FIRE, DROUGHT, AND FOREST MANAGEMENT INFLUENCES ON PINE/HARDWOOD ECOSYSTEMS IN THE SOUTHERN APPALACHIANS[1]

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ABSTRACT: Establishment and maintenance of pitch pine/hardwood ecosystems in the southern Appalachians depends on intense wildfire. These ecosystems typically have a substantial evergreen shrub component (Kalmia latifolia) which limits regeneration of future overstory species. Wildfires provide microsite conditions conducive to pine regeneration and reduce Kalmia competition. Recent droughts in the region have resulted in significant acreages of southern pine beetle killed pine/hardwood stands. Site conditions are amenable to the high intensity fires needed to regenerate pine; however, fire suppression limits the role of wildfire in these ecosystems. Research shows that pines will not regenerate in the absence of severe disturbance, such as a high intensity fire, and mixed pine/hardwood ecosystem will not be maintained. Currently, some of these ecosystems are being slashed, burned, and planted with white pine (Pinus strobus) in an effort to restore site productivity. Our findings show that high intensity prescribed burning results in substantial pine regeneration and re-creation of mixed pine/hardwood ecosystems.
KEYWORDS: pine restoration; prescribed burning; regeneration; ecosystem response

INTRODUCTION

In the southern Appalachians, mixed pine/hardwood ecosystems occupy the most xeric sites (i.e., south/west aspect ridge sites). They are typically comprised of varying proportions of pitch pine (Pinus rigida), virginia pine (Pinus virginiana), and/or shortleaf pine (Pinus echinata) and a mixture of hardwoods, including scarlet oak (Quercus coccinea), chestnut oak (Quercus prinus), and red maple (Acer rubrum). Mountain laurel (Kalmia latifolia), an evergreen ericaceous shrub, is a major component of these ecosystems. While the pine/hardwood ecosystem is limited in extent (e.g., <5% of the landscape in the southern Appalachians), it is a unique vegetation type that provides important habitat for both flora and fauna.

The pine component of many of these pine/hardwood ecosystems is in a serious state of decline. Smith (1991) determined that 98% of the pine/hardwood stands at the Coweeta Hydrologic Laboratory in western North Carolina have little or no remaining live pine. Smith's study showed that pine has been declining since the early 1970's; however, a major loss of pine occurred in the mid 1980's. This loss is coincident with a severe drought in the region (Swift et al. 1989) which caused widespread outbreaks of southern pine beetle (Dendroctonus frontalis) and substantial pine mortality.

The origin of many mixed pine/hardwood stands in the southern Appalachians is largely a result of past cultivation which created microsite conditions conducive to pine regeneration (i.e., mineral soil, limited competition) (Whittaker 1956, Nicholas and White 1984). Their maintenance is hypothesized to depend on intense wildfires (Barden and Woods 1976). Natural or man-caused fires have the potential for the high

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intensity necessary for pine regeneration because pine/hardwood sites are typically dry, hot, and contain substantial amounts of flammable fuels (Vose and Swank 1993). Intense fires are most likely during extremely dry periods. However, most wildfires in the southern Appalachians lack the intensity to promote regeneration of native pines (Barden and Woods 1976).

Fire suppression and low fire intensity has limited the role of either man-caused or natural fires in perpetuating these ecosystems. Fuel loads on these stands are currently substantial due to pine mortality (Smith 1991) and large amounts of mountain laurel (Vose and Swank 1993); however, fire suppression efforts will continue to limit the extent of intense wildfires in these ecosystems. As an alternative, silvicultural treatments may be successful in regenerating pine/hardwood ecosystems. In particular, some of these degraded pine/hardwood stands have been chainsaw felled, burned, and planted to white pine (Pinus strobus) in an attempt to increase overall site productivity (Swift et al. 1993). An additional benefit may be the maintenance and restoration of native pines. In this paper we compare the structure and composition of stands which received the fell and burn treatment 13 years ago, a stand which was burned by wildfire 25 years ago, and unburned "reference" stands. Our objective was to examine the potential role of site preparation burning in restoring and maintaining mixed pine/hardwood ecosystems in the southern Appalachians.

APPROACH

Three separate study sites located in the southern Appalachians of North Carolina were used to assess the role of fire in pine/hardwood ecosystems: (1) information on unburned "reference" stands was obtained from a study examining ecosystem responses (e.g., nutrient cycling, net primary productivity, vegetation diversity) to the slash and burn treatment (see Swift et al. 1993). Data were obtained from pre-treatment measurements on 27 15x33 m plots systematically located in three typical mixed pine/hardwood stands, (2) information on slash and burn stands was obtained from a study examining species composition and vegetation diversity 13 years after receiving the slash and burn treatment (see Clinton et al. 1993). Here, data were collected from 16 15x33 m plots. Although white pine was planted on these stands, we report only data for native pines, and (3) we measured species composition and stand structure on a pine/hardwood stand which had been burned with a high intensity wildfire 25-years ago. Data were collected on a single 30x30 m plot located in a portion of the stand which appeared to have burned uniformly. On all three sites, understory vegetation ($\leq$ 10 cm dbh [diameter at breast height]) was measured on nested 3x3 or 5x5 m subplots. Average overstory (>10 cm dbh) and understory ($\leq$10 cm dbh) vegetation characteristics (basal area and density) were summarized for pines, oaks, other hardwoods, and mountain laurel.

EFFECTS OF FIRE ON STAND COMPOSITION AND REGENERATION

The composition and structure of the reference stand reflected the influence of overstory pine mortality, inhibited pine regeneration, and the dominance of mountain laurel in the understory (Table 1). In the understory, pines represented <1 % of either basal area or density, indicating little or no regeneration. In the overstory, pines represented about 30% of the basal area and about 20% of the density. Recent mortality of the mature overstory pines was obvious (standing dead >10 cm dbh = 13/ha). In contrast, both the site preparation and wildfire sites had a significant pine component. On these sites, pines represented approximately 60-80% of the overstory basal area and 70-80% of the overstory density (Figure 1). Oaks (primarily scarlet and chestnut oak) and other hardwoods (primarily red maple and sourwood) were also represented on the burned sites, substantiating that burning produces a pine-hardwood mixture. On the slash and burned site, most of the hardwood component resulted from stump sprouting of the residual overstory. In contrast, on the wildfire site, many of the hardwoods (particularly oaks) were residual survivors. This represents a major difference between the two types of burns in the mechanism whereby new stands are created. In addition, the post-fire stand structure will differ between the two types of burns. For example, the slash and burn treatment produces a uniform age class distribution and initiates early stages of secondary succession uniformly on the site. In contrast, wildfires have the potential for much more selective mortality which results in a mosaic of successional stages.

Table 1. Stand composition (basal area [BA] in m^2ha^{-1} and density in stems ha^{-1}) on burned and unburned sites.

Species groups	Reference				13-yr-old burn				25-yr-old burn			
	>10 cm		≤10 cm		>10 cm		≤10 cm		>10 cm		≤10 cm	
	BA	Density	BA	Density	BA	Density	BA	Density	BA	Density	BA	Density
Pine	4.8	97	0.01	123	0.7	30	0.8	949	12.8	589	3.6	800
Oaks	7.6	218	2.5	4486	0.1	5	2.2	3922	7.3	155	0.3	160
Other Hardwoods	3.1	138	3.3	18,272	0.1	8	3.3	8808	1.2	78	0.8	880
TOTALS	15.5	453	5.8	22,881	0.8	43	6.3	13,679	21.3	822	4.8	1840

Pine regeneration was substantially greater on the burned sites than on the reference stand (Figure 2). As noted previously, seedling and sapling size pines (≤ 10 cm DBH) on the reference stand comprised <1% of either basal area (.01 m^2/ha) or density (123 stems/ha). In contrast, regeneration was much greater on both burned sites, where density ranged from 800 to 949 stems/ha.

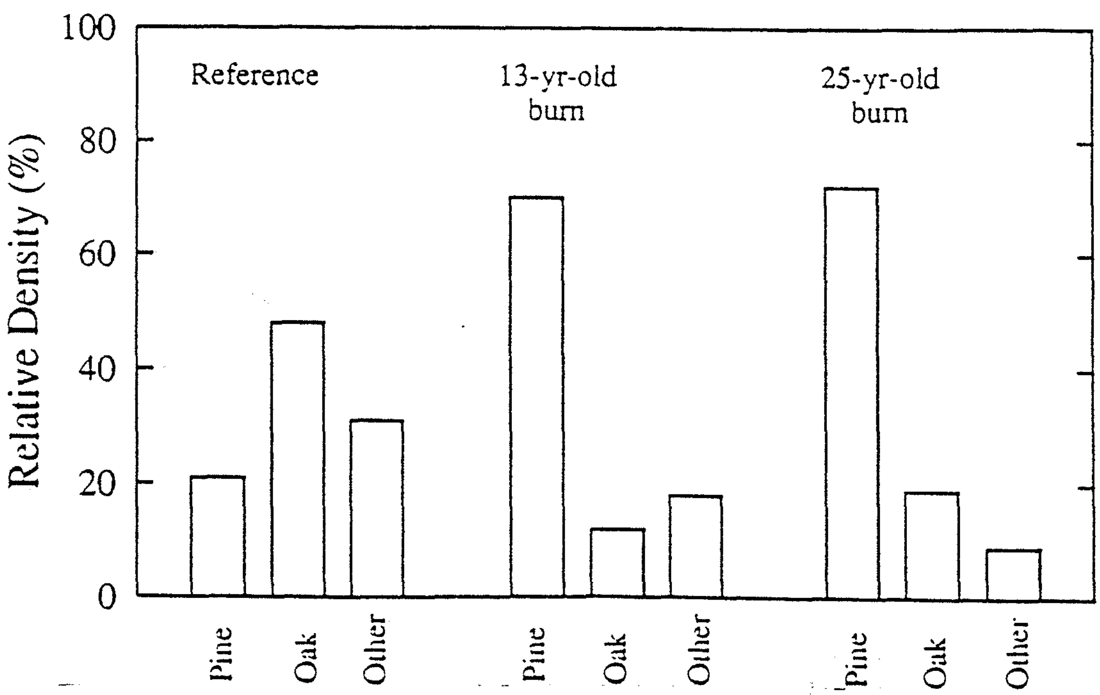

Figure 1. Overstory composition by major plant type for burned and unburned stands. Other includes all hardwood other than oak.

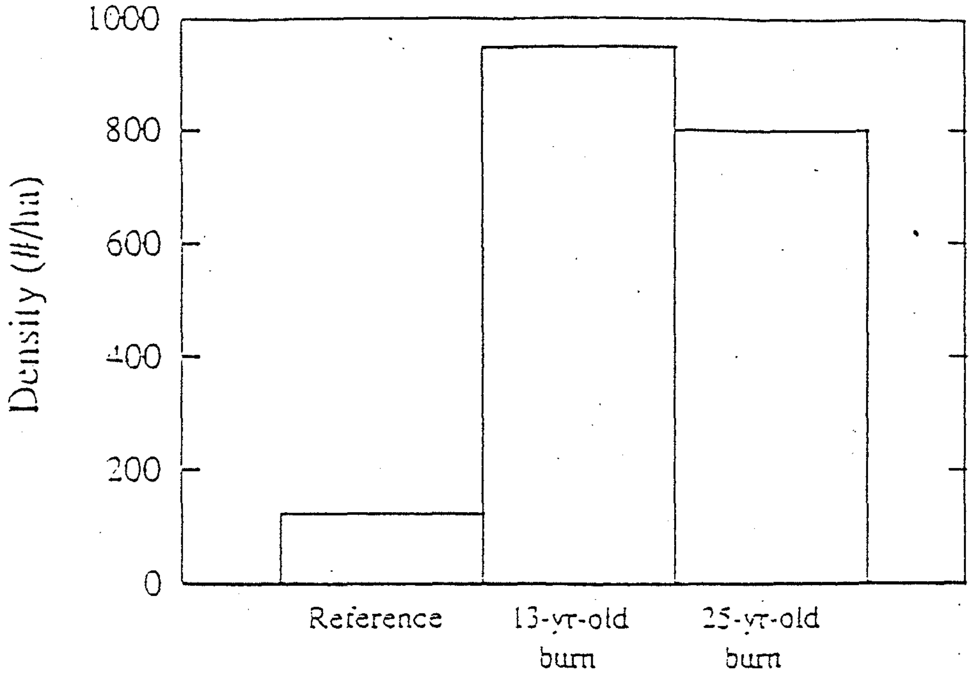

Figure 2. Understory pine density for burned and unburned stands.

Data from both the site preparation burning and wildfire indicate that fire does produce, at least in the first 25 years, a mixed pine/hardwood ecosystem. Without fire, the condition of these stands will continue to degrade because pine regeneration is prevented by the heavy mountain laurel understory. Even as these older pines die due to insect outbreaks or other causal agents, they will not be able to regenerate in shaded conditions.

EFFECTS OF FIRE ON MOUNTAIN LAUREL

The high density and basal area of pines on the burned sites indicates that microsite conditions for germination and establishment were improved by the burning treatment. A major objective of the fell and burn treatment is to reduce competition to planted white pine seedlings. In these ecosystems, mountain laurel is a major competitor; however, burning does appear to minimize mountain laurel's influence on white pine establishment in the first few years (Elliott and Vose, unpublished data). This treatment also benefits regeneration of other species including native pines. While not eliminated from the site, the dominance of mountain laurel is reduced substantially as a result of burning (Figure 3). For example, in the reference stand, mountain laurel basal area (measured at ground level) was 27 m^2/ha and density was 18,148 stems/ha. By contrast, basal area was 6.3 and 10.3 for the fell /burn and wildfire sites, respectively. Due to the prolific sprouting of mountain laurel, density on both burn sites was still quite substantial (e.g., 9,000 to 23,000 stems/ha), indicating that the reduction of mountain laurel competition will be a short-term phenomena. Hence, even with high intensity burning, mountain laurel reasserts its influence on microsite conditions at the forest floor within a relatively short period of time.

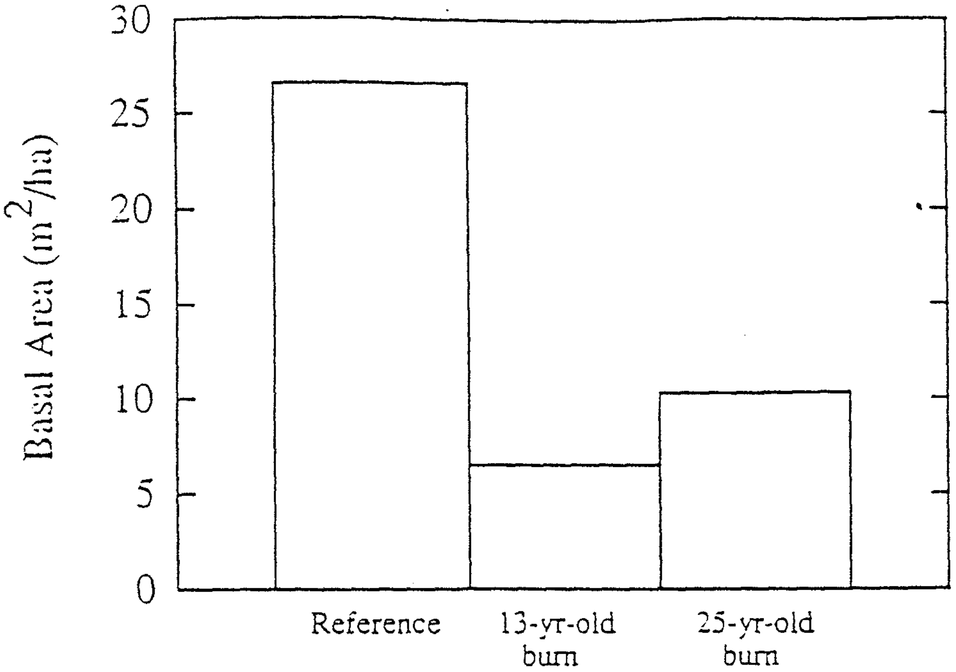

Figure 3. Mountain laurel basal area on burned and unburned stands.

EFFECTS OF FIRE ON OTHER ECOSYSTEM ATTRIBUTES

While fire increases pine regeneration, other ecosystem components need to be evaluated to assess overall ecosystem impacts of burning. First year effects of the fell and burn treatment on several ecosystem processes were evaluated in a multi-investigator study on the Nantahala National Forest in western North Carolina (Swift et al. 1993). Generalized results from this study are presented in Table 2 and detailed results are available in the references associated with each parameter. This study showed that the short-term responses of many ecosystem attributes were positive (vegetation diversity, N cycling rates) or not significant (erosion, stream quality, nutrient pools). The only potentially negative effect is the loss of nitrogen (N) associated with emissions from burning which were estimated to be between 300 and 500 kg N/ha. Because these sites are generally low in available N, such losses may be important to long-term productivity. However, these N losses could be offset by factors such as increased N cycling rates and additions from symbiotic and non-symbiotic N fixation. Hence, a complete assessment of the impacts of site preparation burning on site N requires techniques such as computer models (e.g., Swank and Waide 1980) which integrate all components of the N cycle (inputs, outputs, and internal cycling). As our ecosystem study progresses (e.g., Vose and Swank 1993), we will assess these potential long-term effects on ecosystem N availability.

While we have significant understanding of short-term effects of several ecosystem parameters, there are still many unknowns. For example, we have little knowledge of either the direct or indirect effects of fire in these ecosystems on fauna. In addition, most of the process level information is based on the first or second year response and the longer-term effects are generally unknown.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Fire is hypothesized to play a major role in the maintenance of pine/hardwood ecosystems in the southern Appalachians (Barden and Woods 1976). The pine component of these ecosystems is declining due to successional processes and drought related insect mortality. Our data clearly show that high intensity fire, resulting from either wildfire or site preparation, promotes pine regeneration. Suppression efforts will continue to limit the role of wildfire in the southern Appalachians so it is unlikely that these pine/hardwood

Table 2. Generalized effects (0 = minimal response, + = positive response, - = negative response) of burning on ecosystem properties.

Parameter	Response	Source
Erosion	0	Swift et al. 1993
Stream Quality	0	Knoepp & Swank 1993
Vegetation Diversity	+	Clinton et al. 1993
Nitrogen Cycling	+	Knoepp & Swank 1993
Nutrient Pools	-/0	Vose & Swank 1993

ecosystems will be restored without management intervention. In the southern Appalachians, the fell and burn treatment is used to increase the productivity of the pine/hardwood ecosystems by planting white pine after minimizing competition through cutting and burning. Our results show that this treatment also results in regeneration of native pines (e.g., pitch, shortleaf, virginia) to a level comparable to intense wildfire. Hence, an additional benefit of site preparation burning is the restoration of pine/hardwood ecosystems.

Modifications in the fell and burn treatment could be implemented to more closely mimic wildfire, without substantially altering the original silvicutural objectives. For example, a mosaic of disturbance severity and residual tree size class distributions could be produced by leaving islands of uncut areas (> 0.2 ha), as well as a few large trees scattered within the treatment area.

The vigor of mountain laurel regrowth will restrict recruitment of native pines soon after treatment. Hence, the long-term maintenance of these ecosystems will require recurrent treatments. While the appropriate recurrence interval is unknown, a preliminary guideline is 40-60 years--the approximate age of many of these stands at the first stages of decline.

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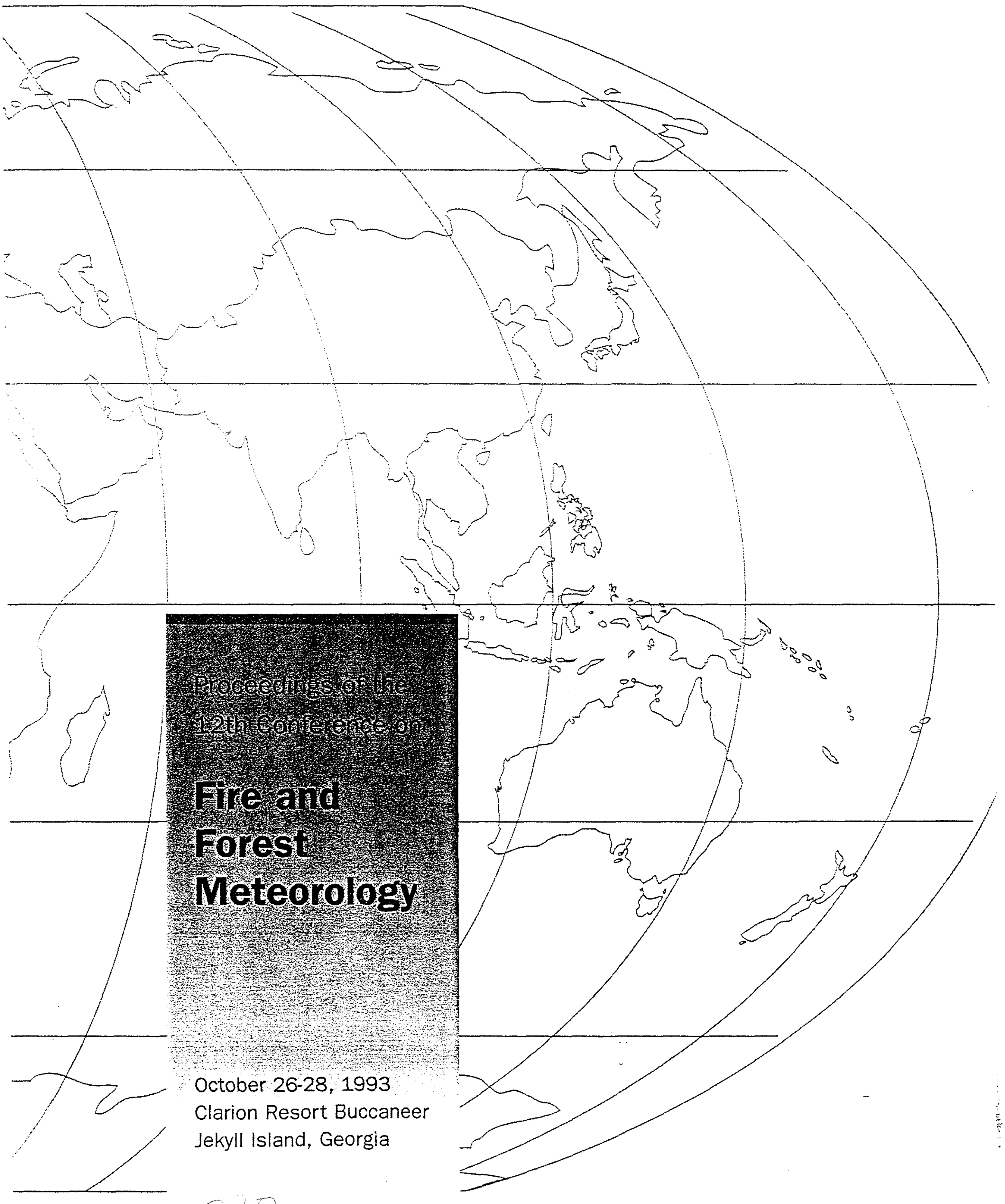

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