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Burning the Seasonal Mosaic: Preventative Burning Strategies in the Wooded Savanna of Southern Mali

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Data are presented indicating a seasonal mosaic *pattern of burning in the savanna of southern Mali. A seasonal mosaic is a landscape that is annually re-created by people, and which contains patches of unburned, early burned, and recently burned vegetation. A survey of over 100 farmers and in-depth interviews demonstrates that rural inhabitants of southern Mali begin an annual burning regime early in the dry season in order to fragment the landscape, with the goal of preventing later fires that can damage natural resources. The process of gradually burning off the driest vegetation creates a seasonal mosaic of habitat patches that increases the potential of the landscape for a variety of dry season land uses, including hunting, gathering of savanna products, and grazing. An analysis of a series of Landsat images shows that the practice of mosaic burning is widespread in the wooded savanna, in which burning usually begins early and large fires are rare. On the basis of recent developments in ecological theory and empirical evidence from similar burning regimes in parts of Australia, it is suggested that seasonal mosaic burning in Mali not only prevents damaging late-season fires but increases biodiversity. It is concluded that discourse on African savanna burning overemphasizes the ecologically detrimental aspects of fire, while neglecting the beneficial ones resulting in misguided policies that pose a threat to human livelihoods and savanna ecosystems.*

KEY WORDS: savanna; fires; West Africa; fire management; indigenous resource management.

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INTRODUCTION

For centuries people living in West Africa have burned extensive areas of the savanna (Bird and Cali, 1998). The fires begin the moment the annual rains stop falling and they continue throughout the long dry season. Burning ends only after new rains have fallen; by this point thousands of square kilometers of vegetation are affected (Delmas *et al.*, 1991). In many areas of the savanna over half of the landscape is burned by fire on an annual basis (Barbosa *et al.*, 1999; Eva and Lambin, 1998b; Menault *et al.*, 1991). Yet, the specific dynamics surrounding anthropogenic burning and the savanna landscape remain largely understudied and poorly understood, especially in regard to the linkages among human burning practices, fire regimes, and savanna vegetation.

The research presented here highlights the importance of linking ground level data with that provided by remote sensing. The data demonstrate a *seasonal mosaic* pattern of burning in the savanna of southern Mali. A seasonal mosaic is a landscape pattern that is annually re-created by people, and which contains patches of unburned, early-burned, and recently-burned vegetation. Findings indicate that researchers studying the causes of savanna fires need to move beyond merely linking specific fire patterns with different land uses to incorporating an understanding of the seasonal fire regime, which highlights the differences between early- and late-burning fires and the reasons for them. These fires affect the environment to varying degrees, and understanding the seasonal pattern of this burning has important implications for the research and policy-making communities.

Fire Regimes and Savanna Ecology

Savannas are distinguished from forests and deserts by their near-continuous cover of grasses, a feature that also ensures that running fire is a particularly important element of savanna ecology. In savannas the length of the annual dry season is between 4 and 8 months. This long dry season is a key reason why fire is an annual, or biennial, event (Cole, 1986; Stott, 1991). In West Africa, fires are most frequent and extensive in the Soudan and Guinea savanna belts, a region lying to the south of the Sahel and to the north of the tropical forest. The vegetation in this landscape is a wooded savanna comprising a mosaic of grasses and trees. In this region there is adequate rainfall to support a variety of tall grass species (over one-meter in height) that dry following the end of the rains, creating a highly flammable fuel bed. Recent estimates based on remotely sensed imagery find that approximately 25–80% of this wooded savanna burns every year, making it the earth's most frequently and extensively burned region (Barbosa *et al.*, 1999; Eva and Lambin, 1998b; Menault *et al.*, 1991).

Throughout this West African region fire is a major determinant of vegetation cover. In wooded savannas, grasses compete with trees and shrubs for space in the landscape (Walker, 1987). Fire acts to modify broad vegetation patterns set primarily by rainfall and edaphic factors and hence plays a critical role in determining the structure and function of these ecosystems (Scholes and Walker, 1993; Walker, 1987). The main impacts of fires are to increase the level of nutrients available to plants immediately following the fire; to enhance, in the short term, the production of some perennial species; and to prevent the replacement of the herbaceous strata by woody species (Menault, 1993). In this regard, the ecological consequences of all savanna fires are not equal; the timing and frequency of fires determine how burning affects vegetation cover. Late dry season fires burn intensely and at a time when trees are most susceptible to fire damage (Devineau, 1997). The late fires kill small trees and can cause damage to larger ones. Conversely, early fires (fires set before grasses are totally dry) cause less damage to trees (Menault *et al.*, 1995). Over the long term the timing and frequency of annual burning, or fire regime, determine whether it will be trees or grasses that will dominate the landscape (Brookman-Amissah *et al.*, 1980; Louppe *et al.*, 1995; Rose-Innes, 1971; Swaine *et al.*, 1992).

The spatiotemporal patterns of fires for West Africa have been mapped repeatedly using satellite imagery. These studies document a variety of different fire regimes, suggesting that there are numerous reasons for the fires and many controlling factors of burning (e.g., Malingreau *et al.*, 1990; Mbow *et al.*, 2000; Eva and Lambin, 1998a, 2000). The differences in fire regimes are often striking. In some areas the landscape is burned over by a few large fires, while in others, fires burn smaller, more fragmented patches. Remote sensing analysts observing these patterns from space suggest that the different burning regimes result from different systems of land use (Eva and Lambin, 2000; Malingreau *et al.*, 1990). In some instances two distinctly different patters of fire have been observed side by side in a single satellite image, suggesting a form of community control over burning (Malingreau *et al.*, 1990; Mbow *et al.*, 2000).

Common Reasons for Fires

The importance of fire follows not only from its pervasiveness in modifying environments, but from the extensiveness of the area affected in proportion to the human effort applied. Rural inhabitants use fire to facilitate many activities associated with daily life. It is widely applied in the tropics as a land management tool. In West Africa, people burn well-delineated plots of land, as is the case in preparing a field for agriculture, and they apply fire more liberally as a management tool by broadcasting it across the landscape to maintain or transform land cover.

The most commonly cited reasons for fires in West Africa are: burning to prepare fields for agriculture, improve pasture land by removing unpalatable stubble and initiating off-season regrowth, eliminating pests, driving game for hunting or preparing hunting grounds, providing firebreaks, and clearing paths. There are also accidental fires, fires of imprudence, and fires for protest and spectacle (e.g., Bartlett, 1955; Hough, 1993; Langaas, 1992; Mbow *et al.*, 2000). Regardless of the actual causes of the individual fires, researchers concur that nearly every fire in the region results from human activities (Cahoon *et al.*, 1992; Schmitz, 1996).[2]

It is readily apparent from research that the impact of savanna burning depends largely on three variables: the timing, the frequency, and the extent of fires. These variables have important implications for land use as well. Frequent late fires significantly retard the rate of tree regeneration on fallow lands in agricultural areas, causing farmers to expand the total area in the rotational agriculture system. Conversely, in areas where pasture is the dominant land use, a regime of frequent late burning may be necessary to prevent bush encroachment. In areas where fires are primarily set to stimulate perennial grasses to resprout for grazing, burning must be appropriately timed when grasses are just dry enough to burn, but before they are totally dry. Moreover, annual grasses do not resprout following a fire and burning in these areas damages pasture (Mbow *et al.*, 2000).

Understanding burning practices in terms of these variables is a critical input for developing fire management strategies and policies, and for determining the drivers of environmental change. The problem is that current on-the-ground social science studies document the reasons for burning using interviews and surveys, but fail to link the causes of the fires to the critical variables (e.g., Hough, 1993; Mbow *et al.*, 2000; Republic du Mali, 1991a,b). The results of many of these studies paint a picture of a complex, even chaotic system where people burn for so many reasons that it is impossible to distinguish one type of fire from another (e.g., Pyne, 1999). We do not know, for example, what percentage of the fires is due to field preparation for agriculture, pasture maintenance, or fire prevention. As such, past works have had little impact on policy-making communities. In contrast, much of the space-based study on burning emphasizes the frequency and extent of fires but fails to examine how and why fire is applied to the landscape. A central

[2]According to Komarek (1967) lightning fires were common in Africa before the arrival of humans. Humans set fires earlier in the dry season than they would occur naturally. He notes that if the human systems of burning were removed, natural fires would regularly occur.

task, therefore, is to develop linkages between the reasons for burning and the patterns of fire detectable in the imagery.

THE MALI CASE STUDY

Nowhere is savanna burning more important than in Mali where, according to the government, uncontrolled burning is causing widespread environmental degradation. The official view is that burning damages pasturelands, increases erosion, and slows the regrowth of vegetation on fallow lands, resulting in increased deforestation and desertification (Doumbia, 1991; Traoré, 1980). Each of the four governments to rule Mali over the past 50 years has instituted new policy to reduce and regulate burning, yet the burning continues.

This research seeks to inform the various debates about savanna burning and landscapes by linking local reasons and rationale for burning with fine-resolution data on the temporal and spatial patterns of burn scars in southern Mali. It combines the results of a survey, informal interviews, transect walks, and the analysis of burn scars in fine-resolution satellite imagery to determine how and why rural Malians burn their landscape. In so doing, the burning patterns found are linked to some of the processes giving rise to them, and the consequences of different kinds of fires on savanna vegetation is illuminated.

The Study Area

The study area (see Fig. 1) is located at the southern edge of the Soudan savanna belt in southern Mali.[3] It is defined by the extent of the overlap in a series of Landsat images, and covers an area of 6,720 km^2. The majority of the study area lies in Mali within the Koulikoro district. The region is characterized by a rainy season that begins in June and ends in October. The average annual rainfall varies between 1000 and 1200 mm (Nasi and Sabatier, 1988). The subsequent dry and fire season normally runs from October through May.

The vegetation in the study area is predominantly composed of a mixture of grasses, trees, and shrubs arranged in a complex mosaic of different patches. Variations in edaphic conditions on the order of 10–100 m are a primary reason for the landscape heterogeneity in the region, as is human use (Nasi and Sabatier, 1988). As in other parts of Africa, soil characteristics including depth, fertility, structure, and texture strongly influence savanna

[3]The study area is located between UTM coordinates 558000 W, 1358000 N and 653500 E, 1292000 S.

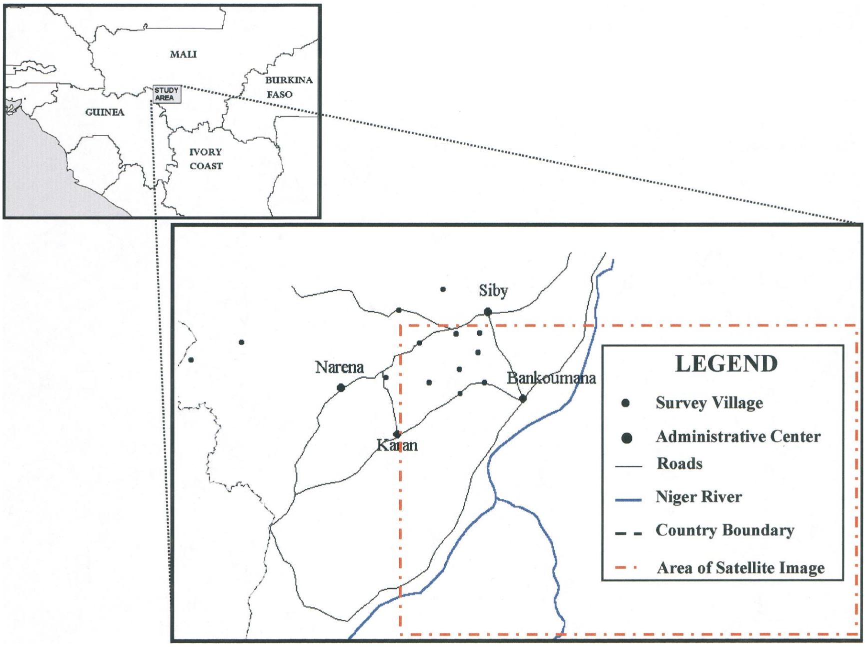


Fig. 1. The study area in Mali.

vegetation at the local scale (Cole, 1986, 1992; Keay, 1949; Koechlin, 1997; Morgan and Moss, 1965).

One particular type of soil, known locally as *bowé* in French or *fuga* in Bambara, covers considerable areas in the West African savanna–woodland including much of eastern Senegal, Mali, and western Burkina Faso. This soil on hardpan, which is often rich in gravel and usually very thin, with minimal moisture reserve, has low suitability for agriculture. Unproductive soils such as *fuga* support sparse vegetation compared with the more alluvial or clay soils in the valleys or depressions (see Fig. 2). Patches of *fuga* are often considered wastelands by the local inhabitants because their vegetation is dominated by short, annual, unpalatable grasses (principally Loudetia tongoensis, but also Andropogon pseudapricus) with only widely scattered trees (Pterocarpus lucena, Combretum micranthum, and Bombax costatum). Because of their low ability to retain moisture, vegetation on *fuga* and other gravel-dominated soil types is the first to dry out following the end of the rains.

According to a recent study by the forestry service (Eaux et Forêts) *fugas* make up 25% of the Soudanian and Guinean savanna in southern

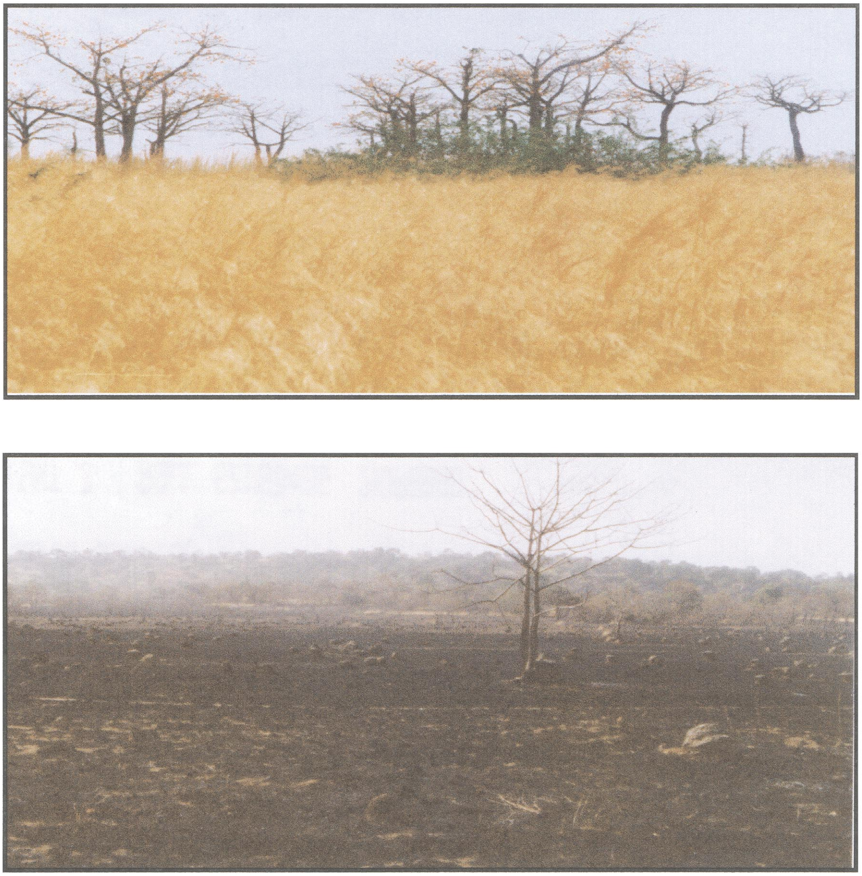


Fig. 2. Burned and unburned *fuga* landscape.

Mali, but their distribution is highly uneven (Nasi and Sabatier, 1988, p. 90). The distribution and pattern of soils has affected settlement patterns and population density in the region, because their presence and concentration dictates the percentage of the land that is deemed arable. In southern Mali this varies from less than 50% to near 80% (Konig *et al.*, 1998).

Except for the cultivated areas, a near-continuous layer of perennial grasses over 1 m in height (*Andropogon gayanus*, *Hyparrhenia dissoluta*, *Cymbopogon giganteus*, and *Schizachyrium pulchellum*) covers the more fertile soils. The predominant tree species are *Isoberlina doka*, *Pterocarpus erinaceus*, and *Lannea microcarpa*, with occasional *Parkia biblobosa* and *Vitellaria paradoxa* (Nasi and Sabatier, 1988).

The vegetation in settled areas has been significantly modified. Perennial grasses are less common (except on long fallow plots of over 15 years) and the landscape is covered by annual grasses, particularly Andropogon pseudapricus and Pennisetum pedicellatum. Characteristic tree species on fallow land include Parkia biblobosa and Vitellaria paradoxa. These species, which produce valuable seed crops, are commonly found on agricultural fields and fallow lands in park-like formations.

The study region is occupied primarily by people from the Bambara and Malinke ethnic groups who pursue an agropastoral economy, often sharing their land with Fulani herders. Since the Sahelian droughts of the 1970s a number of Fulani families have settled permanently in the area. Many others move in with their cattle in the dry season. The principal crops, which are farmed in a rotational agricultural system, are sorghum, millet, corn, peanuts, and cotton. The length of fallow cycle varies tremendously in the study area. In a few densely settled areas portions of the landscape are farmed on an annual basis, while in sparsely settled ones fallow lengths of over 50 years were documented during the fieldwork. In general while the dominant productive land use is agriculture, agricultural fields occupy only a small fraction of the landscape. According to a recent land use and cover survey, the majority of the landscape is composed of large areas in long- or short-term fallow and some noncultivated lands (Nasi and Sabatier, 1988). These areas, which are commonly managed, are prime locations for secondary activities such as animal grazing, hunting, and gathering of wild fruits, oil nuts, and honey.

The region was selected for study because it is representative of the large problems inherent in fire analysis in West Africa. The field research reported here was undertaken from August 1998 to June 1999.

METHODOLOGY

Field Data

Data for the case study in southwestern Mali were gathered from a number of sources using a variety of methods. The field data combine three sources of information: (1) interviews with key informants who identify themselves as hunters, herders, or farmers[4]; (2) a formal survey of

[4]Categories such as hunter, herder, and farmer can be misleading. For one, nearly all hunters in the study area are also farmers although a few are herders. In West Africa hunters may choose to join a regional society of hunters known as the *Donso Ton*. Members of the society will often identify themselves as hunters, but not all hunters join the society. Also, while most cultivators in the region are Bambara or Malinké, a number of settled Fulani (traditional herders) cultivate as well.

110 farmers in 14 villages; and (3) transect walks with local experts to identify and map burn scars and soil/vegetation patterns. Results from the field study were integrated with a series of eight fine-scale Landsat images, which were analyzed in a Geographic Information System (GIS) subsequent to the fieldwork.

Survey of Rural Malians

A formal survey was submitted to a random sample of 110 male farmers in 14 villages. Farmers were asked about the fire history on the lands surrounding their agricultural plots. They were also asked to characterize the predominant vegetation cover, land-use history, and the soil type of the land adjacent to their current agricultural plots. Questions were asked about lands surrounding agricultural plots because (i) agricultural plots in West Africa are typically located a couple of kilometers or more outside the village center and are widely disbursed in the landscape, and (ii) individual farmers tend to visit their plots throughout the year and have a good recollection of the timing and frequency of fires in these areas as well as the predominant soil type and vegetation cover. Additional questions focused on past and present fire prevention policies, and their consequences. Five categories of vegetation cover were included in the questionnaire: agriculture, fallow land, dense woodland, *fuga* or other gravel-dominated soil, and areas that are not farmed, such as streams and hillsides. The responses were used to create a database on what, when, why, and how vegetation burns.

Semiformal Interviews

It is sometimes difficult to calculate the exact proportion of burning that is linked to a specific cause, such as pasture maintenance or preparation of hunting grounds, because fire is often used to accomplish multiple tasks at the same time. Preventative burning around field and villages, for example, also kills pests and keeps snakes at bay. When asked about the reasons for burning, respondents may give one answer and not the other. By shifting the focus from specific to broader temporal and spatial categories of burning, the researcher can avoid this problem to some degree; therefore, I asked people to describe their *burning regime* or annual burning cycle instead of giving specific reasons for burning particular areas.

Semistructured interviews were conducted with over 30 village elders (men over 60 years in age) and a number of men who identified themselves as hunters, farmers, and herders. They were asked open-ended questions pertaining to the annual burning cycle, the reasons for burning, the history of changes in vegetation cover and land use, and their relationships to the burning cycle.

Transect Walks

I conducted 15 transect walks while accompanied by a local farmer, hunter, herder, and/or agriculture extension agent. We recorded points of change in soil type, vegetation cover (including grass species), vegetation use, and registered the areas burned. Coordinates were recorded using a Global Positioning System (GPS).

Field Study Results

Survey results find that 80% of the farmers had some portion of the lands adjacent to their fields burn annually, yet only 41% of the farmers said they were involved in setting fires. This result is not surprising since a single fire can burn the land adjacent to several farms because a near-continuous grass layer connects these areas.

The most common reasons for burning are summarized in Table I. Of those 41% who set fires, by far the most common reasons cited for burning were to protect areas from fire or to prevent later, more damaging fires (74%). People burn to protect trees, agricultural fields, orchards, and villages from later fires, as well as to prevent later fires in general. Thirteen percent of the respondents claimed they burned to separate the landscape into burned and unburned patches—a practice many people argue is done

Table I. Reasons for Burning the Savanna

Reason for burning[a]	Those who set fires (%)	Those who do not set fires (%)	All respondents (%)
Separate areas	12.8	10.5	11.5
Protect trees	25.6	0	10.4
Protect field/orchard	25.6	0	10.4
Protect village	5.1	0	2.1
Protection/prevention	17.9	17.5	17.7
Animals/pasture	15.3	5.3	9.4
Field preparation	7.7	0	3.1
Eliminate pests	2.6	17.1	1
Hunt	0	14	8
Fires of malice	0	12.3	7.3
Careless youth	0	8.8	5.2
Unknown/no reason	0	33.3	19.8
Cut wood	0	3.5	2.1

[a]Some respondents reported more than one reason for burning. The values here represent the percentage of respondents who cited a particular reason.

to prevent large fires. Fifteen percent of the people reported burning for pasture; however, many people note that early burning is done to *protect* some pasture areas from later fires.[5] When these two categories are factored in, the percentage of fires lit for preventative or protective purposes is greater than 74%.

Only a small number reported that fires lit to prepare fields for agriculture burned into the lands adjacent to their plots. In fact, most areas were already burned over by the time agricultural field preparation begins in April or May. In all, 74.4% who burned the lands surrounding their fields did so early in the dry season (by the end of the harvest).

The responses of those who did not light fires, but whose adjacent land nevertheless was regularly burned are also summarized in Table I. They differ significantly from those who did burn. In this case fewer fires were early (64%). When asked why they thought the fires had been started, one-third of the respondents said they did not know the reason for burning or they suggested burning was done for "no reason." Eighteen percent thought the fire was set for protection or prevention and another 11% believed it was to separate the landscape into burned and unburned patches. Most notably, 14% believed the fires were set for hunting purposes, although no one who lit fires gave this response. Another 12% responded that burning was done for malicious reasons.

The survey found that particular soil/vegetation forms burned at specific times in the season. Short grass savanna (grasses on *fuga* or gravel soils) burns early every year, during the first 2 months of the dry season, according to 96% of those interviewed. Results from transect walks support this finding, only areas with *fuga* or gravel soils burned during the first 2 months of the fire season (October and November). Grasses on other soil types were not dry enough to burn this early in the season. Nearly all *fuga* and gravel areas encountered during field reconnaissance were partially or completely burned. Transect walks, field reconnaissance, and interview data show that this pattern was not limited to farmed areas—even areas located great distances from villages and farms had a similar pattern of burning.

Each respondent was asked why these particular areas burn early. The two most common reasons for burning *fuga* were to separate areas to prevent later fires and to protect particular areas from fire (see Table II). Of those who claimed to have lit fires during the past year (1998), 97% said that the reason for burning short grasses is to separate areas and/or prevent later, damaging fires. *Fuga* and gravel areas are burned early to protect villages,

[5]The two types of burning related to pasture maintenance in the study area are as follows: burning to create pasture by burning off dry perennial grasses and burning to protect pasture (usually annual grasses) by burning surrounding areas. The second form is preventative burning. My survey did not distinguish between the two.

Table II. Reasons for Burning *Fuga* or Gravel Areas

Reason for burning *fuga*[a]	Those who set fires (%)	Those who do not set fires (%)	All respondents (%)
Separate areas	57.9	32.7	43
Protection/prevention	39.5	18.2	30.1
Animals/pasture	0	14.5	8.6
Hunt	0	10.9	6.5
Clear paths	2.6	9.1	6.5
Cut wood	0	1.8	1.1
Unknown/no reason	0	7.3	4.3

[a]Some respondents reported more than one reason for burning. The values here represent the percentage of respondents who cited a particular reason.

hamlets, fields, or gardens from fire, and to protect important trees and tree crops (e.g., shea nut trees) from late-season fires.

A significant difference is seen again between the responses of those who claimed to start fires and those who did not. In general, however, there is much greater agreement on the reasons people burn *fuga* and gravel areas than for all areas, 73% of the respondents said that these fires are set for preventative and/or protective purposes. Fifty-six percent of those who do not burn believe that these early fires are set for preventative and/or protective purposes. They gave additional reasons for the fires, including, to clear paths, hunt, cut wood, and for pasture.

In general, the findings support the notion that there is a regime—a regular annual pattern—of burning in the study area. According to the survey results, on the lands that burned annually, 80% of these burned at approximately the same time each year.[6] The majority of the burning was early (69%).[7] Fallow lands burned early most of the time (67%). Only densely wooded areas burned late (January or later) the majority of the time (64%).

Discussion of Survey and Interview Results

The results compare favorably with those from a survey recently undertaken by the Malian government which also finds that people believe early burning prevents fire. The government's survey of 64 villages in the Koulikoro Region found that 57% of those interviewed believe that early burning prevents more serious, later fires (Republic du Mali, 1991a, p. 3). When asked if fire were legalized, would they burn, 73% said "yes." Of these,

[6]The local agricultural calendar was used to determine the timing of fires.

[7]Note: these values concern the percentages of the number of plots of land in the survey that burned at different times of the year. The do not represent the total area burned at different times. For these values see the satellite image analysis below.

94% said they would burn for protective and/or preventative purposes, 61% to protect the village, fields, or orchards, and 33% said to protect pasture, woodlands, and to promote the fruit of important wild tree species. When asked how they would protect specific areas from fire, such as orchards, pasture or "the entire savanna," 25% answered through early burning (Republic du Mali, 1991a, p. 6). The study included the Kati district where I conducted my interviews. In this district the study found that 94% of the population would burn if burning were legal. Fifty-three percent of those surveyed suggested that legalizing early burning would be the single best way to reduce the damage from later fires (Republic du Mali, 1991b, p. 7).

As has been found in other surveys (e.g., Mbow *et al.*, 2000; Hough, 1993), people in the study area were aware of the damaging effects of fires. For example, nearly every farmer interviewed responded that late fires are more damaging to trees than earlier ones. However, people's views on the benefits of early fires were mixed. Some believed that early burning was beneficial while others thought that there was entirely too much burning, be it early or late. In general, people understood the beneficial and detrimental aspects of fire, but there was disagreement over how much fire to permit and how to prevent unwanted fires.

The list of reasons for burning for the Mali study is similar to the findings of many studies on burning (e.g., Bartlett, 1955; Hough, 1993; Langaas, 1992; Mbow *et al.*, 2000). There are notable differences, however, when the reasons for burning provided by those who actually claim to have set savanna fires are compared with the other lists. These differences strongly suggest that the actual reasons for setting fires differ from the ones perceived by the general population. Those *setting* fires claim they do it primarily for preventative or protective purposes, while those *witnessing* fires believe, perhaps wrongly, that a large number of fires are the result of carelessness, malice, or hunting activities. Since 41% of those interviewed claimed they did some savanna burning, it is probable that a high percentage of the total area burned in a given village results from fires set by village inhabitants. Yet the perceptions of the majority of people is that many fires are set by "outsiders" such as hunters, herders, careless youths, or travelers. These are all categories of fire-starters who live outside of the community. Blaming the fires on "outsiders" is one consequence of the decade-long ban on burning in Mali (see below).

Oral Accounts of Fire Regimes

During the in-depth interviews, people were asked to describe the annual burning cycle in their region. The following quotations exemplify the responses given by those interviewed.

The typical burning regime for the study area has three distinct phases, as expressed by an elder farmer:

1. Early fires

> We set these fires at the beginning of the dry season when the grasses are just dry enough to burn. This burning was done to separate areas to prevent wide burns. We burned *fuga* and *bedekun* [gravel soils].

2. Fallow fires

> The areas of *yayalen* or *bara* (*Andropogon pseudapricus* and *Pennisetum pedicellatum*) covering young fallow lands are burned around the millet harvest time [December]. This is also done to separate areas. Also, the Waga (*Andropogon gayanus*) in the fallow land will *poro-poro* (partially burn) in the fields of *yayalen*, thereby reducing the intensity of its burn. Before we would *poro-poro* some of the *lonbalen* (*Andropogon tectorum*) which was near the fallow lands. This is one reason to separate areas . . . if a fire burned *lonbalen* late it would kill trees.

3. Late fires

> At the time of field preparation [April–May], they [hunters or village leaders] would announce the time to burn. Not all areas of the savanna were burned at this time. (Bofan Elder, 1998)

A young farmer from a more sparsely populated region also suggests there are three distinct phases of burning:

> We burn *nkasa* (*Loudetia tongoensis*) grasses first since we do not farm these areas. This separates areas and only fertile valleys are left unburned. Next we burn the fallow lands with *bara* (*Pennisetum pedicellatum*) in January after the millet harvest for two reasons: first, the Shea trees will bear fruit and second, one does not want next year's agricultural fields to burn too early. When fields are ready to plant in May the remaining grasses will burn. But since areas are separated, all will not burn. (Nyumala Farmer, 1998)

When these quotations are compared with the specific reasons given for burning particular areas, it becomes apparent that burning in Mali is better conceived in terms of an annual *burning regime* rather than a series of fires set for individual purposes or land uses. In laboring to create a landscape-scale pattern of burnt and unburnt patches, the annual spatiotemporal pattern of burning is critical (see Fig. 3). The quotations demonstrate that people view early burning as a means to isolate areas that will be burned later in the season for hunting or farming. As the following quotation illustrates, there are multiple reasons for burning in this manner. The first two phases of burning are clearly important for preventing the damaging effects of later fires *as well as* eliminating pests:

> We burn the driest soils at the peanut harvest time [October–November]. Next we burn the fallow lands. This prevents worse fires later and kills snake eggs. It is also good for trees (Kongola Village health agent, 1998).

Fig. 3. Seasonal mosaic burning. Note how the background was burned early and partially, many trees were not touched by fire; however, the burn prevented a later burn (foreground) from burning the area completely.

Satellite Image Analysis

A total of eight Landsat images, six MSS and two TM, were analyzed (see Table III). Three images cover the beginning of the fire season in November, with the remaining images covering the middle of the fire season, i.e., December through mid-February. In general the rainfall levels for the sample years were slightly below average, a pattern that has typified the entire region since the late 1960s (Hulme, 2001).

Table III. Landsat Images for the Study Area

Date	Sensor	Total area burned (%)	Rainfall (mm)
12/5/72	MSS	38.9	725
1/23/74	MSS	41.3	867
11/11/75	MSS	18.1	973
11/19/82	MSS	19.1	989
12/7/82	MSS	39.9	989
1/14/86	TM	37.1	859
2/16/86	MSS	40.9	859
11/14/86	TM	17.1	766

Two aspects of postfire landscapes are responsible for the spectral characteristics of burned areas: the deposition of charcoal and ash as the direct result of burning, and the removal of photosynthetic vegetation (Robinson, 1991). The spectral difference between burned and unburned savanna vegetation is most distinct in the near- and mid-infrared, where reflectance of a burned area is low compared with the surrounding unburned vegetation (Pereira and Setzer, 1993).

The study uses both MSS and TM imagery to map burn scars, thereby maximizing the number of images studied. There are two main differences between these data: first, TM has a finer-scale (30 m) compared with MSS (80 m); and, second, TM imagery has seven bands as opposed to four in MSS imagery. The latter difference is significant because of the availability of two mid-infrared bands with TM data (bands 5 and 7) that have been shown to be particularly appropriate for distinguishing between burned and unburned vegetation (Eva and Lambin, 1998a; Koutsias and Karteris, 2000). The difference in the spatial resolution of the two data sources is less significant because nearly all savanna fires burn an area greater than a single hectare. Despite its limitations MSS data has been effectively used to map burn scars in savanna or wet–dry environments. For example, Russell-Smith *et al.* (1997b) achieved an agreement greater than 80% when they compared their burn scar maps generated from MSS imagery with ground-truth data.

Methods using satellite imagery to map burn scars can be divided into two categories: (i) those that use visual interpretation of the color prints, and (ii) those that perform spectral analysis of the digital data in a GIS. Several studies have used the visual interpretation of MSS imagery to map burn scars in savanna areas (e.g., Press, 1988; Russel-Smith *et al.*, 1997b). This method relies upon the analyst's ability to distinguish between burned and unburned pixels in a false-color composite print. Using this technique, the analyst relies upon both the spectral and spatial patterns of the burns to distinguish them from unburned areas. One drawback is that very small fires of a few pixels may go undetected.

The present study uses a methodology designed to take advantage of both the spectral and spatial patterns of burn scars. An unsupervised clustering algorithm (ISODATA) was first applied to separate pixels into groups with similar spectral signatures. All bands of data (four for MSS and seven for TM) were used in this part of the analysis. Individual clusters were then visually interpreted as burned or unburned by comparing the cluster images with the false-color images. The 4–3–2 and 5–4–3 band combinations proved most useful for distinguishing burned areas from unburned ones in the MSS and TM images, respectively.

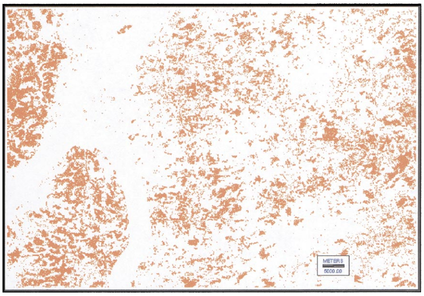
Two to five classes of burn scars were found in the images, depending upon the age and completeness of the burn. As expected there was some degree of confusion between burned areas and savanna vegetation (especially areas with darker soils and thin vegetation cover), and with water bodies and forest. In the first case, the confusion happens when the burn scars are relatively old or where vegetation was not thoroughly burned. In the second case, the mistake is due to the similar reflective properties of clear water, very dark burned surfaces, and some types of forest. To solve these problems a postclassification comparison was used to examine the spatial patterns of the clusters in relation to areas clearly identified as burn scars. Two simple rules guided the visual classification. First, partially burned areas tend to ring areas that are clearly burned. These pixels correspond to areas where fires either died out or did not completely burn through the vegetation. All clusters showing this pattern were classified as burned. Second, the most distinct forest areas in the region are riparian and have a linear pattern that is different from burn-scar patterns. The most prominent water bodies also have linear shapes. All clusters containing these patterns were not classified as burned. In addition, the annual variation in burnt area patterns is much greater that that of forest and water bodies. By comparing multiple images from different dates I was able to distinguish burned areas from unburned ones. As a final measure to avoid confusion with water bodies, the Niger River and a major tributary were masked for the analysis.

Image Analysis Results

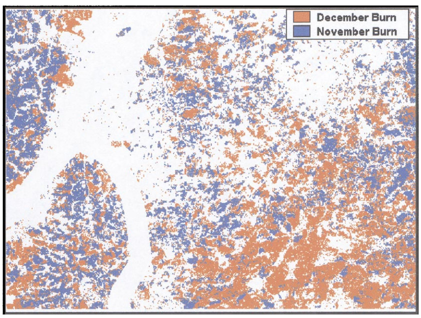
A large number of small burn scars are detected in the early months of the dry season, a smaller number of larger scars are detected later in the dry season. The total burned area was calculated for each of the images. The results of these calculations are shown in Table III. On average, by mid-November 18.1% of the total area has been burned.[8] Figure 4(a) shows the typical early burn-scar patterns for the study area. By the first week of December an average of 39.4% and by mid-January an average of 39.2% of the total area has been burnt. Figure 4(c) shows the larger, more contiguous burns that occur late in the dry season.

It is not surprising that the total accumulated burned area for December was greater than that for the later months (mid-January and mid-February). The method used underestimates the cumulative area burned by this point in the season because some of the earlier burn scars are no longer detectable, for two reasons. First, over time the soot and char is partially removed from the landscape; and second, regrowth of the savanna vegetation make earlier fire scars difficult to distinguish from unburned savanna.

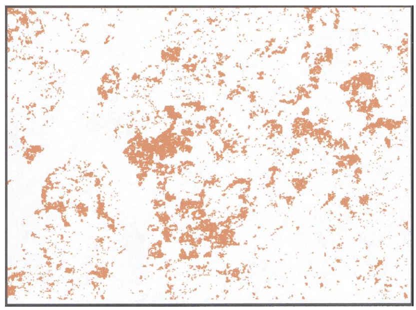
[8]This value is based on the average burned area for three dates: 1975, 1982, and 1986.



(a) Patchy burn scar patterns, the results of early burning (November 1982)



(b) Spatio-temporal pattern of fires (mid-November to mid-December 1982)



(c) Large, contiguous burn scars, the results of late-season fires (February 1986)

Fig. 4. The relationship between burn pattern and fire timing in Mali. Numerous early fires in southern Mali create a fragmented, burn-scar pattern (a). Where patchy burning is extensive, later fires are also fragmented; but in areas with little early burning, later fires burn larger, more contiguous areas (b) (note the large, later fire that occurred in the south). Late (February) fires (c) are fewer and larger than early fires.

Discussion of Image Analysis

The results of the satellite image analysis compare favorably with results from ground-based studies conducted by *Eaux et Forêts*, the Malian Forestry Service. The forest service conducted research to map fires during the 1988–1991 fire seasons in the district of Koulikoro (Republic du Mali, 1991a).[9] Over the 3-year period, the forest service study found that 76.5% of the total area burnt was burned during the month of November and 92.5% of the total burnt area was burned by the end of December. The researchers

[9]The authors warn that data collected on the ground are incomplete and the areas are only estimates. It should also be noted that the area is located immediately to the north and east of my study site.

found that half (49.4%) of all incidents of fire occurred in November and that two-thirds (66.4%) of the incidents had occurred by the end of December. These results led them to conclude that the bulk of the fires were lit early in the dry season (Republic du Mali, 1991a, p. 10).

The results also compare favorably with other studies using fine-resolution satellite imagery in the savanna of neighboring Ivory Coast. Deshler (1974) observed a large number of fire sources at the beginning of the dry season. These fires burned about 20% of the total area burned. Lamotte (1985, cited in Menault *et al.*, 1991) found that 15% to 20% of the northern Ivory Coast burned in November (compared with an average of 18.1% by mid-November for this study). By January 50–60% of the savanna had burned (compared with 39% in this study) and by February or March the burning was completed.

The results compare favorably with coarse-resolution studies as well. Dwyer *et al.* (2000) found that in Africa north of the equator, fire stretches in a band from Senegal to Ethiopia, the main burning season being from November to April with peak activity in late December and early January. Other studies using coarse-resolution (1-km) satellite imagery also find that the majority of burning in the Soudan and Guinea savanna belts in West Africa occurs relatively early in the season (Bucini and Lambin, 2002; Menault *et al.*, 1991; Nielsen and Rassmussen, 1997).

All of the satellite imagery for this study were historical and it was thus not possible to ground-truth the results to determine the accuracy of the burn-scar maps. The wide spectral range of TM data, and, in particular, the availability of two mid-infrared bands make them particularly appropriate for mapping burned areas (Eva and Lambin, 1998a). As a result TM data are often used as a proxy for field studies to ground-truth coarse-resolution burn-scar maps in Africa (Barbosa *et al.*, 1999; Eva and Lambin, 1998a,b; Scholes *et al.*, 1996).

In order to garner an indication of the accuracy of the burn-scar maps generated from MSS data, I compared a burn-scar map generated from a TM image with that from an MSS image for the same date and location. According to the analysis of the TM image 17.1% of the study area burned on November 14, 1986. Using the same method, 16% of the MSS image was classified as burned on this date. A visual comparison of these two images finds that the general pattern of burning is nearly identical. By comparing these images and the false-color composite TM image I find two noticeable differences between the two maps. First, some of the older burn scars classified as burned in the TM image were classified as unburned in the MSS image. And second, there was a spattering of isolated pixels mapped as burned in the MSS image that were not classified as burned in the TM image. The reason for the differences in the two maps can be attributed to the superior ability of the ISODATA algorithm to distinguish between partially burned pixels and "dark" vegetation types when using TM data as opposed to MSS data. At least one cluster from the MSS analysis contained a mixture of burned and unburned vegetation. Since the pattern of this cluster did not fit the criteria of a burn scar, the entire cluster was classified as unburned vegetation.

In short, the method used to map burn scars using MSS data is conservative and may slightly underestimate the amount of area burned. The overall pattern of burning, however, is well represented in the burn-scar maps generated from MSS data. Moreover, it is this general pattern of burning and not necessarily the area affected that this author deems most significant in this case.

Summary of Results: Description of the Mali Burning Regime

The most striking characteristic of the Mali fire regime is the sheer number of small patchy fires that burn each November and December. The savanna fire season begins not with great sweeps of running fire but with multiple, small, irregularly shaped burns that cover areas from a single hectare to a few square kilometers. This pattern demonstrates a major effort by local inhabitants to burn the landscape early and in a fragmented manner.

The burning regime is linked to soil and vegetation type. Fires are lit first on thin *fuga* and other gravel-dominated soils covered by short annual grasses. According to farmers, hunters, and herders, *fuga* areas are not grazed or farmed. People claim they are of little use to the community and therefore should be burned in accordance with a simple rule of thumb "grasses should be burned as soon as they are dry enough to burn."

Early fires are not controlled with firebreaks; rather rural inhabitants utilize the natural variation of the landscape. Areas of dry soil types, where vegetation is composed mostly of annual grasses, are burned at the earliest possible moment. These fires tend to be small and controlled, burning only the vegetation dry enough to ignite, and self-extinguishing when they reach an adjacent patch of moister vegetation (see Fig. 3).

Fires in December tend to fill in the gaps between the earliest fires (see Fig. 4). December fires are often set on fallow lands and burn into areas adjacent to them that were too moist to burn in November. Late December/early January signals the end of the harvest. At this time there is an immediate flurry of fire activity as farmers set fire to fallow lands and surrounding bush without fear of fire burning into and damaging agricultural fields. In areas where early burning has been extensive, these fires remain small, often extinguishing when they reach the borders of fields, denser vegetation, or previously burned areas. Satellite images of this type of burning depict a pattern of fires gradually filling in gaps, not unlike the assembling of a jigsaw puzzle. In areas without early burning, December and January fires may burn large areas of tens of square kilometers.

By mid-January or February fires tend to be larger than earlier ones except where early burning and agricultural plots significantly fragment the landscape. Data from field reconnaissance and interviews show fewer but larger fires in February–May except those for agricultural preparation (usually April and May), which only occasionally burn into the surrounding bush.

This study and others find that the burning season in the savanna-woodlands of West Africa is long, spreading out over a period of up to 8 months (Menault *et al.*, 1991). While there are specific reasons for setting fires at particular times of the year (e.g., setting agricultural fires near the end of the dry season), there is also a clear logic associated with burning the broader landscape gradually and over time. Malians are able to prevent fire from entering into certain patches at undesirable moments by beginning the dry season with an extensive effort to burn off as much of the dry and unwanted grasses as possible. By fragmenting the landscape early in the dry season, people can burn isolated patches of vegetation for more specific uses later in the season, knowing that the fire will be at least partially contained by the early burn patches. The gradual burning process also creates a variety of micro- and edge-habitats that are used by hunters, herders, and gatherers at different points during the long dry season (see Fig. 5).

DISCUSSION

Patch-Mosaic Burning: An Emerging Paradigm

> The mosaic of early burnt, late burnt, and unburnt patches created through the seasonal burning cycle also has implications for the conservation of fauna . . . and arguably, biodiversity generally. Conversely, if such systematic burning is not undertaken, the risk of an intense late dry season fire burning unchecked across the landscape is very real . . . (Russell-Smith *et al.*, 1997a, p. 180)

A recent shift in ecological thinking argues that heterogeneity rather than homogeneity in landscapes is a key source of biodiversity. According to this view disturbances such as fire, which produce spatial and temporal heterogeneity, are now recognized as important (Parr and Brockett, 1999; Turner, 1989; White and Pickett, 1985). Following this logic, an emerging ecological paradigm argues that the spatiotemporal pattern of burning affects ecosystem function and can result in different vegetation outcomes. In particular, a regime of small, fragmented or "patch-mosaic" fires, which divides the landscape into patches of burned and unburned vegetation,

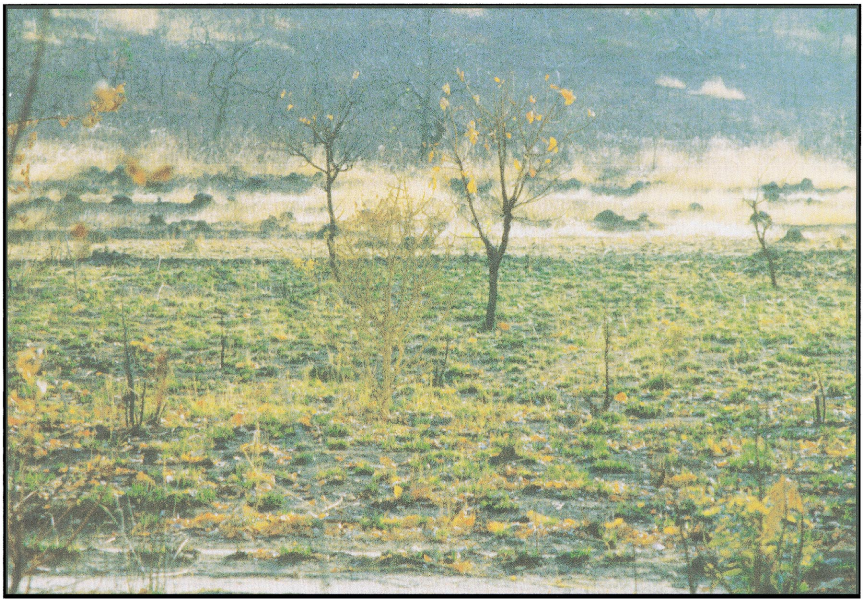


Fig. 5. "Green flush" in a *seasonal mosaic* landscape. The patch of new grass in the foreground is the outcome of two fires lit approximately a month apart. The fragments of dry grasses on the hillside are remnants from the first burn. The foreground was burned at a later date.

produces different vegetation formations than a regime of large, contiguous fires. Research shows that where indigenous peoples practiced patch-mosaic burning two ecological benefits resulted, *edges*—boundaries of ecological areas—that tended to increase ecosystem biodiversity were created, and the potential for a large, destructive, uncontrolled fire later in the season was suppressed (Boyd, 1999b; Parr and Brockett, 1999; Russell-Smith *et al.*, 1997a,b).

Theoretical and applied research in landscape ecology demonstrates that relationships between patch characteristics and arrangements, fire characteristics, and landscape dynamics are interrelated. Studies show how landscape heterogeneity strongly affects the potential of a fire to permeate a landscape (Turner and Bratton, 1987). Patch-mosaic burning, for example, creates an array of patch types that act as natural firebreaks, limiting the spread of fires (Minnich, 1983; Press, 1988). When this pattern of burning is repeated annually, the burnt areas act to "fire guard" particular vegetation patches, creating a diverse landscape where some patches burn regularly and others rarely burn. For example, when examining the impact of fire on gallery forests in savanna areas, researchers found that the timing of fires was critical for protecting forest patches. When the surrounding savanna grasses were burned before the forest fuels were sufficiently cured, the burned areas acted as a buffer zone protecting the fire-sensitive species within the gallery forest (Kellman and Meave, 1997).

It is thought that a patch-mosaic fire regime enhances biodiversity by increasing the variety of microhabitats. Data from the Australian savanna show that there is a significant correlation between mammal species richness and vegetation patchiness. Faunal studies indicate that at the landscape-scale, the ideal fire regime for the conservation of a wide range of species is one where the characteristics of the burns vary, producing a mosaic of patches (Braithwaite, 1996). This is because individual patches support different species and some species require multiple habitat types (Parr and Brockett, 1999).

A Revisionist View of Indigenous Burning

One of the striking findings of cross cultural–ecological comparisons of burning is the common use of fire to create or enhance landscape mosaics. Recent studies on the indigenous practices of wild-land burning find that a broad range of cultures in varying environments burned the landscape in a mosaic pattern (Boyd, 1999a; Lewis and Ferguson, 1988; Parr and Brockett, 1999; Russell-Smith *et al.*, 1997a). The specifics of burning regimes varied by ecoregion, but contemporary analysis finds that in each of these regions, past indigenous patterns of burning resulted in more frequent and smaller fires. Moreover, historical analysis has revealed that when the indigenous patterns of burning were removed from these environments, invariably larger conflagrations ensued (Pyne, 1990, 1997).

Native Americans and Australian Aborigines, for example, modified the “natural” fire regime by controlling the frequency, seasonality, and pattern of fire across a wide spectrum of environments (Lewis, 1982; Lewis and Ferguson, 1988). Recent studies have meticulously documented the mosaic burning practices of Aborigines in northern Australia and have shown that their annual pattern of mosaic burning reduced large, destructive fires and increased biodiversity (Russell-Smith *et al.*, 1997a,b). Denslow (1980, cited in Braithwaite, 1996) argues that the most common patch size (historically) will support the highest diversity of species. A traditional disturbance regime will produce patch sizes that have been most common. This is one reason why the documentation of the traditional burning regime of indigenous hunter–gatherers is of significance for contemporary conservation.

Braithwaite (1996) argues that the present biodiversity in the northern Australia savanna was maintained by an historic Aboriginal fire regime. It is probable that the landscape pattern produced by the traditional burning regime maximized biodiversity through maintaining habitat diversity and protecting endemic species. It was the combination of three elements—early burning, some late burning, and leaving some areas unburned—that is characteristic of the indigenous burning regime that produced the beneficial results.

The view that Aboriginal burning benefited the savanna ecosystem has recently gained acceptance among foresters and range managers. American, Australian, and South African managers are studying the indigenous practices to learn about how to manage fire and promote diversity in wet–dry environments (e.g., Haynes, 1991; Parr and Brockett, 1999; Press, 1988; Russell-Smith *et al.*, 1997a,b). Researchers are finding that early burning is critical because early fires are usually patchy and small in extent, fires increase in size and intensity as grasses cure with the progression of the season. If the burning season begins with small fires the result is a mosaic landscape, with patches of differing composition and structure. Conversely, if the fire season begins late, the ensuing high intensity fires result in a more homogeneous landscape.

The detailed accounts of indigenous Australian burning practices have clear policy implications, which have resulted in new programs to establish early burning regimes using modern techniques of fire ignition. According to the authors of a recent empirical study, which found a significant negative correlation between the amount of early dry season burning and the amount of late dry season burning, "The purpose of this program is to reestablish as far as possible the patterns of traditional Aboriginal burning; to reduce the frequency and extent of late dry season wildfire and to create diversity of habitat" (Press, 1988, p. 174).

Comparison with Documented Cases of Patch-Mosaic Burning

The revisionist view of burning has resulted in land managers in the savannas of Australia and South Africa proposing to reintroduce patch-mosaic fire regimes (Parr and Brockett, 1999; Press, 1988). Fire policy and research in West Africa, however, have ignored this literature and its implications. The predominant view of burning in West Africa continues to hold that there is too much burning and that indigenous burning practices are damaging and should be curtailed. By comparing the Mali burning regime with those from other wooded savanna environments I argue here that they share a marked similarity and thus it is probable that the Mali burning regime has similar ecological benefits. As such, policies regulating indigenous practices of burning need to be rethought.

The Malian practice of burning grasses as "soon as they are dry enough to burn" is identical to that used by the Native Americans near Yosemite in California:

> In the Spring . . . the old squaws began to look for the little dry spots of headland or sunny valley, *and as fast as dry spots appeared they would be burned*. In this way fire was always the servant, never the master . . . By this means, the Indians always kept their forest open, pure and fruitful, and conflagrations were unknown. (Miller, 1887, cited in Biswell, 1989. Emphasis added)

The Malian burning regime closely resembles the northern Australian pattern documented by Lewis (1989), and later by Russell-Smith *et al.* (1997a,b). According to the latter authors, in the Australian system burning was used as a seasonal management tool. In broad terms, burning commenced in the early dry season and was applied systematically and purposefully over the landscape:

> The pattern of burning was relatively small, typically low intensity fires being set into vegetation as soon as it was cured sufficiently, was employed progressively and systematically over the full extent of the dry season . . . Throughout this region, burning was/is undertaken mostly in the early-mid dry season principally in order to *clean* the country (including the preparation of strategic firebreaks for later in the season), for hunting, and for a range of other secular and nonsecular purposes. (Russell-Smith *et al.*, 1997a, pp. 175, 176)

In particular, the use of *early* fire described by Lewis (1989) exactly parallels my observations in Mali. As in Mali, the spread of late season fires "is limited by the already existing mosaic of burnt and unburt areas," such that many areas are "fire-guarded" from late fires (Lewis, 1989, p. 949). Indeed, just as Malians argued in the 1980s, Aborigines argue that the reason there are too many damaging late season fires today is that there is too little early burning because of forestry policy (Lewis, 1989).

Policy Implications

Controlling the impacts of fires on natural resources is a critical issue for forestry departments in numerous African savanna countries. Forest services often allocate scarce resources to cut and maintain firebreaks around national forest lands to protect them from fire damage. In the case of wooded areas on village lands, which make up the majority of the woodlands in most African countries, forest services are most often involved in regulating fire use rather than cutting or maintaining firebreaks. In Mali, Guinea, and Burkina Faso, for example, the forest services have implemented policies aimed at reducing the extent of the area burned by restricting the period when burning may be done or by banning the practice entirely (Brinkerhoff, 1995; Fairhead and Leach, 1995; Schmitz, 1996).

These anti-fire policies have tended to emphasize the negative aspects of burning while ignoring the beneficial ones (Benjaminsen, 2000; Fairhead and Leach, 1995; Schmitz, 1996). A critical problem with fire prevention efforts in West Africa is that the antifire policies have been initiated without thorough consideration of indigenous burning practices. In particular there has been little systematic research to link the reasons for burning with the observed fire patterns. As a consequence, fire policies fail to distinguish between uncontrolled burning, burning for productive land-use, and burning for fire prevention.

Indigenous practices of preventative burning have received little attention in the literature or in policy-making circles. Rural Malians, however, view preventative burning critical to effective fire management. By restricting burning through blanket policies, such as the *Campaign Against Fire* initiated in Mali in 1980 (Traoré, 1980), fire policy can inhibit indigenous fire prevention efforts, resulting in an increase in damages caused by fire. Interviews gathered during this field study suggest that fires were worse during the period of the antifire campaign than before, largely because the indigenous preventative burning practices were curtailed without having been replaced with a reasonable alternative.

History has shown that when faced with the threat of fines and punishment, burning becomes less overt and organized and more covert and chaotic (Pyne, 1982, 1990, 1997). The findings from this study suggest that during the antifire campaign burning became a more covert activity. As this happened it is probable that the perceptions of the portion of the population that was not actively involved in setting fires changed. As the survey results show, those who set fires and those who don't have very different views on the reasons for the fires.

The conflicting perceptions can be attributed to the government's intensive, and often ruthless, campaign to prohibit all fires. During the antifire campaign burning was considered a crime against the state and fire starters were villainized. The forest service dramatically stepped up policing efforts in rural areas. Agents made frequent visits to villages to demand payments of fines for fires that had occurred on village lands (Steiber and du Saussay, 1987). The fines for these fires were often exorbitant, roughly equivalent to the annual per capita income in Mali (Benjaminsen, 2000). In addition, the government sponsored a radio campaign to promote the benefits of fire prevention, which highlighted the damaging effects of fire and argued that burning was causing desertification. To defend themselves, villagers blamed "outsiders"—travelers, hunters, and seminomadic herders—for the fires, many of which were actually set for preventative purposes by villagers themselves.

In the long-term, the government's campaign against fire has resulted not only in conflicting perceptions of fire, but in changes in ideas about fire. The government of Mali recently began devolving control of village woodlands from the forest service to the village level. Villages are now responsible for establishing and enforcing their own rules and practices of environmental management, within the guideline, of the forestry service (Ribot, 1995, 1996). The timing of this field-study overlapped with some of the first efforts of village-level fire regulation. It was evident that as villages began to develop their own formal fire management strategies a debate arose in some instances over the role of early burning, in particular whether some areas should be entirely off-limits to all burning. I documented one instance where a group of villages attempted to institute a ban on burning in a large adjoining area. In this instance, just as with the national-level ban during the 1980s, the community-level effort failed to prevent a fire from sweeping through the area in spite of the village leaders' numerous announcements that the area was off-limits to burning.[10]

CONCLUSIONS

One of the primary functions of fire in West Africa—to fragment the landscape in order to prevent damaging fires while simultaneously rendering it useful for numerous productive activities—has been frequently overlooked by much research and policy. In spite of the recent antifire policy, this study finds that the dominant pattern of burning in southern Mali remains a fragmented, seasonal mosaic, burning regime. While this regime is not directly associated with agriculture or grazing, the two dominant land-uses in West Africa, seasonal mosaic burning may benefit these activities indirectly. This suggests that researchers studying the causes of fires should look beyond linking specific fire patterns with different land-uses and instead focus their efforts on understanding the logic of burning in terms of a seasonal regime that extends the length of the dry season.

The findings of this study and others (Hough, 1993; Mbow *et al.*, 2000) show that people have good knowledge of the beneficial and damaging

[10]The only case where villages have consistently been able to prevent all fire has been in the floodplains. These are seasonal wetlands that are highly valued as dry season grazing areas. I believe that efforts to eliminate fires from these areas were successful for five reasons: (i) the areas were small and clearly defined; (ii) people understood the reason for the ban (to provide grazing areas in the dry season), they were aware of the fine for burning, and most agreed that the law was necessary to protect a valued resource; (iii) the areas were located near the villages and regularly "policed" by the community; (iv) those who violated the rules were fined; and (v) the grasses in these areas remained moist long after fires had burned the surrounding grasses. By the time the wetland grasses were dry they had been heavily trampled and grazed.

effects of different types of fires (e.g., early verses late fire). However, the Mali study finds people's knowledge of the reasons for burning differ, depending upon whether they set fire to the savanna grasses or not. The implications are that past studies on the reasons for burning have been based on people's *perceptions* of the causes of fires and not necessarily on the views of those who actually light fires. The results of the Mali study suggest that these are not the same, thus past studies on the causes of fires contain a bias. If Mali is representative of the broader region, it is probable that fewer fires in West Africa are the result of accidents, carelessness, and disobedience than previously believed, and much more burning is done for preventative purposes.

Schmitz (1996) argues that in some cases the campaigns to ban fires in West Africa were so oppressive that they resulted in a cultural change whereby a tradition of late fire was introduced into certain societies. While few countries had more severe penalties against burning than Mali, my study results led me to be more optimistic about the future of fire management. One of the findings of this study is that where late burning is a problem, it derives more from a reduction in early burning than from an increase in late burning activities. The results of this study and others (Republic du Mali, 1991a,b) indicate that people in Mali clearly want to halt destructive late-season fires. Ironically one of the legacies of the campaign against fire is that people have a much clearer understanding of the dangers of late fires since many people witnessed them on a large-scale for the first time during this period.

Fire is a unique determinant of environmental change because the actions of a very few hold the potential to alter the resources of many. The implication in terms of fire policy is that general bans on burning are detrimental. Contrary to arguments put forth by those setting policy, who often seek to prevent all fires, some burning is critical for fire prevention. Fire in savanna environments is inevitable. The rural inhabitants of Mali have long understood this and have set about burning their environment accordingly.

It remains to be seen how the differing perceptions of villagers concerning the causes of fires elaborated above will play out in the current context of decentralized natural resource management in Mali. If local-level natural resource management is to be successful the forest service must shift from its traditional role as a police force to that of a consensus builder. This change will require increased effort on the part of rural forestry agents to comprehend the strengths and weaknesses of indigenous practices of burning and to understand the reasons for the sometimes competing desires of local populations. The goal of the forest service should be to aid villages (and clusters of them since fire does not stop at village boundaries) to reach consensus about how they wish to manage fire. Where local populations agree a fire problem exists, the forest service should work with the existing local institutions to develop and test alternative strategies of fire management. Policing and the adjudication of offenders should be left in the hands of villages.

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