three aspects of Integrated Fire Management can be depicted by another triangle: the ***Integrated Fire Management Triangle*** (Figure 8).

Figure 8. The Integrated Fire Management Triangle presents a conceptual framework that integrates basic community perceptions about fire and their need to use fire, and the beneficial and detrimental roles that fire may play in ecosystems, with all aspects of fire management.

This triangle conveys the notion that fire management decisions should be made within the ecological and socio-economic/cultural contexts in which fires are occurring or from which they are excluded. Such integration will help ensure that the underlying causes of fire and the ecological propensity and need for certain ecosystems to burn are addressed. Otherwise, outcomes will be unsuccessful, leading to vegetation changes, more fires destructive to both the environment and to human livelihoods and biodiversity loss, all at a high economic cost.

The vision of ***Integrated Fire Management*** is to:
Markedly and measurably reduce fire threats in conservation areas, on communal and private lands and within watersheds by maintaining the ecologically acceptable range of variation of fire regimes, and improving trends on those lands that are burning too much, inappropriately or not enough.

The goal of ***Integrated Fire Management*** is to:

1. Increase support among decision-makers at multiple levels, as evidenced by the effectiveness of local and national institutions charged with managing fire, by
2. integrating biological, environmental, and social needs and benefits into fire management programs and responses, such that
3. socially and ecologically acceptable and sustainable solutions to fire problems are attained.

Components of an Integrated Approach to Fire Management

Integrated Fire Management can be applied at multiple scales from the individual fire through local communities and conservation areas, to national government policies and fire plans and multi-national cooperation. Integrated Fire Management involves understanding fire's benefits and risks and developing integrated solutions to fire problems by implementing strategies that deal effectively with both beneficial fires and detrimental fires (Figure 9). Integrated Fire Management strategies, whether focusing on beneficial fires, damaging fires or both, include,

1. The assessment and analysis of needs and issues;
2. The identification of fire management goals and desired future condition;
3. The development and implementation of appropriate fire policy;
4. The design of fire prevention strategies appropriate to the ecological and social situation;
5. The implementation of fire use strategies;
6. The strengthening of fire preparedness and response at all levels;
7. The implementation of recovery, restoration and ecosystem maintenance actions; and
8. Research (e.g. fire ecology, fire behavior, social sciences).

All strategies and actions are driven by adaptive management, i.e. the feedback of monitored trends and transfer of lessons learned.

1. Assessment & Analysis of Situation & Issues

The first step in developing and implementing Integrated Fire Management involves

A. Assessing the ecological, social, cultural and economic roles of fire within a given area or region of interest;

B. Determining the level and underlying causes of fire-related threats, plus the degree and trend of ecosystem degradation or improvement;

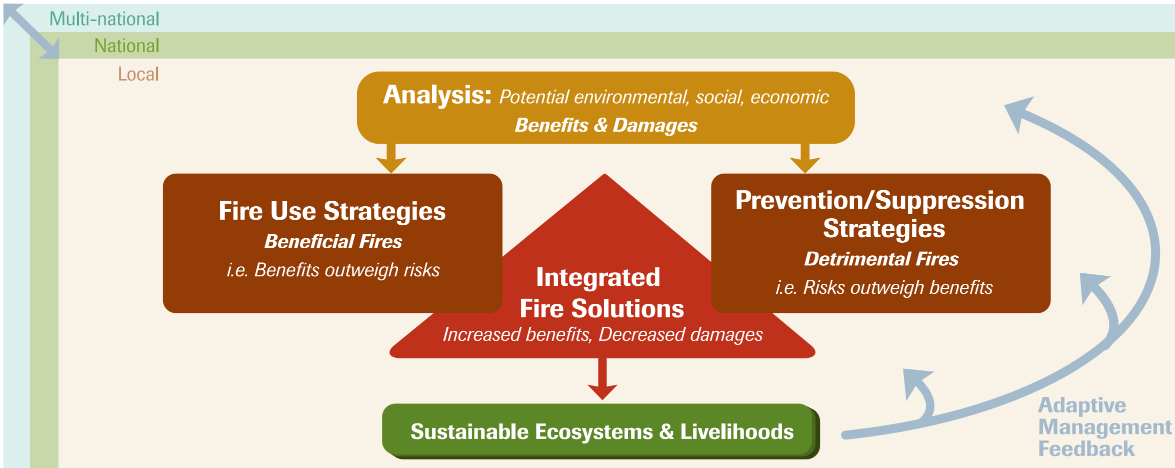


Figure 9. Integrated Fire Management involves identifying and analyzing the potential environmental, social and economic benefits and damages of fire at the local, regional, national or multi-national scale. Where fire's benefits outweigh the risk of damages, fire use strategies are predominant. Where damaging aspects of fires outweigh benefits, prevention and suppression strategies prevail. Integrated solutions involve appropriate assessments, goal setting, public policies, education, fire management technologies, and evaluation. Sustainable ecosystems and livelihoods are fostered through increased benefits of using fire and decreased damages from undesirable types of fires. In most real-world situations, there will be a combination of fire use strategies and prevention/suppression strategies that can be applied at multiple scales, from the effects of a single fire through multi-national cooperation.

C. Understanding fuels, their related fire behavior and potential fire effects; and

D. Determining the nature of other threats that interact with fire such as land use, invasive species and climate change.

All need to be done at an ecologically-relevant scale, i.e. across ownership boundaries.

Ecological Role and Impact of Fire

It is essential to identify and understand how ecosystems vary in their propensity to burn and in their post-burn responses. Ecosystems can generally be placed into one of the three fire response categories previously mentioned: fire-dependent, fire-sensitive and fire-independent. The condition and dynamics of fire-influenced ecosystems also need to be identified. Each requires different fire management approaches and actions. It is also important to understand how fire affects the important targets of conservation such as keystone species, rare and endangered species, and the species that control the fire regime.

An assessment may have to address issues related to two or more of the fire response categories in situations where two or more occur within a specific conservation area or region of interest, and take into account the dynamic relationships that occur among them. For example, fires originating in fire-dependent ecosystems may enter, affect the boundary of or limit the extent of fire-influenced and fire-sensitive ecosystems. Boundaries will shift in response to a changing incidence and season of human ignitions, and due to short-, medium- and long-term climatic trends. Different strategies may have to be used in different parts of the conservation area to maintain and protect desired examples of each ecosystem.

Economic and Social Context

People use fire to meet basic needs and to facilitate important activities such as hunting, stimulating desirable plants used for food or other needs (e.g. fiber, fuel wood), clearing vegetation for agriculture (Figure 10), improving forage for domestic animals, controlling pests, easing travel and communicating over long distances. Where vegetation is not fire-prone, human activities almost invariably alter fuel structure and fuel characteristics that ultimately lead to more flammable vegetation, i.e. frequently burned fire-dependent ecosystems expand at the expense of less fire-tolerant ecosystems. Novel, fire-prone vegetation types may develop such as savannas and grasslands dominated by non-native species. Only where societal restrictions are successfully imposed, or incentives provided, is the trend halted or reversed. In many places, expanding rural population pressures, as well as colonization and subsequent conversion of natural lands are overwhelming the capacity of many ecosystems to persist in the face of changing fuels and increasing ignitions. It is important to view people not solely as the cause of fire problems but rather as being the source of potential solutions.

We need to identify not only why and how people are burning and why they burn the way they do, but also who is doing the burning. In some cultures, particularly in Africa, it is the women who do the burning, so in those instances educational programs need to be designed for and directed toward women.

Figure 10. Slash and burn techniques to prepare land for the planting of crops are widely used throughout forested lands in the tropics. Escaped fires from these plots are one of several sources of destructive fires in tropical forests. (Photo by Carlos Pinto)

Fire use by one segment of society may not be compatible with the needs and wants of other segments of society. Annual burning for forage improvement may reduce the availability of fuel wood for a different segment of society. Air quality and human health are frequently at odds with fire use. People also want to be protected from fires that are destructive to their values and livelihoods. They need to be educated in how to prevent unwanted or damaging fires, and how to protect themselves and their property from fire. They also need to have a basic understanding of the role of fire in the ecosystems in which they live and the propensity of certain vegetation types to burn. Strategies may range from the ***Fire Smart*** messages and programs used in Canada, the ***Firewise Communities*** in the United States, and the poverty reduction program ***Working on Fire*** in South Africa to volunteer, community-based fire brigades being formed in South and Southeast Asia, Latin America and Africa. Fire use may be an important strategy in protecting people from destructive fires.

Managing fires requires understanding (1) how and why different cultural groups view and use fire in specific environments, (2) how economic incentives affect decisions about land use and thus burning and (3) how government policies affect and become ingrained in human attitudes about fire that may either help or hinder the implementation of more enlightened approaches to managing fires.

It is important to understand why people burn the way they do. People burn in different ways depending on their objectives and on the environments in which they live. For example, farmers in the humid tropics often burn during what would be considered severe burning conditions by most fire managers, or they routinely ignite fires to burn with the wind or upslope, thus creating fires more likely to escape control. They may be burning this way because those are the only conditions that allow them to get the economic results they need in that particular environment. It may do little good to try to convince farmers to burn at night or with fires backing into the wind or down slope if making those changes negatively impacts their livelihoods. Subsistence farmers have little incentive or leeway to adopt undemonstrated technologies without assurances that their yields will not be negatively affected. Failure to recognize and understand these environmental differences and economic impacts may result in inappropriate educational programs and policies. Guidelines dealing with safe burning practices need to be adapted to local situations. It may be that wider fire breaks or more people tending a fire would be more effective practices than shifting the timing of burns.

A subsistence farmer is unlikely to take the risk of altering his or her burning practices or become involved in a community-based fire management program unless his or her perceived benefits exceed perceived costs. Farmers simply cannot risk taking on a novel activity or the modification of an existing practice that might reduce or otherwise negatively impact their already subsistence-level production. This means that techniques or community activities need to be demonstrated and supported with production or economic data before people will become involved.

Fuels and Fire Behavior

Fires on the landscape cannot be managed without understanding basic fuel characteristics and how those characteristics, coupled with topography and weather, influence fire behavior. Understanding fuels and how fuels can be managed and manipulated to obtain desired effects is essential to (1) containing and controlling fires, (2) reducing fire intensity and (3) producing and maintaining desired conditions in both natural ecosystems and in domesticated landscapes. Knowledge of fire behavior and its relationship to fuels and fire regimes is an essential requisite for effective fire management decisions and educational programs.

Assessment of other Fire-Related Threats

Fire is tied to several other conservation issues and threats to biodiversity. They include (1) inappropriate logging or forestry practices including post-fire salvage or rehabilitation operations that change fuel characteristics and, in some parts of the world, are often followed by agricultural colonization concomitant with burning practices, (2) inappropriate grazing practices that may either increase or decrease available fuels, and may involve burning too frequently or during the wrong season for certain groups of species, (3) road building and subdivision of the landscape for homes, which create urban/wildland interfaces and fragmented landscapes, (4) changes in hydrologic regimes through drainage or water use, (5) the introduction and spread of invasive species that are flammable and thus capable of hijacking the fire regime (these species invasions are usually closely associated with 1 and 2) and (6) climate change.

2. Fire Management Goals & Desired Ecosystem Condition

Current Conditions

In order to develop fire management approaches and strategies that will meet protected area, community and regional conservation and development goals, one must assess how fire and land use histories have interacted over time to create the current conditions at the site, and how those conditions may help or hinder reaching or maintaining desired conditions. Components or processes within and among ecosystems may be missing or irreversibly altered, such as lack of inter-habitat connections, species extirpations, exotic species introductions, and changes in hydrologic regime. Certain components or processes may now control the fire regime that did not exist in the past, e.g. invasive flammable grasses, or a proliferation of forest edges. Fuel conditions may be altered to such a degree that reintroducing fire will lead to undesirable outcomes, or that suppressing or preventing fires are nearly impossible.

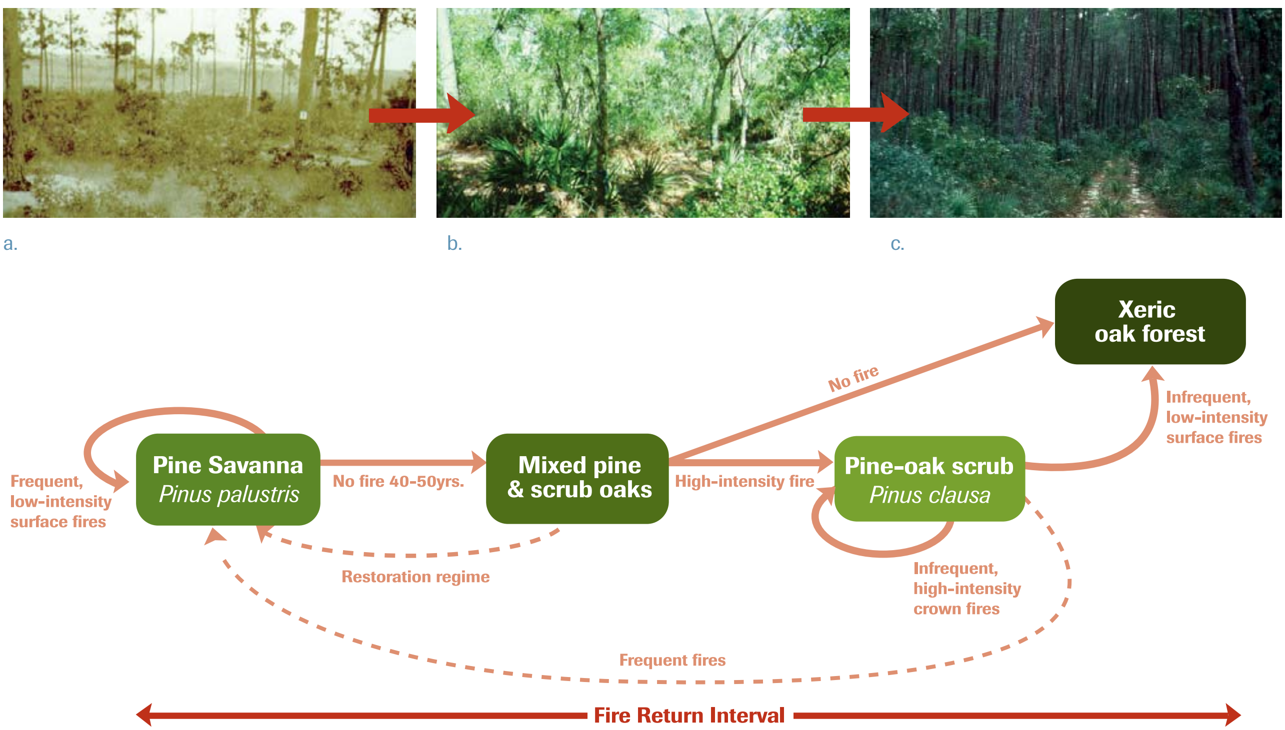


Figure 11. A simple, conceptual ecological model illustrating the relationship of fire regime to vegetation type in the uplands of central Florida, USA. On the same soil parent material, three different fire regimes maintain three different stable vegetation states: pine savanna (a), pine-oak scrub (c), and xeric oak forest (not shown). There is a transitional stage of mixed pine species and scrub oaks (b) that is unlikely to persist on a particular spot, but is likely to occur somewhere on the landscape at any given time. Photographs (a) and (b) are the same view taken in 1929 (two years after the last fire) and 1984 (after a 57-year fire-free interval), respectively. A particular site can maintain all four vegetation types. Management goals determine where and how fire will be managed to produce or maintain desired conditions. More detailed models can illustrate fire regime variability within each stable vegetation type; for example, different fire frequencies and spatial patterns may produce different pine stand densities and age classes in the pine savanna or pine-oak scrub. (Adapted from Myers 1985)

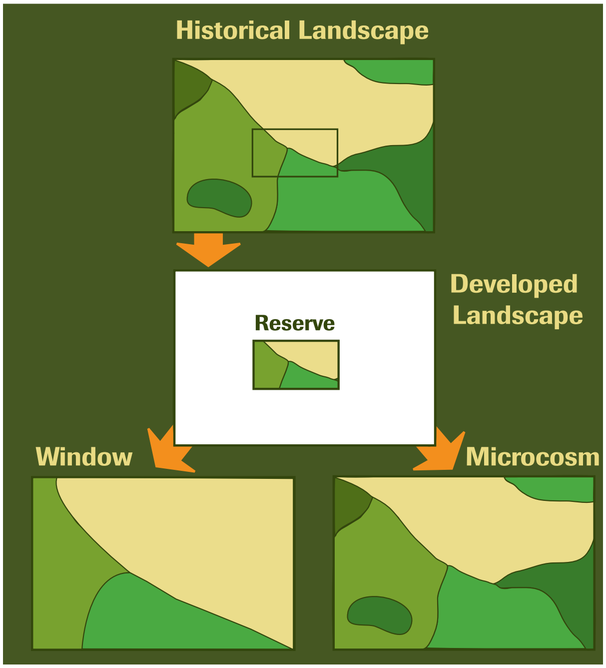


Figure 12. Management options for a conservation area in a remnant landscape. Patches may represent either different vegetation types maintained by unique fire regimes or the same vegetation type with each patch a different age since last burn. The "window" re-creates or maintains what had been historically on the remnant. Other habitats are lost, but species with large habitat requirements may benefit. The "microcosm" creates and maintains the diversity of habitats that once existed on the larger landscape. Habitat diversity is greater, but species with large habitat requirements will be lost. One approach is not inherently better than the other; it depends on the goals for the remnant landscape.

A site or certain vegetation types may need ecosystem recovery periods that may require focused burns with specific objectives, or aggressive fire exclusion and other restoration efforts such as mechanical treatments.

Desired Future Condition

Desired future condition represents a spatially explicit arrangement of desired vegetation or biotic community patterns and processes in a landscape that will provide sustainable resources and services expressed as management or conservation goals. Desired future condition draws on known or presumed vegetation history and/or reference conditions, i.e. vegetation examples considered to be in a relatively pristine state. But, desired future condition must be incorporated into the existing landscape context by taking into account current and desired land use, biological corridors and conservation buffer zones.

Achieving desired conditions may range from preventing and suppressing fires to encouraging fires to play their appropriate ecological role. Different fire regime scenarios can be illustrated and assessed using conceptual ecological models (Figure 11) that show the relationships among vegetation types and fire regimes. Restoration actions, such as the re-introduction of fire, may initially move an ecosystem further away from its desired state and it may take centuries to establish or restore desired conditions.

Because conservation reserves and protected natural areas are inevitably fragments or remnants of vegetation types that once covered a much larger area, fire is frequently a process that operated on scales larger than the extant natural landscape. In deciding on desired future conditions and how a particular remnant area should or should not burn, two general options or models are available to managers (Figure 12):

1. Restore and maintain the remnant as if it were a "window" of what used to be on the larger landscape. This allows the maintenance of a few large representations of vegetation that have long existed on the remnant landscape that may be important for species with large habitat requirements.

2. Restore and maintain the remnant as a "microcosm" of what existed on a much larger landscape in the past by managing fire such that burns are small compared to what once existed on the historical landscape. This allows for greater habitat diversity but at the expense of species with large specific habitat requirements.

An example of the second model is Emas National Park in the Cerrado of central Brazil (Figure 13). The 131,868-hectare park of grasslands and savanna is almost completely surrounded by agricultural lands, except for a biological corridor being established that will connect it to the Pantanal region lying to its southwest. Over the past several decades, the park has experienced fires that burned the entire park in a single season. This suggests that fires historically have operated at a larger scale than the size of the park. The present-day large fires temporarily limit habitat for the giant anteater, emus and untold other species, by eliminating nearly all cover, food sources, escape refugia and population sources for recolonization of burned areas. In order to limit the size of fires that occur each year and to prevent all habitats and refugia being affected in a single fire, park managers annually subdivide the park with a series of very long blacklines (fire breaks that are created by burning) that serve to stop the spread of fires. To date, no prescribed burns are conducted within the units circumscribed by these blacklines because management burns are prohibited within Brazil's national parks, but the fire break network allows the park to burn as a microcosm of how the larger landscape burned in the past, each year leaving large areas of unburned patches to serve as refugia, sources of recolonization and nesting sites.

Fire Management Goals and Objectives

Fire management goals define the specific outcome of managing fires in an integrated fashion to protect people and property, reach the desired future condition, maintain specific habitats, and restore, enhance or maintain ecosystem services and products. These fire management goals also should be in line with overall conservation goals and community needs. This implies restoring, designing and maintaining appropriate fire regimes for specific targets of conservation such as key species, vegetation types, landscape patterns or sustainable products. Strategies may include removing, ameliorating or modifying sources of fire-related threats such as the lack of control of agricultural fires; managing unplanned fires to limit their detrimental effects and to take advantage of their benefits; and applying fire as prescribed burns to mimic the appropriate role of fire in a safe and controlled manner.

3. Laws, Policy & Institutional Framework

In many countries, national and local laws regarding vegetation fires are not conducive to meeting appropriate fire management or conservation goals. The role of fire in maintaining certain ecosystems is frequently not recognized throughout society even in academic circles, let alone among decision makers. This has led to policies and laws that view all fires as bad, prohibit the use of prescribed fire in protected natural areas even though parks and reserves have stated goals to maintain and restore ecosystems (that require fire) and criminalize the agricultural use of fire without understanding needs of subsistence farmers or providing alternatives.

Criminalizing fire use rather than promoting safe and effective burning may actually lead to more escaped fires because people will set what they perceive as needed fires but leave them unattended so they cannot be held responsible.

Laws should reflect the needs of rural communities and promote proper use of fire while preventing unwanted ignitions and escapes and managing other negative impacts of fire such as its effects on air quality. This is best approached through a system of incentives, sanctions, education and government/community partnerships that encourage responsible uses of fire that support and improve a variety of activities, such as agriculture, silviculture, grazing, hunting, land clearing, watershed protection, ecosystem maintenance and the specific needs of priority species. Laws and policies should be integrated and compatible with other land uses and land management and environmental policies and deal effectively with issues such as land tenure and liability. Institutions that have responsibility for, or oversight of, land uses that involve fire, need to be integrated with each other and must have consistent and compatible messages, incentives and programs. Forestry departments frequently

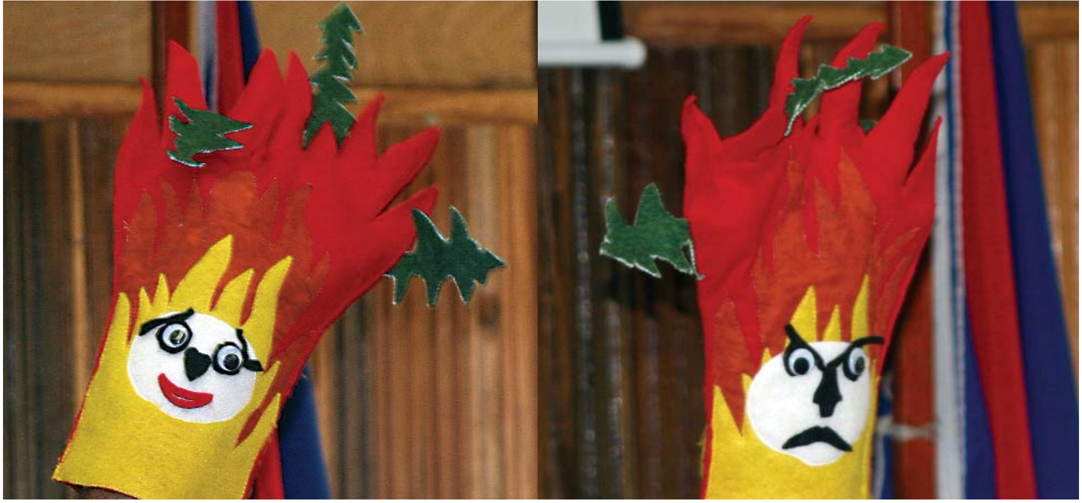
Figure 13. Part of an extensive fire break network created by burning "black lines" that subdivide a savanna reserve into relatively small fire units to prevent large fires from affecting the entire natural area at one time. Emas National Park, Brazil. (Photo by Ary Soares)

concern themselves only with forest fires even though many of those fires originate in the agricultural sector.

A relatively new incentive that could help landowners prevent fires in fire-sensitive vegetation is payment for ecological services. The payment for ecological services is probably best exemplified by the innovative program in Costa Rica that pays land owners to maintain their forested lands and restore cleared land to forest. It includes taking steps to reduce the probability of fire. This usually means constructing fire breaks which may or may not be effective in stopping fires. Payment for ecological services could be expanded to provide rural communities with resources to support paid, community-based fire brigades that would not only suppress unwanted fires but also conduct prescribed burns, help landowners keep their agricultural and pasture burns under control, pre-burn high-risk areas prior to the fire season and maintain fire breaks. The brigades could be financed through fees on water services in larger cities that derive their water from protected watersheds. The income would help reduce poverty and enhance livelihoods in local communities.

In regions where prescribed fire is a legally accepted management practice, landowners need liability protection as an incentive to maintain appropriate fire regimes. Likewise, government agencies need to protect their

Figure 14. Puppets depicting "good fire" and "bad fire" are being used in some educational programs in Latin America to explain the dual role that fire may play in ecosystems and communities. (Photos by R. Myers)



personnel from personal lawsuits and provide job security should damages occur from an appropriately conducted burn. The State of Florida in the United States has a "right-to-burn" law that limits liability of landowners using fire as long as a State-sanctioned planning and approval process is followed that includes certification (i.e. a specific level of training and experience) and the landowner is not proven grossly negligent in conducting a burn.

4. Prevention & Education

Preventing damaging wildfires is a requisite component of all Integrated Fire Management approaches irrespective of ecosystem needs and tolerances. In most places, in spite of the fact that fires may be necessary, free-ranging wildfires can rarely be tolerated due to the potential toll they can take in human life and property. The most cost-effective approach to unwanted fires is prevention. A number of strategies are needed to successfully limit the number of unwanted ignitions:

Education

Education and outreach need to be tailored to specific environments and targeted to community needs. One useful approach is to characterize fire as having two faces using a message of "**the two faces of fire**," or "**good fire**" versus "**bad fire**" (Figure 14). Good fires are agricultural burns that remain under control. Good fires are those burning in a fire-dependent ecosystem with minimal negative impacts on human livelihoods and property, and with long-term benefits. Bad fires are escaped agricultural fires and other fires that threaten life and damage property and conservation areas.

All too often, fire prevention campaigns focus on preventing all fires even in ecosystems that need to burn and may be burning appropriately through traditional fire use or in places where people have no other alternative but to use fire. Cultural perceptions about the benefits of burning are seldom incorporated into fire prevention messages. The notion that all fires are destructive becomes ingrained in people's minds and traditions through such campaigns as the popular Smokey Bear character encouraging fire exclusion in all cases in the United States. When the need for using fire becomes recognized by the managers of conservation lands, the public invariably expresses its considerable resistance to managing fires or to prescribed burning.

Where fire is a necessary tool to maintain the livelihoods of rural communities, education and community programs should be directed toward empowering people with the incentives, tools, information and skills to help them keep their needed fires under control so that their burning meets individual, community and ecosystem objectives.

Whenever possible, traditional knowledge should be incorporated into messages and activities. Communities need to be guided so they recognize the economic and social benefits of keeping their burns under control benefits such as water quality and quantity, sustainable forest products such as fuel wood, and ecotourism income. Communities may also need to be trained, organized and equipped to suppress unwanted fires, or given the tools and information they need to increase fire prevention capacity.

Fires can be prevented or the incidence of fires reduced by addressing conflicts between different groups of people. Resolving land tenure disputes has been shown to reduce fires set as forms of protest or vengeance in Sumatra (Suyanto *et al.* 2004).

Education is also needed within land management agencies, political entities, interest groups and the scientific community. Many current roadblocks to effective fire management exist because scientists and land management and fire professionals do not understand the role that fire plays in ecosystems and in people's lives. It is not

Figure 15. Subsistence farmers planting rice in lands cleared by traditional tavy methods (swidden agriculture), eastern Madagascar. Tavy agriculture and its associated burning are considered a primary threat to remaining tropical forests in Madagascar.

uncommon to have the role of fire in many ecosystems completely unknown to, or misunderstood by, top-level scientists within countries or regions. The views of these people proliferate because they are the ones who are teaching and training the professional environmental managers and scientists of the future. Technical/scientific transfer of knowledge is a key component of education. The translation of emerging concepts and technologies into multiple languages is paramount.

5. Fire Use

Fire use takes on a myriad of forms and effects. Two discussed below include (1) the traditional uses of fire by rural people that are either needed to maintain livelihoods or have persisted even as the social/economic context of the region has changed, along with the role that people have played in creating, maintaining or changing desired ecosystems and their components and (2) the managed use of fire to restore and maintain desired ecosystem states or desired ecosystem products and services within conservation areas. The latter may range from prescribed burning in fire-dependent ecosystems to managing unplanned fires in these ecosystems and using fire to eliminate or reduce fuel to control the spread of fire into fire-sensitive ecosystems.

Traditional Fire Uses and Needs

In fire-dependent ecosystems, people invariably have played a long-standing role in creating, maintaining, expanding or changing the ecosystems that are desired today for conservation purposes. Many landscapes that are now important to conservation were created, shaped and/or maintained by human burning. In fire-influenced and fire-sensitive ecosystems, burning associated with swidden (slash-and-burn) agriculture has had an equally long history (Figure 15).

In many places, traditional uses of fire are either (1) persisting in an environment of increasing population growth and the current level of burning is out-stripping the maintenance capacity of the ecosystem or (2) being reduced through fire prevention efforts, suppression and changing land uses that no longer require or are tolerant of fire. An important component of Integrated Fire Management is recognizing and understanding the important role that human fire use has played in any given landscape. Current burning practices may or may not be at odds with conservation goals. In either case, rather than working against those uses through prevention, it may be more practical to look for ways to modify current fire use, either to mitigate current negative impacts or in some cases to actually exploit existing fire uses to facilitate reaching fire management objectives and conservation goals.

For example, burns set by local communities for non-conservation purposes can be strategically placed or timed to contain the spread of wildfires later in the dry season or to prevent fires from burning into reserves. Such cooperation requires overcoming the challenges of different world views, languages and cultural perspectives of conservation managers, indigenous people and non-indigenous rural populations. Collaboration with local users of fire is especially critical where large tracts of conservation lands and their buffer zones are under the direct ownership and/or control of indigenous people, or are communal lands of rural communities. Box 1 describes four scenarios where traditional human fire use has been or could be included into conservation area management.

Box 1. Case Studies: Incorporating Human Fire Use Into Conservation Area Management

- In Australia, aboriginal burning practices have been integrated into the fire management programs of northern Australia's national parks and aboriginal lands (Morrison & Cooke 2003; Lewis 1989). Conflicts have arisen in the best example of this practice in Kakadu National Park because aboriginal burning practices have not always been consistent with biodiversity goals (Keith *et al.* 2002).

- In Canaima National Park, in the Gran Sabana of south-eastern Venezuela, the landscape is a mosaic of grassland and wet tropical broadleaved forest. There has been a long-standing conflict between scientists and technicians and the Pemon Indians regarding the use of fire (Rodríguez 2004). The conventional view among vegetation ecologists and land managers in Venezuela is that the savanna is edaphically derived rather than a result of fire.

  This probable misconception adversely affects fire management approaches in the park which could have negative impacts on the viability of both the forests and grasslands of the park. The policy of the national park service is to prevent fires, though they have limited capacity to respond to fires when they occur. Indigenous people who live within the park regularly burn the savanna for reasons critical to their livelihood, e.g. to improve access, to attract wildlife to recently burned patches to facilitate hunting and for long-distance signaling. They perceive fire as an integral part of the environment that "cleans" the savanna and prevents large destructive fires in the forests.

  Burning begins at the beginning of the dry season when the grasses are still green. The high moisture content dampens fire intensity and most fires go out as humidity recovers at night. These fires rarely burn into the moist forest vegetation. By the height of the dry season, when fires could enter the forest, most of the savanna has been burned and the forests are protected from the possibility of severe, late dry-season fires. During protracted droughts, fires do enter forested areas and can be quite destructive. When the forest is damaged, the change in fuel characteristics, coupled with the frequent ignitions in the savanna, hinders recovery.

  If park staff ever become effective in reducing the incidence of early dry-season fires, there are two possible outcomes: (1) complete success in preventing fires would lead to a loss of savanna through forest encroachment or, more likely, (2) large continuous tracts of grass fuels would persist into the late dry season potentially fueling large, intense fires which would cause widespread forest damage. The result would be a rapid expansion of grassland at the expense of forest.

  Alternatively, if park managers could develop a working relationship with the indigenous people so they would strategically place some of their early dry season fires near critical forest recovery zones and areas of high risk for fires entering the forest, traditional fire use could become an important tool in managing the relative abundance of forest and grassland habitat in the park.

- In Zambia, prior to the 1990s, widespread uncontrolled burning annually affected vast areas of lowland grasslands and upland woodlands. Most of the burning was done to promote a green flush of grasses for livestock, but the fires were negatively affecting woodland resources such as fuel wood and thatch. In the early 1990s a joint Zambia-Dutch initiative prepared an Integrated Fire Management program by assessing the ecological aspects of fire, the negative and positive socio-economic impacts, existing and needed fire policy, and current fire use patterns. Their review has led to an Integrated Fire Management policy of planned and controlled burning of selected rangelands and a reduction in burning and alteration of burning practices in the woodlands. The program is implemented by local communities. Technical assistance is provided to facilitate decision-making by the communities (Goldammer *et al.* 2004).

- In La Sepultura Biosphere Reserve in Chiapas, Mexico, most of the reserve lands are either in private hands or held as community property in ejidos (peasant communities). The reserve landscape consists of farm and grazing lands at lower elevations, pine forest at mid-elevations, and montane, wet-tropical broadleaved forest at higher elevations. Farmers burn their agricultural plots and fields on an annual basis. Escaped agricultural fires frequently burn the understory of the pine forest. Residents also periodically burn the pinelands for a variety of reasons. As evidenced by a lack of pine regeneration, the pine forests are probably burning too frequently. During extreme droughts some of these fires enter the montane forest and are very damaging.

  In 2005, The Nature Conservancy, in cooperation with the Mexican Protected National Areas Commission (CONANP) and the NGO Conservación y Desarrollo, A. C. implemented a project in which they provide technical assistance to several communities to help them keep their agricultural fires under control, develop fire management goals for the pinelands that are compatible with their needs and biodiversity conservation, and design and apply an appropriate prescribed fire regime to the pinelands. Plans, decisions and implementation are all developed and carried out by the community.

Although traditional fire uses can be integrated into conservation area and regional fire management plans and activities, care should be taken to not over-emphasize traditional uses. There are likely many different competing uses of fire, each benefiting different groups of people that may be at odds with each other and with conservation goals. For example, problems tend to arise when the indigenous population has been supplanted by an immigrant population that possesses different or no fire traditions. An example is in the Peten of northern Guatemala. This landscape was once the homeland of the Maya culture, but their agricultural lands were reclaimed by forests when their culture largely disappeared centuries ago. Only recently has this region been opened up to colonization by landless peasants from the Guatemalan highlands who possess little knowledge of fire use. Over the past decade, the Peten has been the Meso-American epicenter of destructive fires from escaped agricultural and land clearing burns. In 2003, the impacts were so severe that the United Nations had to supply the region with emergency food shipments because the fires not only destroyed forest vegetation but also the crops of many farmers. Community-based programs have since been implemented to teach the farmers how to burn safely.

Community-based fire management frequently involves a diverse set of stakeholders with competing needs and views about fire. A primary demand among these stakeholders is their securing the right to use fire as a vegetation management tool to suit their purposes. The key to successful community-based Integrated Fire Management is reaching agreement on where, when and how fire should be used in different environments for different objectives. Where fire is part of the culture, and where the needs and uses of fire vary and are often in conflict, the goal should be to optimize the ***overall*** set of benefits of burning such that each group of stakeholders understands its contribution to sustaining personal, community and ecosystem products and services—such as balancing nutrient-rich forage for domestic livestock or game animals with producing fuel wood for cooking and heat—while at the same time minimizing detrimental impacts and halting or reversing declining ecosystem and biodiversity trends that will ultimately degrade the entire community and region.

Fire Use Approaches

Prescribed fire is the application of carefully controlled burns under defined fuel and weather conditions to meet land management or ecological objectives ***involving a written plan***. The objectives usually involve both desired fire effects of each burn, plus a long-term trend or goal from the application of fire over time, i.e. a fire regime goal. In other words, a ***prescribed fire regime*** is a repeated pattern of burning designed to reach some desired or predicted outcome. Prescribed burning is becoming an increasingly important tool in maintaining and restoring fire-dependent ecosystems within protected natural areas, in protecting human infrastructure in fire-prone landscapes, and in managing large-scale agricultural and forestry operations. It is more prevalent in regions of the world that have the resources and technical capacity to develop and implement prescribed burn plans, and where liability from damage caused by escaped fires is high.

A ***controlled burn*** is essentially the same thing but ***without a written plan***. Safe controlled burning, rather than prescribed burns, is usually the goal of individual farmers and community-based fire management programs in developing countries. The farmer conducting a burn has a plan, understands local fuels and weather conditions, and has specific objectives—all kept in his or her head.

Controlled and prescribed burns do not necessarily need control lines but rather can rely on vegetation and fuel changes, and changing fuel availability during the day or at certain times of the year. Much of the burning that takes place in grasslands and savannas around the world depends on the igniter's knowledge of where and when a fire will stop, not on the pre-placement of control lines.

Wildland fire use is the management of unplanned wildfire, usually within conservation areas, to obtain beneficial outcomes that lead to management goals. It takes advantage of the ecological work that an unplanned fire will accomplish. The level of management of unplanned fires may range from observation and monitoring within predetermined limits placed on fire size by existing natural and cultural fire breaks to more aggressive containment within specified zones. A sound technical background in fire behavior and fuels is usually a requisite for making wildland fire use decisions.

Prescribed fire and controlled burning have their place in both fire-dependent and fire-sensitive ecosystems. In fire-dependent ecosystems, burning can be used as a restoration tool, with focused burns planned such that an area will return to former or desired conditions. Burning can be used to replace, augment or modify a current fire regime in areas where some or all free-ranging wildfires can no longer be tolerated. The controlled use of fire can also create fuel breaks and patches of low fuel loads to facilitate the control of unwanted fires or to corral unplanned fires that are being managed for resource or conservation benefits.

In fire-sensitive ecosystems, prescribed burning is an important tool in creating fire breaks at reserve boundaries and to pre-burn around zones of high risk of damage if a wildfire should occur. Prescribed fire techniques can be used by farmers, livestock herders and ranchers to keep their fires from escaping into fire-sensitive vegetation.

Effective prescribed burning requires intensive training, an understanding of fire behavior, fuels, weather, topography and fire effects, along with considerable experience. The level of training needed varies with the complexity and size of the area being burned and the associated risks to the surrounding area should the fire escape control. Careful planning and contingencies are essential and there must be the capacity to suppress an escaped fire.

Because prescribed burning is labor intensive and relatively expensive, many governments may never obtain the capacity to use prescribed fire effectively on a large scale in protected natural areas. In such instances, it may be more effective to provide local communities with the skills to adapt their traditional burning practices to meet conservation goals of protected areas.

Prescribed fire has other drawbacks. It may be difficult to re-create the fire regime variability necessary to meet biodiversity goals using prescribed fire. Box 2 lists some additional potential pitfalls.

Prescribed burning has a number of other uses in conservation areas, including fuel or hazard reduction burning to protect people living in flammable vegetation; silvicultural burning to protect forest crops; site-preparation burning to facilitate forest regeneration, disease and pest control; and wildlife habitat management.

Prescribed fire training and educating the general public and local communities about the benefits and needs of using prescribed or controlled fire are sorely inadequate or non-existent in many countries and regions. In many

Box 2. Potential Prescribed Fire Pitfalls

1. *Applying fire regimes that are too narrow:* Prescribed burning involves making decisions about the components of the fire regime such as the interval between burns, fire intensity, size and pattern of burn and season of burn. For planning convenience and for safety and security reasons, managers tend to focus on average properties of these components or on a very narrow range of the component. For example, burns are applied at fixed intervals, frequently during a season when the fires can be easily controlled and will have modest impacts. However, this timing and intensity may not be consistent with the reproductive needs and growth constraints of key species. Prescribed burns are usually surface fires, but higher severity crowning or ground fires may create effects and habitats needed by some species. Managers are reluctant to plan for these types of fires. As a result, there have been instances where prescribed fire regimes were unwittingly applied that were too narrow or lacked the variability required to sustain certain species or maintain the ecosystem long-term. Instead of achieving the desired outcome, wholly unexpected results can gradually be created that include species extinctions (Gill & Bradstock 1995). Variation within fire regime components may be more important ecologically than average properties.

   To avoid this pitfall, it is important to understand, or to make well-founded inferences about, the life histories and response to fire of (1) keystone species such as those that control the fire environment by producing fuel, (2) dominant species that give the ecosystem its overall character and (3) species of special concern. Because decisions are made from inferences, fire applications and subsequent responses must be monitored and adapted through time.

2. *Problems of scale:* These develop when there is a failure to understand the habitat size requirements of desire-species, where trade-offs have to be made between habitat size and habitat diversity, or where there has been a loss of landscape context due to fragmentation and fire can no longer operate at the scale that it once did. Some of these problems can be overcome by reserve design (e.g. see Figure 12). They also require clearly stated goals, monitoring of outcomes and using feedback from monitored trends to inform future fire management actions.

3. *Distinguishing between restoration and maintenance phases:* Restoration involves focused burning with specific outcomes for each burn. It may also require recognition that fire alone will not restore the desired outcome. Maintenance burning calls for variable fire applications within the appropriate fire regime ranges for a given ecosystem.

4. *Coping with exotic species:* Where non-native invasive species control the fire regime—such as where they produce the available fuel that carries fire—novel fire regimes may have to be designed that may gradually reduce the dominance of the exotic, or that burn in such a way to limit adverse impacts on desired ecosystem components and processes given the existing fuel characteristics. Where invasive species are a threat from the outside, fire regimes may have to be designed to discourage colonization.

5. *Dealing with transitional vegetation:* Fire needs to play its role in transitional vegetation types, i.e. fire-influenced ecosystems. Frequently, fire-dependent vegetation is distinguished from fire-sensitive vegetation. The former is burned or allowed to burn, while in the latter fire is excluded by using permanent fire breaks. This leads to the elimination of important transition zones and their habitats. Fires can be allowed to enter fire-influenced ecosystems if the relative differences in flammability of vegetation types are understood.

cases, long-standing fire prevention programs have created a strong and ingrained bias against using fire in conservation areas or in and around communities.

Burning also affects air quality and people's health and well-being and shapes people's perception of fire. Major international airports are sometimes closed for days in countries like Bolivia, Honduras and Indonesia where dry season fires are ubiquitous. Prescribed fire provides techniques for managing smoke that are unavailable when burning is pervasive and uncontrolled.

Biomass burning can also be a significant source for atmospheric carbon, though an appropriate fire regime in a fire-dependent ecosystem is in steady state with respect to carbon. What is released from a burn is recaptured during the fire-free interval. It is fire suppression in fire-dependent vegetation that ultimately results in carbon release as severe damaging fires occur in abnormally heavy fuels. In fire-sensitive forests and shrublands, deforestation is the source of carbon release. Fire is one of the tools that facilitate that deforestation.

In many countries, the use of prescribed fire in national parks and protected natural areas is prohibited by law or administrative policy even in areas that are recognized as fire-dependent. This is generally a philosophically based restriction of management activities in natural areas. Oftentimes, policies and laws also require agencies to suppress all fire regardless of threat or potential resource benefit. For prescribed fire and wildland fire use to reach their potential, a considerable educational effort has to be undertaken to change public policy and people's perceptions about the role and potential benefits of fire in ecosystems that society has sought to protect.

6. Preparedness & Response

Countries, land management agencies and communities have to be prepared to respond effectively to inevitable unwanted damaging fires. Strategies include the development and implementation of (1) early warning and predictive systems, i.e. fire danger rating, climate and weather monitoring and prediction, (2) fire detection and response processes and infrastructure, e.g. wildfire response planning, fire caches, and aerial/satellite/land observation detection systems, (3) communication systems and multi-lateral/multi-agency cooperative agreements with unified command and control structures (Incident Command System or ICS), so diverse entities can communicate, plan, and mobilize resources effectively and (4) highly competent and trained personnel at all levels, from professional fire managers and fire fighters to volunteer community fire brigades.

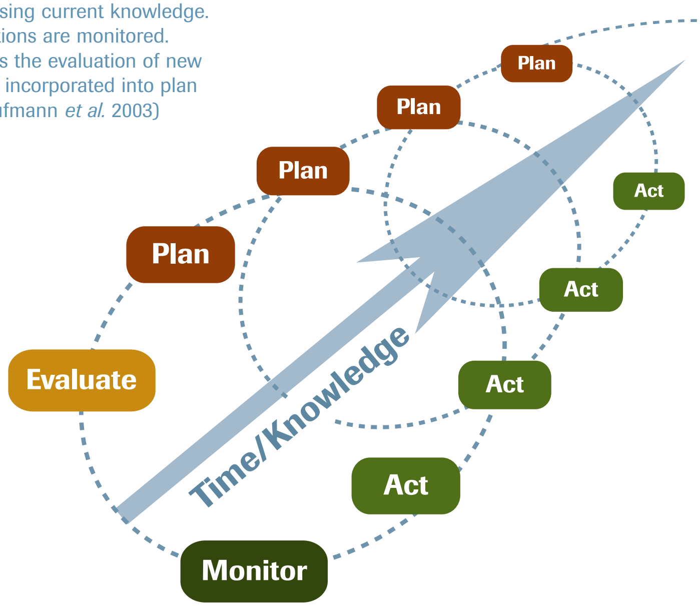
There are a wide range of technological resources available to assist with preparedness, response planning and fire suppression operations. Too often, however, governments and citizens simply react to large fire events that are handled at a national level as emergencies to protect people and resources from a disaster in progress. The media reinforce these perceptions and reactions. Thus, responses are event-driven. Huge sums of money are poured into the suppression and recovery efforts. In the immediate aftermath of the event, money frequently goes to purchase sophisticated and very expensive suppression and detection equipment such as air tankers, engines and helicopters. During intervals without significant media-driven events, interest wanes and resources dwindle. The process repeats itself when the next event occurs.

Although there is a place for sophisticated equipment and infrastructures in fire detection and fire suppression, a more integrated approach to preparing for and managing fires would look at fires not just as events, but as regimes (Gill *et al.* 2002). A regime approach looks at current conditions and desired outcomes as the result of a series of events that have already occurred and will likely reoccur over time. Rather than responding to events as emergencies, and in the immediate aftermath expending emergency monies on tools that might have been useful during that event, a regime approach would look at the cumulative effects of prior actions, existing factors and changing environments such that mitigating actions are continuously in progress to reduce the intensity and/or impacts of individual events. These mitigating actions, such as ecosystem maintenance burning, fuel reduction activities, community-based fire management programs and community fire brigades, can tailor prevention, suppression and fire use activities to local conditions, needs and availability of resources.

7. Restoration, Recovery & Maintenance

Recovery after fires can be viewed as either an event response or as a long-term regime maintenance action that in effect puts management restraints on potential extreme events, thus limiting the instances that require emergency community assistance and aggressive ecosystem recovery efforts. There are many instances post-fire where considerable effort and expense go into building and maintaining tree nurseries, and implementing planting and reseeding projects, when the ecosystem is capable of self-recovery if it remains sufficiently fire-free. Efforts might be better directed at reducing the probability of additional ignitions. Salvage logging is another event response that should be evaluated in the context of ecosystem responses and community needs.

Figure 16. The continuous adaptive management cycle. Plans and strategies are developed using current knowledge. Plans are implemented and those actions are monitored. Feedback from monitored trends, plus the evaluation of new knowledge developed elsewhere, are incorporated into plan revisions and new actions. (From Kaufmann *et al.* 2003)



8. Adaptive Management, Research & Information Transfer

Designing and managing ecologically appropriate fire regimes that benefit both people and nature requires the development of fire management goals. People have created protected natural areas, national parks and forest reserves because they contain something of value including needed products and services. These products and services are the conservation "targets." They may require fire, be sensitive to it or able to tolerate only certain types of fire or specific fire regimes. Because these areas have something of value that people want to restore, maintain or enhance and these things or processes are affected by fire, fire management goals need to be set for those targets.

Goals have to be based on both knowledge and inferences about current status, life histories, habitat requirements, sustainable yields and fire dynamics of the conservation targets, within the context of the constantly changing environment in which they occur. Because management actions are based on inferences about the targets, rather than on complete knowledge, those management actions must be monitored. It is feedback from monitored trends and new knowledge that should drive future management actions. This is ***adaptive management*** (Figure 16).

For adaptive management to be influential and effective beyond a specific site or conservation area, success stories, lessons learned and new tools developed in one place need to be translated for and disseminated to other sites and adapted to new situations. Traditional modes of technology transfer such as professional journals, manuals, conferences, training courses and internet sites will continue to be important. Nevertheless, the lack of scientific and technical articles and training courses in local languages is a huge impediment to understanding the role of fire in ecosystems and to having the capacity to integrate knowledge about fuels, fire behavior and fire management techniques in many countries. Additionally, university and technical schools need to be sources of innovation so that new concepts and applications regarding fire are continually being fed into agencies, organizations and communities.

A tool that is proving effective in transferring information and technology is structured learning networks. The Nature Conservancy, in collaboration with fire agencies and other partners, is using ***fire learning networks*** in Latin America, the Caribbean and the United States as a mechanism to join forces effectively to achieve mutual goals related to fire by bringing people together to identify common needs, problems and barriers to the implementation of effective fire management, and to develop and test strategies that are likely to succeed on different landscape areas (Figure 17). Through synthesis and shared experience, learning networks not only communicate existing knowledge but also create new knowledge as experiences and ideas are adapted to local situations.

Through facilitated workshops, site assessments, mentoring and exchanges, internet discussion groups, websites and e-newsletters, learning network participants are introduced to the best available science and management options. They are guided through a process of identifying fire-related threats using conceptual ecological models and situation diagrams that illustrate ecological and social relationships affecting—and affected by—fire, identifying desired future conditions and fire management goals, and designing integrated strategies, i.e. integrated ecologically and socially appropriate fire management, to reach those conditions (see www.tncfire.org/usfln and www.tncfuego.org).

The Regional Wildland Fire Networks being fomented around the world by the United Nations Food and Agriculture Organization (FAO) and the Global Fire Monitoring Center are another venue for information exchange and international cooperation (see www.gfmc.org).

Guiding Approaches to Integrated Fire Management

The diversity of ecosystem responses to fire and the diverse cultural perceptions and economic realities of people deriving their livelihoods from these ecosystems, coupled with the status and trend of fire regime alteration, point to the need for flexible and multifaceted fire management approaches. Add to this the current capacity, or lack thereof, of governments and society to address fire-related threats, and a daunting picture emerges—one of degraded landscapes, costly damages, decreasing standards of living and declining human health.

What are some of the guiding approaches (see Box 3) that will help countries and land managers implement Integrated Fire Management and abate fire-related threats? One of the most important approaches is to connect fire ecology to fire management. Another is the need to understand the underlying causes of fire problems. Combining fire ecology and the socio-economic causes of most fires with the techniques of fire management multiplies the potential effectiveness of the latter and limits the possibility of fire management actions working at cross-purposes to societal and environmental needs. It makes fire management much more powerful, solving problems rather than preparing for and responding to events.

Places need Integrated Fire Management plans that incorporate ecological and socio-economic issues and identify constraints. Plans can be developed at multiple scales from the community or protected natural area to an entire country. Many government fire agencies have as their sole focus "fire protection," i.e. prevention and suppression. Many are reluctant to broaden their mandate to encompass the full scope of fire management decisions and technologies. They do not want to become fire management organizations, let alone incorporate ecological and social concepts and pursue ecological goals. Failure to consider the benefits of fire use and to understand fire use technologies prevents agencies from grasping the full potential of Integrated Fire Management with its ecological and socio-economic connections.

Where agencies are unable to develop full-fledged fire management organizations, it is possible to bridge the connections by forming multi-agency working groups or fire management councils that include communities and non-governmental organizations. These entities can then

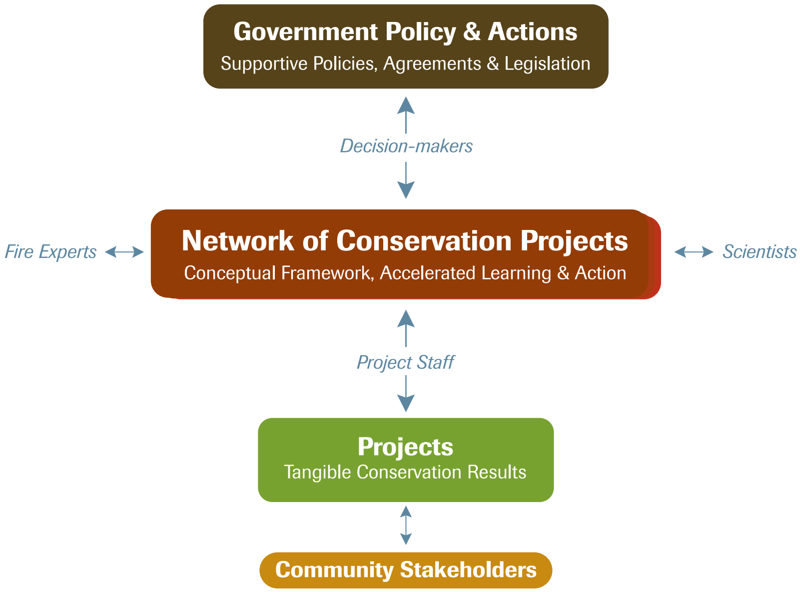


Figure 17. Fire learning networks consist of conservation projects with similar fire threats and fire management issues. Participants are brought together with fire experts, decision-makers, and scientists in facilitated workshops, training courses, exchanges, mentoring programs and study tours and are connected via the internet. The process accelerates learning of Integrated Fire Management concepts and the development and implementation of fire management plans that produce tangible conservation results. Through local workshops and programs, community stakeholders are brought into the process and may take the lead in implementing some of the strategies.

develop an institutional framework at local, national and multi-national levels that embraces a broad integrated approach to fire management that takes into account the diversity of vegetation types and community needs, rather than narrowly focusing on prevention and suppression of fires in forested vegetation, or simply responding to events. The institutional framework must be able to develop a flexible ***national fire policy*** or ***national fire management plan*** that integrates regionally-varied ecological, economic and social components of fire and ensures that these policies will be implemented. It also must incorporate these new approaches into educational and training curricula.

Conclusion

In this paper I have described what I believe is a useful framework for addressing fire problems irrespective of the type of environment and the economic capacity to develop and implement appropriate strategies. The purpose of Integrated Fire Management is to reduce the threats posed by fire to both people's livelihoods and to biodiversity while at the same time recognizing and maintaining fire's important role in many ecosystems and economies. The approach demands that we first understand how an ecosystem responds positively or negatively to fire before we make decisions about whether people are burning too much, not enough or in a manner that promotes or is at least consistent with conservation objectives. It then asks that we understand the underlying causes of fires and how fire is integral to the livelihoods of many rural people around the world. Inappropriate burning and wildfires can then be viewed as somewhat predictable regimes that can be managed effectively and safely to meet specific conservation, community and national goals.

Box 3. Guiding Approaches to Fire Management

1. Understand the role of fire in the ecosystems being managed and the influence any changes in the fire regime have on key ecosystem characteristics and conservation values.
2. Document, promote and, where necessary, modify the beneficial aspects of traditional fire use, and develop the knowledge, capacity and technology to apply fire safely where it is needed.
3. Reduce the incidence of human-caused ignitions in places where too much fire is a problem through community-based education programs including incentives, capacity-building and training either to reduce the need for burning and/or reduce the probability of needed burns escaping control.
4. Develop laws and policies that ease restrictions on the use of prescribed fire and provide mechanisms to reduce the liability or insurance costs incurred by agencies and landowners for escaped prescribed burns.
5. Develop and implement adequate and cost-effective detection, prediction and response tools and procedures to respond to inevitable unwanted fires and manage them to minimize impacts, while also providing a process to take advantage of potential benefits that they may present.
6. Promote programs such as payment for ecological services to private landowners and to the holders of communal lands for maintaining appropriate fire regimes through their judicious placement of prescribed burns and fire breaks, and where appropriate support community fire brigades that can both fight fires and conduct prescribed burns.
7. Link community-based fire management programs to poverty reduction, food security and human welfare initiatives.
8. Gain buy-in and support from local communities living and working in and around fire-dependent conservation zones to work with conservation area staff to take advantage of, and perhaps modify, the burning they do to better meet conservation goals.
9. Promote a "two faces of fire" message, i.e. good fires versus bad fires, instead of the typical "prevent all fires" campaigns. In fire-dependent ecosystems, good fires are those that fall within an appropriate range for the fire regime that maintains the desired ecosystem but cause little or no economic damage or loss. Good fires in fire-sensitive ecosystems include necessary agricultural fires that remain under control. Tools and knowledge to limit escaped agricultural fires and manage other fires can be made available through community-based fire management programs.
10. Incorporate ecological information and the Integrated Fire Management framework into fire curricula and training programs.

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Photos:

Cover Image: Fires set by chagras (Andean cowboys) to renew forage grasses are favoring páramo grasslands in Ecuador at the expense of *Polylepis* species that dominate Andean dwarf forests. © Pete Oxford/Minden Pictures

Top Back Cover: The Brazilian Cerrado, once covering 22 percent of the country or 2 million sq. km, is a mosaic of savanna and shrubland molded by a diversity of fire regimes. © Tui De Roy/Minden Pictures

Middle Back Cover: Traditional agriculture (tavy) in Madagascar. © Frans Lanting/Minden Pictures

Bottom Back Cover: Burning to help herd cattle during the annual cattle round-up in northern Andes páramo grassland in Ecuador. Páramo is a fire-dependent ecosystem but the ecologically appropriate fire regime is poorly understood. © Pete Oxford/Minden Pictures

Inside Front Cover: Slash-and-burn agriculture in eastern Bolivia. © Carlos Pinto

Inside Back Cover: Prescribed burn in fire-dependent Caribbean pine savanna in Belize, Central America. © Ron Myers

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