Research Article

Unauthorized Firesetting as Socioecological Disturbance: A Spatiotemporal Analysis of Incendiary Wildfires in Georgia, USA, 1987–2010

Michael R. Coughlan

Department of Anthropology, University of Georgia
250A Baldwin Hall, Jackson Street, Athens, Georgia 30602-1619, USA
Tel.: 001-706-542-6160; e-mail: coughlan@uga.edu

ABSTRACT

I analyzed the spatiotemporal patterning of intentional, unauthorized landscape fires in the state of Georgia, USA, for the years 1987 through 2010 with the aim of delineating socioecological constraints on and firesetter preferences for the timing and placement of ignitions. Unauthorized fires represent complex phenomena through which actors compete over social and ecological outcomes that transcend the spatiotemporal confines of individual fires themselves. Current classificatory systems define unauthorized firesetting behavior as irrational, destructive, and malicious. Because landscape fires cause both positive and negative consequences for biological diversity and ecosystems services, perceived costs and benefits of fires are contestable and relative to point of view. The locational and temporal patterns of unauthorized landscape fires examined in this study do not show firesetter preferences for maximizing damage to landscapes. Instead, unauthorized fires in Georgia potentially contribute to the maintenance of landscapes adapted to frequent, dormant- and early growing-season fire regimes.

RESUMEN

En este trabajo analicé el patrón espacio-temporal de incendios intencionales y no autorizados en el estado de Georgia, EUA, entre 1987 y 2010, con el objetivo de delinear los condicionamientos socio-ecológicos sobre las preferencias del incendiario en cuanto al tiempo y lugar de las igniciones. Los incendios no autorizados representan fenómenos complejos a través de los cuales los autores compiten por resultados sociales y ecológicos que trascienden los confines espaciotemporales de cada incendio individual. Los sistemas de clasificación corrientes definen al comportamiento de los incendiarios como irracional, destructivo y malicioso. Dado que los incendios tienen consecuencias positivas y negativas para la diversidad biológica y los servicios ecosistémicos a nivel de paisaje, sus costos y beneficios son debatibles y dependen de los puntos de vista con que se analicen. La ubicación espacial y temporal de los incendios no autorizados examinados en este estudio no muestran preferencias del o la incendiaria por maximizar daños en el ecosistema afectado. Al contrario, los incendios no autorizados en Georgia pueden contribuir potencialmente al mantenimiento de paisajes adaptados a regímenes de fuego frecuentes que ocurren durante la dormancia o al inicio de la estación de crecimiento.

Keywords: Georgia, incendiary fire, socioecological disturbance, spatiotemporal analysis, unauthorized fire, USA, wildfire regimes

Citation: Coughlan, M.R. 2013. Unauthorized firesetting as socioecological disturbance: a spatiotemporal analysis of incendiary wildfires in Georgia, USA, 1987–2010. Fire Ecology 9(3): 45–63. doi: 10.4996/fireecology.0903045

INTRODUCTION

This paper examines of the spatiotemporal patterns of unauthorized firesetting in Georgia, USA, using wildfire data compiled by the Georgia Forestry Commission (GFC) for the years 1987 through 2010. Unauthorized landscape fires are intentionally set without the knowledge or authorization of a landowner or without a state issued permit. In the state of Georgia, as in much of the United States, unauthorized fires are officially classified as "incendiary wildfire," a type of arson subject to legal prosecution as a criminal felony. While the legality of the fire is encoded in the term "incendiary," causality with respect to human decision making remains ambiguous. Indeed, beyond anecdotal evidence, the destructive intent or general malfeasance of unauthorized firesetting remains unsubstantiated in either social or ecological research. I explored 24 years of unauthorized firesetting in Georgia with the objective of characterizing the phenomenon as a socioecological disturbance. Because unauthorized fires are caused by individuals whose firesetting success is tied to conditions at the specific time and place of ignition, the range of spatiotemporal variability of such fires may be understood as the range of conditions that enable "successful" firesetting. From a socioecological perspective (Coughlan and Petty 2012), ignitions, as intentional acts, represent the outcome of firesetter decision processes. Consequently, spatiotemporal patterns of unauthorized fire provide information about the social and ecological preferences and constraints for unauthorized firesetting.

Few studies have attempted to analyze spatiotemporal characteristics of anthropogenic fire regimes in the southeastern United States. Notable exceptions (Lafon *et al*. 2005, Maingi and Henry 2007, Dixon *et al*. 2008, Grala and Cooke 2010) do not consider the implications that particular anthropogenic fire regimes have for understanding the role of human behaviors with respect to socioecological interaction. In fact, fire ecology studies of anthropogenic regimes often attribute fire location, frequency, and timing to climate-vegetation interaction, with little consideration of the role human cognition and agency plays in determining the fire regime (Coughlan and Petty 2012). Researchers have had good reasons for excluding human behavioral factors from their studies since explicit evidence is lacking with regard to unauthorized firesetters' decision-making processes due to the illegality of the activity and the small percentage of criminal convictions (Prestemon and Butry 2008).

By default, scholars have assumed that unauthorized fires are set with the intention of spread, but without any measures of control for size or severity of the resulting fire. This assumption characterizes the behavior as reckless, ecologically destructive, and sociopathic. However, if firesetters wish to achieve particular social or biophysical goals with the use of fire, malicious or otherwise, the decision of when and where to start a fire implies considerable knowledge of ecological cause and effect (Lewis 1978). For example, fuel moisture, which varies considerably through time and space, presents a significant factor controlling fire spread and severity (Anderson 1982, Rothermel 1983). As a consequence, the most efficient way for humans to control fire concerns the manipulation of the timing and placement of ignitions (Granstrom and Niklasson 2008). Thus, if each ignition represents the outcome of a specific decision to burn at a particular time and place, spatiotemporal ignition patterns indicate firesetter preferences for conditions conducive to desired fire intensity, spread, containment, and biophysical effects on the landscape. Where ignitions are more arbitrary with respect to spatiotemporal patterning, firesetters may lack either sufficient ecological understanding or interest in the biophysical consequences of fire. The identification of spatiotemporal ignition patterns can provide more nuanced understandings of unauthorized fires and can help to clarify the actual social and ecological dynamics associated with this type of disturbance.

Historical Context and Previous Research

Human use of fire in North America likely dates to the settlement of the continent by Native Americans (Fowler and Konopik 2007). The long term influences of Native American fire use is considered by some to have been significant in southern temperate forests (Abrams 1992; Cowell 1995, 1998; Delcourt and Delcourt 1998; Abrams and Copenheaver 1999; Guyette *et al*. 2002; Black *et al*. 2006; Guyette *et al*. 2006; Foster and Cohen 2007). Landscape fire use was also common in traditional Euro-American land management practice in the southeastern United States (Shea 1939*a*; Stoddard 1962; Pyne 1982; Otto 1983, 1984, 1986). Shifts in land use and tenure in the Southeast (Eller 1982), as well as the ascendancy of a forestry science inimical to fire (Pyne 1982), led to the criminalization of landscape fire use in the first half of the twentieth century and the widespread emergence of clandestine burning practices (Kaufman 1939*a*, Kuhlken 1999, Jurgelski 2008). Although the ecological and economic benefits of fire use in southern forests were recognized relatively early in the history of scientific forest management (Green 1931; Chapman 1932*a*, *b*; Demmon 1935; Hardtner 1935; Stoddard 1935; Wahlenberg 1935; Garren 1943), the popular acceptance of fire as a legitimate forest management tool has only occurred over the last few decades. Prescribed fires are today legal, provided one follows the law, yet unauthorized firesetting persists.

A handful of social science studies in the mid-twentieth century addressed unauthorized fire setting in the South. While some researchers concluded that firesetters were primarily agents of destruction and ecological harm (Shea 1939*a*, *b*, 1940*a*, *b*; Bertrand and Baird 1975), others emphasized the fact that firesetting was rooted in local knowledge and represented normative behavior (Kaufman 1939*a*, *b*; Hansbrough 1963; Dunkelberger and Altobellis 1975; Doolittle and Lightsey 1979). More recent research on unauthorized fire in Florida suggests that the southern incendiary phenomena fits an "economic model of crime" (Butry and Prestemon 2005, Prestemon and Butry 2005) and therefore may have shifted from a normative behavior to a more malign practice over the last 30 years (Prestemon and Butry 2008). Kuhlken (1999) posits that "rural incendiarism" in the southern United States represents a form of political protest rather than conventional violent crime. Building on Scott's notion of fire as a "weapon of the weak" (Scott 1985), political motivations for unauthorized fires have been suggested elsewhere as well (Pyne 1998, Kull 2002, Seijo 2005, Lovreglio *et al*. 2010). Motives for setting unauthorized fires are numerous (Prestemon and Butry 2008); however, few studies have attempted to parse these from the aggregated incendiary category. Lovreglio *et al*. (2010) identified three categories for intentional unauthorized fire in southern Italy: profit seeking, protest, and resentment towards forests, but analysis relied on the opinions of officials directly involved in fire prevention and control rather than the characteristics of the incidents themselves.

In the majority of analyses of unauthorized firesetting, these fires are assumed to be inherently destructive and individuals setting unauthorized fires are assumed to have malevolent, if politically rational, motivations. This perception persists despite the fact that most land managers now recognize fire as an important ecological disturbance and a useful forest management tool. In part, such dissonance is explained by a widely held assumption that wildfires, as opposed to prescribed fires, negatively affect timber quality and yield over the long term (Maingi and Henry 2007, Grala and Cooke 2010). Although timber quality may be impacted by fire, most wildfires in the southern United States are of low intensity and do not actually kill many trees (Maingi and Henry 2007). Ecological and economic outcomes of landscape fires are highly variable and perception of fire disturbance and its effects depends upon the relative interests of those affected by it. As Kull (2002, 2004) points out for Madagascar, landscape fire is an ambiguous phenomenon and people use this ambiguity to accomplish a variety of nuanced political and ecological goals. Nonetheless, unauthorized wildfire remains predominantly associated with the notion of forest destruction and firesetters are presumed to be ecologically unaware actors.

Spatiotemporal Analysis and Firesetter Preferences

Reported unauthorized fires are systematically suppressed by wildland fire fighters, so outcomes intended by the firesetters cannot be ascertained. For example, it is impossible to know if fire size and duration results from ignition timing and placement or from suppression activities. Further, the identity, size, and distribution of the population of firesetters remain unknown. Firesetter preferences for fire severity cannot be ascertained from the firesetters themselves. Consequently, it is difficult to characterize the type and nature of unauthorized fire as a socioecological disturbance regime, specifically in terms of its social and ecological drivers and effects. However, it may be possible to infer firesetter preferences from the spatiotemporal information of the fires themselves.

The primary assumption underlying this analysis concerns the supposition that firesetters have agency and are goal seeking: they intentionally choose the timing and place of their ignitions from an array of options and possibilities in order to achieve particular goals. A secondary assumption concerns the idea that preferences for and constraints on firesetting form a reciprocal relationship in which, given sufficient knowledge, firesetters will show a preference for optimal conditions for setting fires. Thus, as biophysical and social constraints on ignition become stronger, there will be fewer ignitions. As constraints on ignition become weaker and conditions become more optimal, ignition frequency will increase. The criteria for optimal conditions vary by both region and the specific goals of the firesetter. The intentionality inherent in unauthorized fires thus allows for the extrapolation of preferences from constraints through a definition of the spatiotemporal distribution of ignitions.

Given these assumptions, what do the spatiotemporal patterns of unauthorized fires suggest about the severity of the emergent fire regime? Do spatiotemporal patterns of unauthorized fire reflect firesetter preferences for producing high severity fires capable of maximizing social and ecological costs through damage to landscapes? Alternatively, are the spatiotemporal patterns of unauthorized fires arbitrary with respect to potential fire effects? Lastly, have these patterns changed over the 1987–2010 period?

METHODS

Wildfire Data

The GFC provided spatially explicit, tabular wildfire data encompassing the entire state of Georgia for the years 1987 through 2010. These data represent over 40 000 reported unauthorized wildfires, verified and controlled by wildland fire response crews. The data were organized chronologically by individual fire incidents and include a variety of information including fire location, times and dates, land ownership, relevant fire weather parameters, fuel type, area burned, and administrative units such as county and state forest district. The GFC also provided prescribed fire data for years 1996–2008. This data was organized by county but lacked a more precise spatial reference.

Fire Locations and Spatial Distribution

I used a geographic information system (GIS) to create shapefiles for spatial analysis of the wildfire data. Georgia is a large state spanning a number of distinct biogeographic zones ranging from coastal estuaries to the Appalachian Mountains. The state is also fairly heterogeneous with respect to settlement patterns and land use. Regional socioecological analysis therefore required limiting and dividing the data by both physiological and sociopolitical factors. Although county size and shape is variable in Georgia, the large number of counties combined with the tendency for county borders to follow natural breaks in the landscape such as rivers and ridgelines suggest that the county level is a more appropriately scaled resolution for assessing regional fire regimes than the aggregate state level. Counties also provide a convenient sociopolitical scale of analysis since historical differences in county level planning and zoning ordinances translate to differences in land use and ownership patterns. I used a county-based shapefile to display fires on a county by county basis by totaling the number of fires per county and dividing this number by the county size. I identified contiguous counties with fire densities greater than the first standard deviation above the mean in order to delineate areas where unauthorized fire activity is more common. Below, I refer to the three resulting groups of contiguous counties as a regional locus (RL) of unauthorized fire activity.

I created a GIS point layer geolocating unauthorized fire incidents based on reported coordinates. From January 1987 through June 2002, fire coordinates were reported at a 1 arc-minute resolution (approximately 1855 m) while data for the period from July 2002 to December 2010 were reported at a 1 m resolution. It should be noted, however, that although the higher resolution points were assigned unique locations at a 1 m resolution, accuracy and consistency with respect to data collection methods, spatial precision, and representation remain uncertain. Therefore, fire points could represent the point of ignition, the center point of the burned area, or some other feature.

I used ArcGIS Spatial Analyst (ESRI, Redlands, California, USA.) for a kernel density analysis of the high resolution (1 m^2) incendiary fire points (July 2002 through December 2010). I excluded lower resolution fire points from the kernel density analysis since the mapping process assigned multiple fires to each arc-minute vector, masking the actual distribution of fires below that resolution. The kernel density analysis uses a kernel function to measure the magnitude per unit area (in this case, 2000 m^2) of specified points. The first standard deviation above the mean distance to a point's nearest neighbor (2998.9 m) provided the bandwidth or search radius. I did not utilize the population field since each point represented one fire occurrence. I defined high density concentrations of unauthorized fires as areas where the kernel density value was higher than the second standard deviation above the mean.

To account for spatial distributions of the remaining data points (1987 through June 2002), I created a vector-based grid with 2 km^2 quadrats for the entire state. The 2 km^2 ensured that the quadrat was the approximate resolution of the data points themselves and also represented the unit area used in the kernel density analysis. I then used the "count points in polygon" function to find the number of fire points (1987–2010) per quadrat. I identified quadrats where density levels were higher than the second standard deviation from the mean point density. In order to create sampling units for areas with a "high density" of unauthorized fires (HD units), I merged the high density areas from the kernel density analysis with the high density quadrats. This process retained the spatial resolutions of the original data sets.

Land Cover and Fuel Characteristics

For land cover determination of fire points, I used a 30 m resolution 1998 Landsat raster data set with 18 classified land cover types (Natural Resource Spatial Analysis Laboratory 1998). Accurate land cover classification presented some difficulty since: (1) the land cover data itself was only 85% accurate, (2) the point-located fires were limited to the years 2002–2010, and (3) the land cover attributes at each point-located fire represented only the land cover pixel where the fire was point-located and not necessarily the land cover of ignition or area burned. Therefore, I cross checked land cover classifications extracted from the raster dataset by fire point locations with the fuel type category and percentages of open, planted, or natural cover burned included in the original wildfire data in order to ascertain the relative congruence between the reported information and the remotely sensed land cover. Due to the relative incompatibility between reported fuel type and land cover categories, accuracy of the analysis varied between 75% and 88% for the "evergreen forest" land cover type, depending on which fuel types were considered typical of the evergreen forest land cover.

Fire Timing and Temporal Distribution

Seasonality. In order to compare differences in seasonality of incendiary fires, I took sub-samples of fire incidents based on location with reference to the RL and HD sampling units and further divided these data by land cover and ownership. I identified fire seasons by peaks in the number of unauthorized fires set where the number of fires per month exceeded the monthly average. I then evaluated the inter-annual variability in the ratio of number of fires to area burned through a linear regression of the total number of fires (independent variable) and total burned area (dependent variable) per fire season by year. So, for example, if a particular sample unit's peak fire season were composed of the months February and March, I summed the number of fires for those two months for each year and tested these data against the total February-March burned area for the corresponding year. The strength and significance of correlations between number of fires and area burned per season can be interpreted as a measure of the spatiotemporal regularity of the emergent fire season across years.

Fuel moisture. I used the Palmer drought severity index (PDSI) as a proxy for fuel moisture conditions at the monthly and seasonal scale as these data provide an index of available moisture relative to historical conditions. Monthly PDSI data were downloaded from the National Climatic Data Center (National Oceanic and Atmospheric Administration 2010) for all Georgia climate divisions for the years 1987–2010. The PDSI uses a combination of precipitation, evapotranspiration, and soil moisture data to develop a standardized water balance model (Alley 1984). For higher resolution analysis, I used the Keetch-Byram drought index (KBDI), which references daily estimated soil and ground cover moistures at a local level and is commonly used in fire management in the US Southeast (Keetch and Byram 1968, Roncoli *et al*. 2006). In order to assess the relationship between relative moisture availability and unauthorized firesetting for each sample unit, I modeled the linear regressions between (1) monthly PDSI and the number of unauthorized fires per month by year and, (2) daily KBDI normalized by fire season specific distributions and the frequency of fire occurrence for each score. Lastly, I examined changes in the relationship between KBDI and unauthorized fire using a 4 yr moving window for the distribution of KBDI values for fires occurring during peak fire season.

RESULTS

Statewide

Between 1987 and 2010, unauthorized fires represented 21 % of total wildfires and 27 % area burned statewide. As an overall trend, the number of unauthorized fires has decreased: the moving 3 yr average of number of unauthorized fires per year dropped 72 % over the period studied. For the same period, the average fire size shows a 12 % increase, from 2.22 ha to 2.53 ha.

On a statewide level, unauthorized fires followed a fairly pronounced seasonal pattern with a peak from February through April with 44 % of fires and 54 % of area burned for the total 24 yr period occurring during those months. The pattern mirrors prescribed fires and, on a month-by-month basis, the number of incendiary fires correlated relatively well with the number of prescribed fires (correlation coefficient of 47.3, $P < 0.001$, for the years 1996–2008). By contrast, lightning fires peak in the months of June, July, and August, when both incendiary and prescribed fires are few (Figure 1). Aggregated, the seasonality of ignitions in HD clusters across the state did not differ significantly from the total statewide pattern. However, land ownership patterns did differ with ignitions on forest industry owned land doubling in HD clusters (Figure 2).

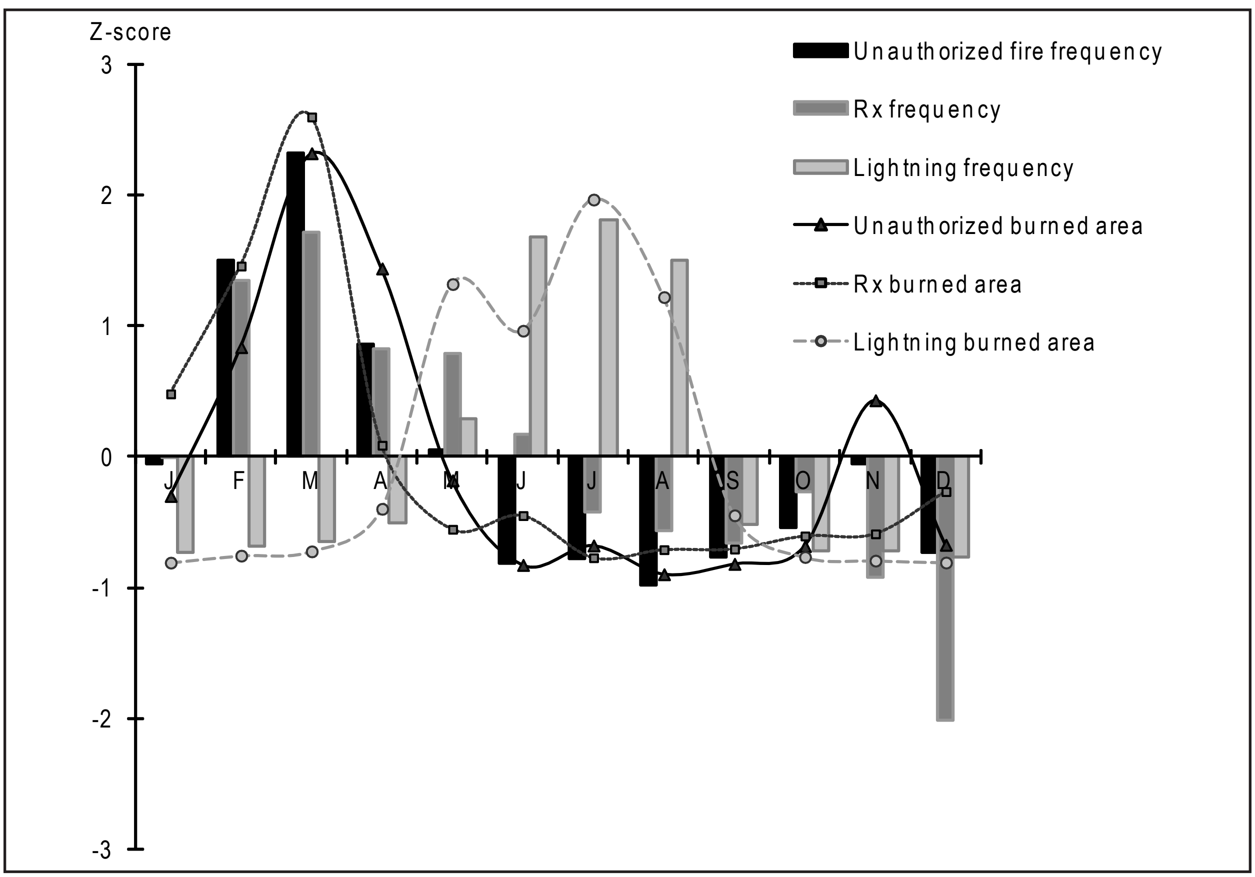

Figure 1. Z-Score values for the aggregated monthly fire frequency and area burned for unauthorized fires, prescribed (Rx) fires, and lightning-caused fires in the state of Georgia for the period 1987 to 2010.

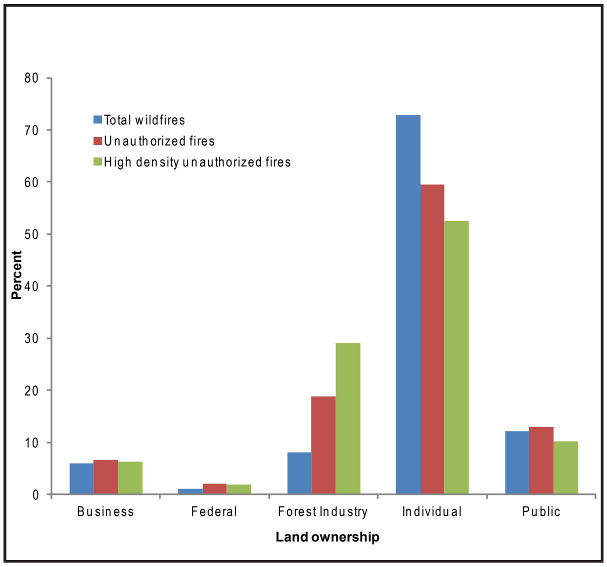

Figure 2. Percentages of all wildfires, unauthorized fires, and unauthorized fires located within high density clusters categorized by land stewardship.

Analysis of Regional Loci

I identified three regional loci of unauthorized fire activity: RL1, in the ridge and valley physiographic province; RL2, along the "fall line" between the coastal plain and Piedmont physiographic province; and RL3, on the coastal plain. Most of the HD clusters were located within the RL (Figure 3).

RL1, ridge and valley. RL1 sits in the ridge and valley physiographic province located in northwestern Georgia. The landscape is characterized by southwest-northeast trending ridges with farms and developed space occupying the valley bottoms and forest cover dominating the ridge tops. Land cover is dominated by the southeastern ridge and valley hardwood forest type composed of oak (*Quercus* spp.), hickory (*Carya* spp.), and pine (*Pinus* spp.). Frequency and intensity of fire disturbance is an important factor controlling the relative proportion of deciduous to evergreen trees (Christensen 2000). Other common land cover types include pine forest and plantation, row crop, and pasture, as well as succession vegetation types. Pine plantations are less common than in the rest of Georgia, but nonetheless comprise a considerable portion of the landscape.

Between 1987 and 2010, RL1 contained 23% (n = 9330) of Georgia's incendiary fires and 34% of its burned area. For the spatially explicit data (July 2002 through 2010), the largest percentage of incendiary fires in northwest Georgia corresponded with ignition points classified as hardwood forest (28%), followed by evergreen forest (22%), pasture (16%), transportation corridors (12 %), clear cut (11%), mixed forest (6%), and nine other land cover types making up the remaining 5%. Aggregated ignitions from all land cover types in RL1 displayed modest similarity to the statewide seasonal pattern, but with a sharper peak in March and steeper decline through April. Differences do exist between the three most frequently burned land covers and the overall seasonal distribution. For example, a secondary peak for pasture land cover occurs in August whereas evergreen land cover shows a secondary peak spanning October and November.

RL2, fall line. RL2 consists of Richmond County, located just below the "fall line," which divides the Georgia Piedmont from the coastal plain. Developed land comprises a large portion of the county with the city of Augusta at its center. Farmland interspersed with pine plantations characterizes much of the southern portion of the county. Natural land cover is dominated by longleaf pine forest (*Pinus palustris* Mill), much of it with an open understory well adapted to low intensity surface fire (Moser and Wade 2005).

Between 1987 and 2010, just under 1.3% of Georgia's unauthorized fires occurred in Richmond County (n = 550). These fires concentrated around the city of Augusta and burned approximately 0.6% of the state's total area burned by unauthorized fire. For the period from July 2002 through December 2010,

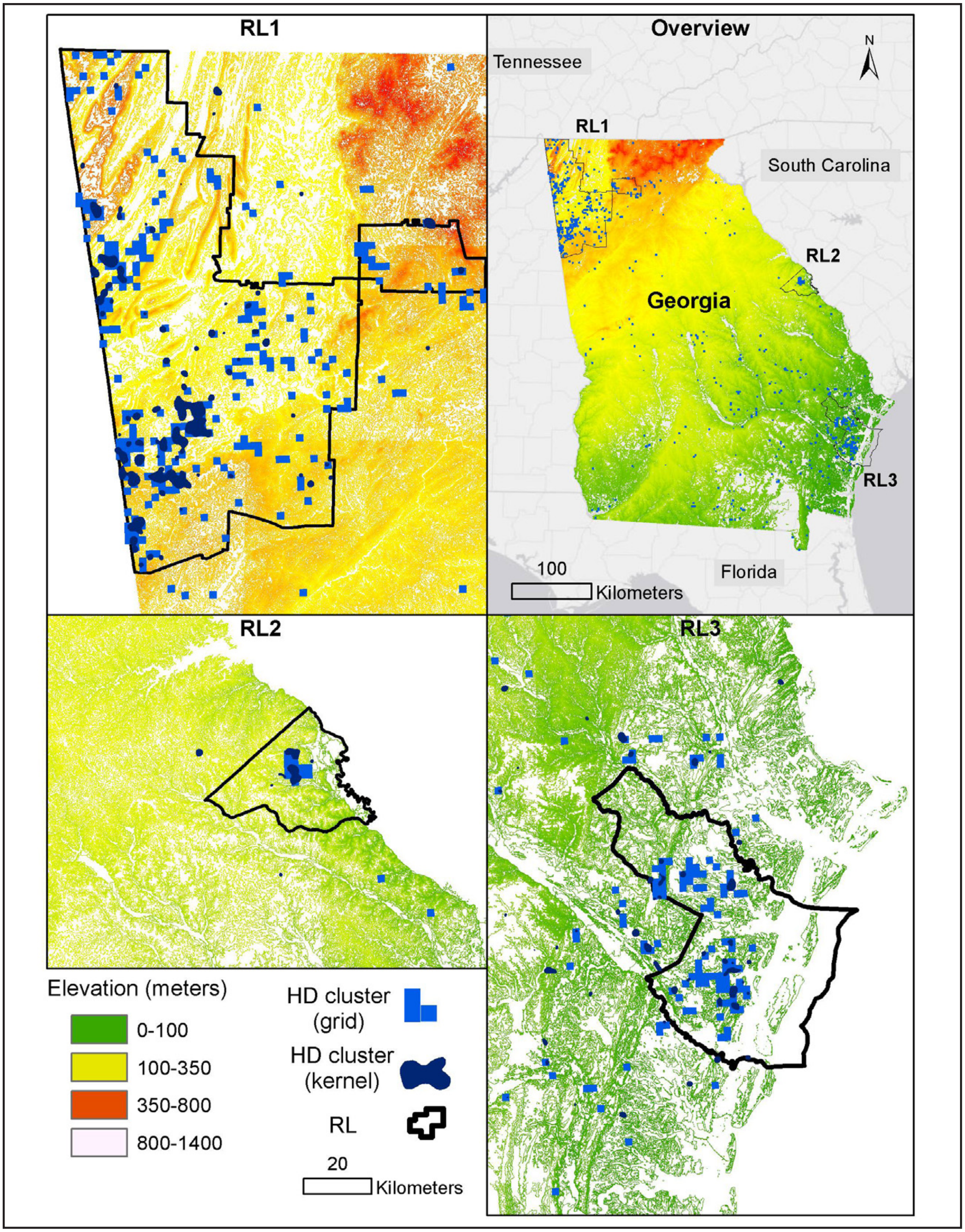

Figure 3. Map of Georgia showing topography and density analysis of unauthorized fires, 1987-2010. Regional loci (RL) represent contiguous counties with a high density of fires. HD clusters represent areas of high unauthorized fire densities identified through kernel density analysis.

28% of ignition locations fell on land cover pixels classified as evergreen forest, 17% fell on developed land, 14% occurred on agricultural lands, 10% occurred on transportation corridors, 9% occurred on forested wetlands, 8% occurred on clear cuts, and 6% on hardwood forest, while the remaining four land cover types represented less than 5% each. The seasonality of fire in RL2 exhibited a slightly less concentrated pattern with discordant fire frequency to area burned ratios. Evergreen land cover showed an April-May peak with a secondary July-September peak. The second most commonly burned land cover, developed land, showed relatively equally distributed peaks in March and September.

RL3, coastal plain. RL3 is located on the lower coastal plain of the Atlantic Ocean and is comprised of McIntosh and Liberty counties. The landscape is of relatively low relief and dominated by pine forests, clear cut or successional land cover, forested wetlands, and marsh. Ground cover often consists of "southern rough": saw palmetto (*Serenoa repens* [W. Bartram] Small), gallberry (*Ilex coriacea* [Pursh.] Chapm.), and wire-grass (*Aristida stricta* Michx.), a highly flammable vegetation type. RL3 registered 5.5% (n = 2274) of Georgia's unauthorized fires and 3.5% of area burned between 1987 and 2010. Ignition points from July 2002 through December 2010 extracted the following proportion of land cover values: 42% transportation corridors, 17% evergreen forest, 13% clear cut, 13% wetland forest, and 6% mixed evergreen and deciduous forest, with four other land covers comprising less than 3% each. Seasonality of unauthorized fire in RL3 concentrated in the spring peak (February-April) with only a small secondary peak for wetland forest in September.

Fire Timing and Fuel Moisture

PDSI. Monthly PDSI values for the years 1987 through 2010 were regressed with the number of fires per RL sample unit (Table 1). The PDSI correlated strongest and most significantly with fires in summer months, but the strength varied by sample unit. For example,

Table 1. Results matrix for correlation between the number of incendiary fires for each RL by month indicated (rows), and the monthly PDSI for the corresponding Georgia climate division, years 1987–2010 (columns).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PDSI Georgia climate division 1, RL1*												
May		0.15	0.18	0.16	**0.28**							
Jun				0.22	0.22	**0.37**						
Jul					0.16	**0.34**	***0.41***					
Aug		0.23	0.23	**0.36**	**0.37**	**0.35**	***0.38***	***0.48***				
Sep									**0.24**			
Oct										0.19		
PDSI Georgia climate division 6, RL2												
Jul						**0.25**	**0.26**					
Aug			0.16	0.17	0.21							
PDSI Georgia climate division 9, RL3												
Jan	0.13											
May					0.14							
Jul							0.14					
Oct									0.13			

* Significant results shown: $P \leq 0.05$, $P \leq$ **0.01** (**bold**), and $P \leq$ ***0.001*** (***bold italics***).

RL3 had the weakest relationship with PDSI. Fires occurring during months with the strongest relationship to PDSI also displayed significant lag effects. The timing and regularity of fire seasons in terms of ignition frequency and average fire size (Table 2) show that significant effects of PDSI are predominantly limited to periods of relatively low fire activity. For example, during the peak fire seasons in RL1, PDSI showed significant effects only for October, the month with the weakest PDSI influence. RL1 displayed the most year to year regularity between the number of fires and fire size, but ignition patterns did not gravitate toward seasons significantly influenced by drought. RL2, on the other hand, displayed the least regularity, but did have a secondary peak during July, the month most affected by PDSI.

KBDI. Drought is a relative concept and drought indices are no exception to this rule. Although KBDI is driven by daily weather, the relative meaning of KBDI values are also seasonally and spatially variable (Roncoli *et al*. 2006). Consequently, ignition preferences for fuel moisture were non-linear at the annual interval. For example, for RL1, a scatter plot of the frequency of fires by standardized (Z-Score) KBDI value illustrated a completely different relationship between the variables for spring (February–April) and fall (October–November) (Figure 4). Both fire frequency and burned area for RL1 spring season negatively correlated with KBDI values, whereas the fall season showed a weak, but positive correlation with KBDI. For the spring season, nearly 70 % of fires were set in below-average KBDI conditions (mean KBDI

Table 2. Fire season and interannual variability by sample unit. HD clusters selected were those with the largest sample sizes for each RL.

Sample unit	Fire season	% of fires [a]	Stand. dev. % [b]	Ave. size (ha) [c]	Stand. dev. (ha) [d]	Adj. R^2 [e]	*P* value[f]
Statewide	Feb–Apr	44.54 %	11.87 %	2.86	1.18	0.640	<0.001
Statewide	Nov	9.45 %	6.74 %	3.15	4.19	0.413	<0.001
RL1	Feb–Apr	46.56 %	14.42 %	3.49	2.67	0.715	<0.001
RL1	Oct–Nov	20.05 %	13.70 %	2.32	1.64	0.942	<0.001
RL2	Feb–May	53.79 %	20.93 %	1.52	1.27	0.349	0.001
RL2	July	8.78 %	13.54 %	0.86	2.18	0.312	0.003
RL3	Jan–Apr	69.04 %	15.43 %	1.77	1.38	0.429	<0.001
HD224 (RL1)	Feb–Apr	48.73 %	21.95 %	1.63	1.23	0.482	<0.001
HD224 (RL1)	Oct–Nov	22.00 %	19.37 %	1.72	3.51	0.571	<0.001
HD197 (RL2)	Mar–May	46.27 %	23.80 %	1.03	1.20	0.490	<0.001
HD197 (RL2)	July	9.70 %	21.86 %	0.75	2.20	0.052	0.146
HD70 (RL3)	Jan–Apr	70.00 %	22.91 %	2.22	3.17	0.214	0.013

[a] % of fires = percentage of fires from the 24 yr total that occurred during the fire season.
[b] Stand. dev. % = the standard deviation of the annual percentage of fires that occurred during the fire season over the entire 24 yr period.
[c] Ave. size (ha) = average fire size for the indicated fire season over the entire 24 yr period.
[d] Stand. dev. (ha) = standard deviation of the annual average fire season-fire size for the entire 24 yr period.
[e] Adj. R^2 = the adjusted R^2 value for the linear regression of the annual number of fires per fire season with the annual area burned during the fire season.
[f] *P* value = probability statistic that the null hypothesis (there is no linear relationship between number of fires and area burned) is true.

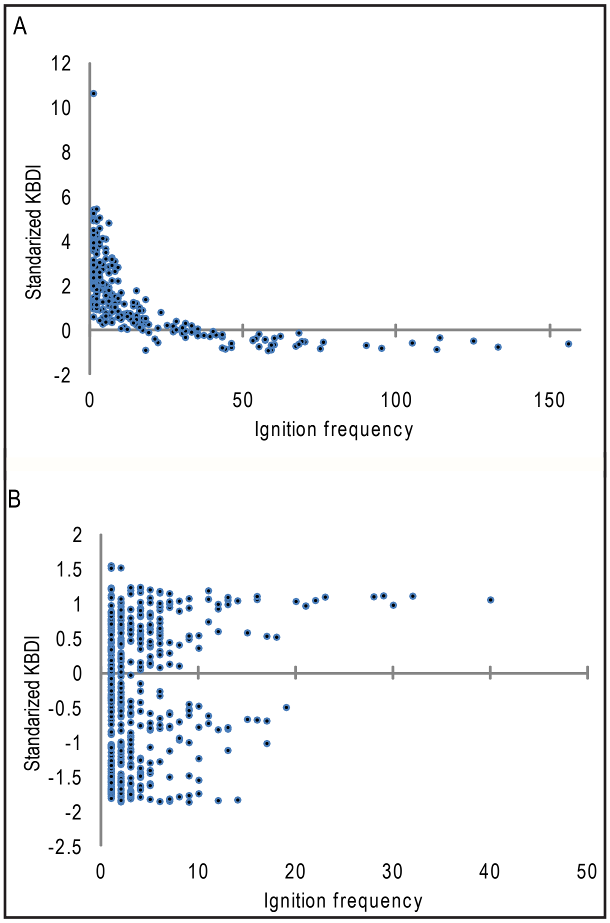

Figure 4. Ignition frequency by standardized KBDI values for RL1, (A) Feb–Apr 1987–2010 (aggregated), (B) Oct–Nov 1987–2010 (aggregated).

for spring ignitions 1987–2010 = 49, *n* = 4231). For the fall season, 57% of fires were set in above-average KBDI conditions (mean KBDI for fall ignitions 1987–2010 = 410, *n* = 1898). Peak fire seasons in the other RL did not correlate as strongly with KBDI, but in both RL2 and RL3, KBDI negatively affected fire frequency during the spring burning season (Table 3).

In order to examine change over time, I analyzed the relationship between KBDI and fire parameters using a 4 yr moving window for the spring burning seasons in both RL1 and RL3. The RL1 regression results showed a progressive decline in the strength of the correlation (Figure 5) in tandem with a decrease in the effect of the relationship. For example, in the 1991–1994 window, the frequency of fires decreased by 0.26 for each whole number increase in KBDI, but by the 2007–2010 window, an incremental change in KBDI only affected the frequency of fires by 0.01. For RL3, the majority of 4 yr windows were not statistically significant. However, the general trend went from a weak negative association between KBDI and fire frequency for the years 1987–1990, 1988–1990, and 1993–1996, to a similarly weak positive association for the years 1996–1999 through 1999–2002.

Table 3. Results for regressions of fire frequency and area burned with KBDI values 1987–2010 by RL and peak burning seasons. Non-significant results omitted.

Sample unit	Fire season	Dependent variable	Adj. R^2	*P* value	Coefficient	Mean KBDI	Stand dev. KBDI
RL1	Feb–Apr	Frequency	0.378	< 0.001	–0.1734	49.2	55.4
RL1	Feb–Apr	Area	0.282	<0.001	–1.4027		
RL1	Oct–Nov	Frequency	0.037	<0.001	0.0046	410.4	221.1
RL1	Oct–Nov	Area	0.024	<0.001	0.0415		
RL2	Feb–May	Frequency	0.082	<0.001	–0.0024	156.1	135.2
RL2	Feb–May	Area	0.034	0.008	–0.0185		
RL2	July	Frequency				576.2	146.0
RL2	July	Area					
RL3	Feb–Apr	Frequency	0.054	<0.001	–0.0051	220.4	184.7
RL3	Feb–Apr	Area					

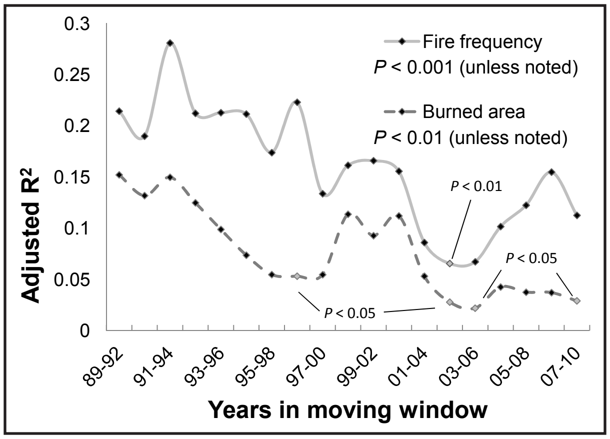

Figure 5. Significant adjusted R^2 values for Feb–Apr 1989–2010 (aggregated) fire frequency and burned area by KBDI values for RL1, using a 4 yr moving window. Both 1987–1990 and 1988–1991 displayed statistically insignificant results for burned area.

DISCUSSION

The spatial and temporal patterns in unauthorized ignitions presented here suggest that these types of fire regimes differ by location, time of year, climate and weather conditions, and land cover. At the regional level, emergent fire patterns convey not only conditions of ignition success, but firesetter preferences for particular land covers and burning conditions. Among the most striking patterns, seasonality of fire (i.e., firesetter preferences for burning in particular times of years) varied by both region and vegetation type. Additionally, for certain locations, climate and weather differentially affected both fire frequency and area burned according to season.

Given the intertwined political economic history of fire and land use and tenure in the southeastern US, one might expect to see spatiotemporal patterns indicative of malicious firesetting on forest industry land or forest plantations (Pyne 1982, Kuhlken 1999). Indeed, forest industry lands appear to be disproportionally affected in terms of the density of fires. However, ignitions in areas with higher fire densities did not exhibit temporal patterns that were significantly different from areas with more dispersed fires.

Notably, seasonality of unauthorized fire in Georgia correlated with that of legal, prescribed fires. Seasonality in prescribed fire in the Southeast has primarily reflected a historical concern with controlling fire severity (Brockway and Lewis 1997); winter-dormant season burns more often produce low severity surface fires and pose less risk to timber. But seasonality controls more than simply fire severity; it differentially impacts forest composition (Glitzenstein *et al.* 1995, Brose and Van Lear 1999), understory composition (Brockway and Lewis 1997), reproductive success of game birds (Stoddard 1935, Johnson and Hale 2000), and availability and quality of deer browse (Dills 1970, Hallisey and Wood 1976, Ivey and Causey 1984). Preferences for fire season therefore provide different outcomes in terms of both land cover and human-centered cost and benefits. The seasonal patterning of unauthorized fires is not inconsequential for understanding firesetter motives and, more generally, the nature of these fires as a socioecological disturbance regime.

Preferences for burning seasons could be attributed to ecological constraints on ignition success. For example, ignitions in hardwood forests in the early spring benefit from a leafless canopy, which allows the warm, spring sun to quickly dry last year's leaf fall and cured grasses. Success in other times of the year, such as the summer season, appears to be associated with drought conditions, which are by definition anomalous. This may be especially true for RL1, a hardwood dominated region, which displayed relatively strong relationships between fire frequency and PDSI values for the months of May through August, the period in which the fewest fires were set. RL3, however, showed even stronger skew toward the spring fire season, but had the weakest relationship with drought overall. The dominance of evergreen forests with flammable pine needle litter (duff) may moderate the importance of abnormally dry conditions for setting fires in the summer season.

In RL1, the relatively robust negative effect of KBDI on both fire frequency and burned area during the spring season may reflect the influence of ecologically "benevolent" firesetting. These results point to preferences for both ecological conditions conducive to fire spread (i.e., dry leaves and grasses) and weather conditions that moderate fire severity and prevent more severe ecological effects. Instead, such fires may maintain existing land covers, for example, by favoring the regrowth of rhizomatic plants. Traditional firesetting in the Southeast, especially in early spring, has a deep historical association with hunting (Johnson and Hale 2000), since it favors populations of game animals that benefit from the fire-vegetation interactions. In oak forests, dormant season fires cause the least amount of damage to the overstory, whereas growing season fires caused the most damage (Brose and Van Lear 1999). March burning, peak fire frequency in Georgia, bridges these seasons, perhaps capturing a period of intermediate disturbance. Intermediate disturbances are thought to encourage biological diversity (Connell 1978, Fox and Connell 1979), either by promoting understory diversity or by increasing landscape heterogeneity.

The fall peak in RL1 is much more arbitrary with regard to drought, but the number of fires did show a slight positive relationship with drought conditions. Fall fires may also be related to hunting; for example, hunters may set fires to flush game. In these cases, drier days may be preferred since fires will carry more broadly and evenly across the landscape. On the other hand, firesetters interested in maximizing damage to timber may choose to burn in the fall since the season presents both drier weather and an abundance of dry, dead fuel on the forest floor.

The majority of unauthorized fires in RL2 occurred on or in close proximity to developed or developed-open space land covers. Because we can assume that landscape fires in or near developed land are socially undesirable, unauthorized firesetting in RL2 likely represents the mischievous type of firesetting that we might associate with other types of crime (Prestemon and Butry 2005). RL2 displayed the most temporally diffuse, least clustered pattern and had the weakest seasonality for unauthorized fire. This timing and placement is more arbitrary and comes closest to the conventional understanding of incendiary fire setting since it is suggestive of malicious, opportunistic burning, or a combination of ecological ignorance and malfeasance.

Trends in both RL1 and RL3 suggest that peak fire season ignition preferences are shifting toward drier conditions, but are also becoming more arbitrary with regard to KBDI. As others have suggested, the more normative aspects of unauthorized burning may be waning (Prestemon and Butry 2008). At the same time, patterns indicative of truly malicious burning have not surfaced. For example, seasonality of unauthorized fire remains strongly clustered during the traditional spring season. If the majority of unauthorized fires are set with the intent to maximize damage to timber, firesetters remain remarkably ignorant with regard to key factors such as fire weather and forest ecology. Indeed, unauthorized firesetting may have an overall protective effect on forest resources by preempting more severe fires ignited in the growing season.

The results presented here contradict the conventional logic that unauthorized fire ubiquitously represents malicious intent to inflict social and ecological damage. Unauthorized fires predominantly occur in the dormant- and early-growing season when fuel conditions enable fire spread but prevent severe fires from developing. Given these findings, fire suppression efforts may be ecologically extraneous and policies concerning the suppression of unauthorized fire should be revisited.

Understandings of fire use in the US Southeast have long suffered from an anti-fire bias in forestry and a concomitant derogatory view of southern rural populations and their local knowledge (e.g., Shea 1939*a*). While some explanations of unauthorized fire in the South have been more sympathetic to southern fire-use practices, they perpetuate the view that fire is a tool of destruction and have ignored the implications of more nuanced understandings of fire ecology. Unauthorized firesetting in Georgia represents a heterogeneous category with significant spatiotemporal variability. Analyses of anthropogenic fire regimes must account for heterogeneity in human-fire relationships in order to cut through the ambiguity conventional causal categories pose for understanding socioecological systems. While analyses of aggregate data have a role to play in human fire ecology research, future studies will need to evaluate local knowledge, preferences, and other relevant socioecological parameters at the landscape level.

ACKNOWLEDGEMENTS

This paper is dedicated to the memory of Dr. Robert Rhoades, whose encouragement and guidance was foundational to the initiation of this project. I thank the Georgia Forestry Commission for access to wildfire data. This research was supported in part by a National Science Foundation award DEB-0823293 from the Long Term Ecological Research Program to the Coweeta LTER Program at the University of Georgia. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author and do not necessarily reflect the views of the National Science Foundation or the University of Georgia.

LITERATURE CITED

Abrams, M.D. 1992. Fire and the development of oak forests. BioScience 42: 346–353. doi: 10.2307/1311781

Abrams, M.D., and C.A. Copenheaver. 1999. Temporal variation in species recruitment and dendroecology of an old-growth white oak forest in the Virginia Piedmont, USA. Forest Ecology and Management 124: 275–284. doi: 10.1016/S0378-1127(99)00071-7

Alley, W.M. 1984. The Palmer Drought Severity Index: limitations and assumptions. Journal of Climate and Applied Meteorology 23: 1100–1109. doi: 10.1175/1520-0450(1984)023<1100:TPDSIL>2.0.CO;2

Anderson, H E. 1982. Aids to determining fuel models for estimating fire behavior. USDA Forest Service General Technical Report INT-122, Intermountain Forest and Range Experiment Station, Ogden, Utah, USA.

Bertrand, A., and A. Baird. 1975. Incendarism in southern forests: a decade of sociological research. Mississippi Agricultural and Forestry Experiment Station Bulletin 838, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Mississippi, USA.

Black, B.A., C.M. Ruffner, and M.D. Abrams. 2006. Native American influences on the forest composition of the Allegheny Plateau, northwest Pennsylvania. Canadian Journal of Forest Research 36: 1266–1275. doi: 10.1139/x06-027

Brockway, D.G., and C.E. Lewis. 1997. Long-term effects of dormant-season prescribed fire on plant community diversity, structure and productivity in a longleaf pine wiregrass ecosystem. Forest Ecology and Management 96: 167–183. doi: 10.1016/S0378-1127(96)03939-4

Brose, P., and D. Van Lear. 1999. Effects of seasonal prescribed fires on residual overstory trees in oak-dominated shelterwood stands. Southern Journal of Applied Forestry 23: 88–93.

Butry, D.T., and J.P. Prestemon. 2005. Spatio-temporal wildland arson crime functions. <http://www.researchgate.net>. Accessed 25 September 2013.

Chapman, H.H. 1932*a*. Is the longleaf type a climax? Ecology 13: 328−334. doi: 10.2307/1932309

Chapman, H.H. 1932*b*. Some further relations of fire to longleaf pine. Journal of Forestry 30: 602−604.

Christensen, N.L. 2000. Vegetation of the southeastern coastal plain. Pages 397−448 in: M.G. Barbour and W.D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, Cambridge, United Kingdom.

Connell, J.H. 1978. Diversity in tropical rain forests and coral reefs. Science 199: 1302−1310. doi: 10.1126/science.199.4335.1302

Coughlan, M.R., and A.M. Petty. 2012. Linking humans and fire: a proposal for a transdisciplinary fire ecology. International Journal of Wildland Fire 21: 477−487. doi: 10.1071/WF11048

Cowell, C.M. 1995. Presettlement Piedmont forests: patterns of composition and disturbance in central Georgia. Annals of the Association of American Geographers 85: 65−83.

Cowell, C.M. 1998. Historical change in vegetation and disturbance on the Georgia Piedmont. American Midland Naturalist 140: 78−89. doi: 10.1674/0003-0031(1998)140[0078:HCIVAD]2.0.CO;2

Delcourt, P.A., and H.R. Delcourt. 1998. The influence of prehistoric human-set fires on oak-chestnut forests in the southern Appalachians. Castanea 63: 337−345.

Demmon, E.L. 1935. The silvicultural aspects of the forest-fire problem in the longleaf pine region. Journal of Forestry 33: 323−331.

Dills, G.G. 1970. Effects of prescribed burning on deer browse. The Journal of Wildlife Management 34: 540−545. doi: 10.2307/3798860

Dixon, P.G., G.B. Goodrich, and W.H. Cooke. 2008. Using teleconnections to predict wildfires in Mississippi. Monthly Weather Review 136: 2804−2811. doi: 10.1175/2007MWR2297.1

Doolittle, M.L., and M.L. Lightsey. 1979. Southern woods-burners: a descriptive analysis. USDA Forest Service Research Paper SO-151, Southern Forest Experiment Station, New Orleans, Louisiana, USA.

Dunkelberger, J., and A. Altobellis. 1975. Profiling the woods-burner: an analysis of fire trespass violations in the South's national forests. Alabama Agricultural Experiment Station Bulletin 469, Alabama Agricultural and Mechanical College, Auburn, USA.

Eller, R. 1982. Miners, millhands, and mountaineers: industrialization of the Appalachian South, 1880−1930. University of Tennessee Press, Knoxville, USA.

Foster, T.H.I., and A.D. Cohen. 2007. Palynological evidence of the effects of the deerskin trade in forest fires during the eighteenth century in southeastern North America. American Antiquity 72: 35−51.

Fowler, C., and E. Konopik. 2007. The history of fire in the southern United States. Human Ecology Review 14: 165−176.

Fox, J.F., and J.H. Connell. 1979. Intermediate-disturbance hypothesis. Science 204: 1344−1345. doi: 10.1126/science.204.4399.1344

Garren, K.H. 1943. Effects of fire on vegetation of the southeastern United States. Botanical Review 9: 617−654. doi: 10.1007/BF02872506

Glitzenstein, J.S., W.J. Platt, and D.R. Streng. 1995. Effects of fire regime and habitat on tree dynamics in north Florida longleaf pine savannas. Ecological Monographs 65: 441−476. doi: 10.2307/2963498

Grala, K., and W.H. Cooke. 2010. Spatial and temporal characteristics of wildfires in Mississippi, USA. International Journal of Wildland Fire 19: 14−28. doi: 10.1071/WF08104

Granstrom, A., and M. Niklasson. 2008. Potentials and limitations for human control over historic fire regimes in the boreal forest. Philosophical Transactions of the Royal Society B-Biological Sciences 363: 2353−2358. doi: 10.1098/rstb.2007.2205

Green, S.W. 1931. The forest that fire made. American Forests 37: 583−584, 618.

Guyette, R.P., R.M. Muzika, and D.C. Dey. 2002. Dynamics of an anthropogenic fire regime. Ecosystems 5: 472−486.

Guyette, R.P., M.A. Spetich, and M.C. Stambaugh. 2006. Historic fire regime dynamics and forcing factors in the Boston Mountains, Arkansas, USA. Forest Ecology and Management 234: 293−304. doi: 10.1016/j.foreco.2006.07.016

Hallisey, D.M., and G.W. Wood. 1976. Prescribed fire in scrub oak habitat in central Pennsylvania. The Journal of Wildlife Management 40: 507−516. doi: 10.2307/3799955

Hansbrough, T. 1963. Southern forests and southern people: 12th annual forestry symposium. published for the School of Forestry and Wildlife Management and the General Extension Division. Louisiana State University Press, Baton Rouge, USA.

Hardtner, H.E. 1935. A tale of a root—a root of a tale or, root hog or die. Journal of Forestry 33: 351−359.

Ivey, T.L., and M.K. Causey. 1984. Response of white-tailed deer to prescribed fire. Wildlife Society Bulletin 12: 138−141.

Johnson, A.S., and P.E. Hale. 2000. The historical foundations of prescribed burning for wildlife: a southeastern perspective. USDA Forest Service General Technical Report NE-288, Northeastern Research Station, Newtown Square, Pennsylvania, USA.

Jurgelski, W.M. 2008. Burning seasons, burning bans: fire in the southern Appalachian Mountains, 1750−2000. Appalachian Journal 35: 170−217.

Kaufman, H.F. 1939*a*. A psycho-social study of the cause and prevention of forest fires in the Clark National Forest; June−October 1938. Exhibit B. Pages 1−55 in: J.P. Shea, editor. Man-caused forest fires: the psychologist makes a diagnosis. USDA Forest Service, Washington, D.C., USA.

Kaufman, H.F. 1939*b*. Social factors in the reforestation of the Missouri Ozarks. Thesis, University of Missouri, Columbia, USA.

Keetch, J.J., and G.M. Byram. 1968. A drought index for forest fire control. USDA Forest Service Research Paper SE-38, Southern Forest Experiment Station, Asheville, North Carolina, USA.

Kuhlken, R. 1999. Settin' the woods on fire: rural incendiarism as protest. Geographical Review 89: 343−363. doi: 10.2307/216155

Kull, C.A. 2002. Madagascar aflame: landscape burning as peasant protest, resistance, or a resource management tool? Political Geography 21: 927−953. doi: 10.1016/S0962-6298(02)00054-9

Kull, C.A. 2004. Isle of fire: the political ecology of landscape burning in Madagascar. University of Chicago Press, Illinois, USA.

Lafon, C., J. Hoss, and H. Grissino-Mayer. 2005. The contemporary fire regime of the central Appalachian Mountains and its relation to climate. Physical Geography 26: 126−146. doi: 10.2747/0272-3646.26.2.126

Lewis, H.T. 1978. Traditional uses of fire by Indians in northern Alberta. Current Anthropology 19: 401−402. doi: 10.1086/202098

Lovreglio, R., V. Leone, P. Giaquinto, and A. Notarnicola. 2010. Wildfire cause analysis: four case-studies in southern Italy. iForest-Biogeosciences and Forestry 3: 8−15.

Maingi, J.K., and M.C. Henry. 2007. Factors influencing wildfire occurrence and distribution in eastern Kentucky, USA. International Journal of Wildland Fire 16: 23−33. doi: 10.1071/WF06007

Moser, W.K., and D.D. Wade. 2005. Fire exclusion as a disturbance in the temperate forests of the USA: examples from longleaf pine forests. Scandinavian Journal of Forest Research 20: 17−26. doi: 10.1080/14004080510041048

National Oceanic and Atmospheric Administration. 2010. National Climatic Data Center. <http://www.ncdc.noaa.gov/oa/ncdc.html>. Accessed 24 July 2011.

Natural Resource Spatial Analysis Laboratory. 1998. Land cover map of Georgia. Institute of Ecology, University of Georgia, Athens, USA.

Otto, J.S. 1983. The decline of forest farming in southern Appalachia. Journal of Forest History 27: 18−27. doi: 10.2307/4004858

Otto, J.S. 1984. Traditional cattle-herding practices in southern Florida. The Journal of American Folklore 97: 291−309. doi: 10.2307/540611

Otto, J.S. 1986. Open-range cattle-ranching in the Florida pinewoods: a problem in comparative agricultural history. Proceedings of the American Philosophical Society 130: 312−324.

Prestemon, J.P., and D.T. Butry. 2005. Time to burn: modeling wildland arson as an autoregressive crime function. American Journal of Agricultural Economics 87: 756−770. doi: 10.1111/j.1467-8276.2005.00760.x

Prestemon, J.P., and D.T. Butry. 2008. Wildland arson management. Pages 123−147 in: T.P. Homes, J.P. Prestemon, and K.L. Abt, editors. The economics of forest disturbances: wildfires, storms, and invasive species. Springer, Dordrecht, The Netherlands. doi: 10.1007/978-1-4020-4370-3_7

Pyne, S.J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, New Jersey, USA.

Pyne, S.J. 1998. Forged in fire: history, land, and anthropogenic fire. Pages 62−103 in: W. Balee, editor. Advances in historical ecology. Columbia University Press, New York, New York, USA.

Roncoli, C., N. Breuer, J. Bellow, D. Zierden, K. Ingram, and K. Broad. 2006. Potential applications of Keetch-Byram Drought Index forecasts for fire management decisions in Georgia and Florida. South East Climate Consortium, Gainesville, Florida, USA.

Rothermel, R.C. 1983. How to predict the spread and intensity of forest and range fires. USDA Forest Service General Technical Report INT-143, Intermountain Forest and Range Experiment Station, Ogden, Utah, USA.

Scott, J.C. 1985. Weapons of the weak. Yale University Press, New Haven, Connecticut, USA.

Seijo, F. 2005. The politics of fire: Spanish forest policy and ritual resistance in Galicia, Spain. Environmental Politics 14: 380−402. doi: 10.1080/09644010500087665

Shea, J.P. 1939*a*. Man-caused forest fires: the psychologist makes a diagnosis. USDA Forest Service Confidential Report, Washington, D.C., USA.

Shea, J.P. 1939*b*. Our pappies burned the woods. American Forests 46: 159−162, 174.

Shea, J.P. 1940*a*. Getting at the roots of man-caused forest fires: a case study of a southern forest area. Confidential Report 41, US Government Printing Office, Washington, D.C., USA.

Shea, J.P. 1940*b*. New design for forest fire prevention in the South. USDA Forest Service, Biloxi, Mississippi, USA.

Stoddard, H.L. 1935. Use of controlled fire in southeastern upland game management. Journal of Forestry 33: 346−351.

Stoddard, H.L. 1962. Use of fire in pine forests and game lands. Tall Timbers Fire Ecology Conference 1: 31−42.

Wahlenberg, W.G. 1935. Effect of fire and grazing on soil properties and the natural reproduction of longleaf pine. Journal of Forestry 33: 331−337.