5C.1 ANTHROPOGENIC FUEL ALTERATION AND CHANGES IN SPATIAL FIRE BEHAVIOR IN A SOUTHEASTERN PYROGENIC ECOSYSTEM

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1. ABSTRACT*

Southeastern pyrogenic ecosystems have evolved and adapted along with natural fire regimes. Humans have disrupted natural fire regimes by fragmenting fuels, introducing exotic species, and suppressing fires. Information is needed quantifying how these alterations specifically affect spatial fire extent and pattern. To address this need, we applied historic (1920 and 1943) and current (1990) GIS fuels maps and the FARSITE fire spread model to quantify the differences between historic and current fire spread distributions. We held all fire modeling variables (wind speed and direction, cloud cover, precipitation, humidity, air temperature, fuel moistures, ignition source and location) constant with exception of the fuel models representing different time periods. Model simulations suggest that modern fires are much smaller than historic ones and that anthropogenic features play a major role reducing landscape flammability. Fire extent declined linearly with patch density, and there was a quadratic relationship between fire extent and percent landscape covered by urban features. As little as10 percent urban landcover caused a 50 percent decline in fire extents.

2. INTRODUCTION

A fire regime is the result of many interactions with physical and biophysical variables (Christensen 1985), which influence vegetative characteristics, distribution of species, biogeochemical cycling, and ecosystem function within an area. Fire is governed by and influences many naturally complex landscape processes, which have been further complicated by anthropogenic influences. Fire is one of the most intensely studied disturbances acting on the landscape, but relatively few studies directly quantify anthropogenic influences on the modern fire regime and even fewer quantify spatial aspects of this relationship.

In this study we use historic and current fuels maps with a mechanistic fire model to quantify the effects of anthropogenic influences (fuel fragmentation, fire suppression, exotic species) on potential fire spread through time. This approach allowed us to isolate the effects of increasing anthropogenic influences by holding all fire modeling variables constant, except the fuel models representing a time series of landscape change in a southeastern pyrogenic community. Our study focuses on fire extent and burn pattern alteration, which links our results to fire regime dynamics in a larger context. Previous modeling studies in this area of research (Turner et al. 1989, Davis and Burrows 1994) have been more theoretical, leaving out quantitative detail, making integration of this important information with land management practices difficult.

3. STUDY SITE

Kennedy Space Center (KSC)/Merritt Island National Wildlife Refuge (MINWR) comprises 57,000 ha in Breavard and Volusia counties located along the east coast of central Florida (Figure 1). Portions not directly used by The National Aeronautics and Space Administration (NASA) for space operations support are managed by the U.S. Fish and Wildlife Service as MINWR. Urban development on KSC consists of industrial facilities and infrastructure to support launch operations. KSC/MINWR occupies a barrier island complex comprised of a diverse assemblage of fire-adapted terrestrial vegetative communities. Upland xeric sites are dominated by oak scrub vegetation (*Quercus spp*.), while mesic sites are dominated by flatwoods (e.g., *Serenoa repens*, *Lyonia spp*., *Ilex sp*., and an overstory of *Pinus elliotii*) (Schmalzer and Hinkle 1992a,b). Because the landscape is comprised of relict dunes forming ridge swale topography, there are interleaving swale marshes and hammocks on hydric soils between the xeric ridges. The swales are dominated by *Spartina bakeri* and *Andropogon spp*., while the hardwood hammocks are dominated by *Quercus virginiana* and *Quercus laurifolia* that have a structure that is much less flammable than surrounding communities. There is still remnant citrus agriculture on KSC/MINWR. Many groves planted before NASA ownership are currently leased and farmed.

Cape Canaveral is a large, geologically-recent (formed during the Quaternary period) barrier island with predominantly well-drained soils. Most of Cape Canaveral, totaling about 6,475 ha, has been within Cape Canaveral Air Force Station since the 1950s. Coastal strand and coastal scrub are the predominant types with oak scrub inland (Schmalzer et al. 1999).

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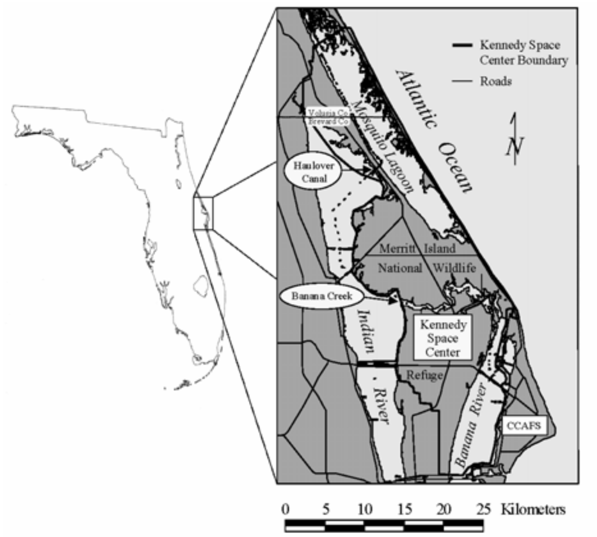

Figure 1. The geographic location of Kennedy Space Center and Cape Canaveral Air Force Station in Florida. Geographic barriers to fire are indicated.

Coastal scrub occurs on neutral to alkaline sandy soils; a shrub form of live oak (*Quercus virginiana*) is the dominant species along with saw palmetto (Serenoa repens). Typical scrub oaks (*Quercus geminata, Q. myrtifolia, Q. chapmanii*), saw palmetto, and ericaceous shrubs (e.g. *Lyonia* spp., *Vaccinium* spp.) predominate. Much scrub has been unburned for >30 years and has developed xeric hammock features (Schmalzer et al. 1999). Mesic hammocks occur near the Banana River. An extensive network of industrial infrastructure and facilities supporting launch operations are present on CCAFS.

4. METHODS

We used the Fire Area Simulator model (FARSITE) version 3.0 (Finney 1998) for all spatial fire modeling with input directly from ARC/INFO GRID software (Environmental Systems Research Institute 1997). We modeled the landscape at 10 m resolution to include narrow, linear anthropogenic features such as roads. To increase modeling efficiency at this resolution, we split the study area into north, central, and south regions by using natural geographic barriers to fire.

We converted 1920, 1943, and 1990 landcover maps (Duncan et al. 2000, Duncan et al. 2003 in review) into fuel maps by assigning each landcover type to one of the 13 standard fire behavior fuel models (Anderson 1982). Freshwater marshes were assigned to Fuel Model 1 (short grass). Standard fire model 3 could also have been used but caused simulated fires to burn unrealistically fast. Disturbed freshwater marshes were assigned to Fuel Model 2. Hammocks, mixed hardwoods, and wetland hardwoods were assigned to Fuel Model 8 (ground litter fuels under forest canopy), and categories such as salt marsh or others associated with water or non-flammable features were assigned to Fuel Model 98 (non-fuel). Because our study concentrated on the effects of anthropogenic change and its effect on terrestrial flammability, and because it is difficult to separate flammable from non-flammable salt marsh, we modeled salt marsh as a non-flammable type.

The FARSITE model's limited spotting capabilities made it necessary to model narrow dirt roads as Fire Behavior Fuel Model 8. To accurately model fire spread consistent with our observations during average meteorological conditions, we assigned narrow dirt roads to the slow burning Fuel Model 8 to simulate observed spotting rates. Other landscape inputs to the model include overstory canopy coverage in percent, elevation, slope, and aspect.

Wind data are required by FARSITE on an hourly basis with wind speed, wind direction, and cloud cover all being required by the model. Daily inputs for precipitation, minimum temperature, hour of minimum temperature, maximum temperature, hour of maximum temperature, minimum humidity, maximum humidity, and elevation of meteorological collection site are also required by FARSITE. The model also required initial fuel moistures. Fuel moistures for each of these categories were generated by either averaging moisture values for summer samples of individual species for each category or by consultation with USFWS fire personnel at MINWR.

We selected July 20th through 27th 1999 for our modeling window, because it represented typical meteorologic conditions during the summer when lightning strike probabilities were high. Because lightning initiates most fires during summer in this region, we selected lightning as our ignition source. The output fire and fire enclaves (unburned islands within burned areas) were exported directly to ArcView within FARSITE. The software package FRAGSTATS was used to compare spatial configuration of fuels on each historic landscape (McGarigal and Marks 1995). Statistical analyses were then conducted to test the relationship between percent burned and fuel fragmentation with null hypotheses of no relationship between amount burned and fuel fragmentation.

After the initial fire simulations were complete we selected both forest and non-fuel features (industrial facilities, transportation, and agriculture) from the 1990 central KSC fuels map and added them directly to the

1920 fuels map separately to create two new fuels maps. Fire was then simulated across the central KSC region using these fuel maps and maintaining all other modeling variables. Because the 1920 landscape contained very few anthropogenic features, this methodology allowed us to isolate how these specific contemporary landscape features influence fire extent.

5. RESULTS

For each region, the largest simulated fire occurred in 1920, and fires became smaller for each successive modeling date (Figure 2). Fire pattern changed with the reduction in fire extent; many of the 1943 and most of the 1990 fire boundaries coincided with anthropogenic features (Figure 3). The largest decreases in fire size occurred between 1943 and 1990 in all regions except the southern region. In the northern region, 81% of the area burned in 1920 also burned in 1943, and 46% of that area burned in 1990. In the central region, 77% of the 1920 area burned in 1943, and 11% burned in 1990. In the southern region, 40% of the 1920 area burned in 1943 and 16% burned in 1990. On Cape Canaveral Air Force Station, 79% of the 1920 area burned in 1943 with 8% burning in 1990.

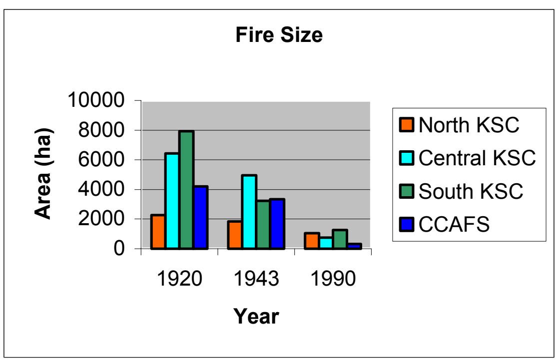

Figure 2. Fire sizes by time period and region

Average burn rates decreased through time for each region (table 1). The linear regression between percent area burned and patch density was significant (F = 21.05, R^2 = 0.678, P < 0.001) (Figure 4), indicating a strong relationship between habitat fragmentation and percent area burned. There was a significant negative quadratic regression between percent burned and percent anthropogenic features (F = 8.1, R^2 = 0.643, P < 0.01) (Figure 5). Non-fuel features restricted fire extent more than forest features in the central region of KSC (Figure 6) and (Table 2).

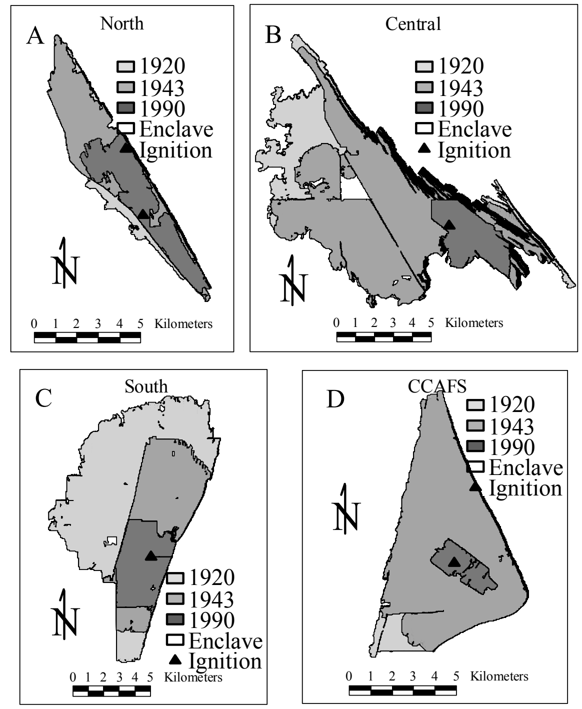

Figure 3. Overlaid fire simulation maps for A) northern B) central C) southern KSC and D) CCAFS.

Table 1. Average burn rates for fire simulations on north, central, southern KSC, and CCAFS, Florida. Average burn rates determined by dividing fire area by fire duration.

Location/yr	Fire area (ha)	Avg. burn rate(ha/hr)
North KSC 1920	2,269	13
North KSC 1943	1,830	10
North KSC 1990	1,047	6
Central KSC 1920	6,429	36
Central KSC 1943	4,949	28
Central KSC 1990	744	4
South KSC 1920	7,926	44
South KSC 1943	3,217	18
South KSC 1990	1,264	7
CCAFS 1920	4,203	24
CCAFS 1943	3,326	19
CCAFS 1990	323	2

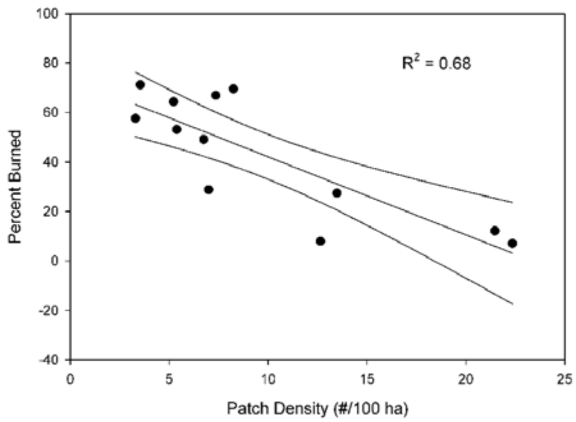

Figure 4. Regression plot showing the relationship between percent of landscape burned and fuel fragmentation (patch density).

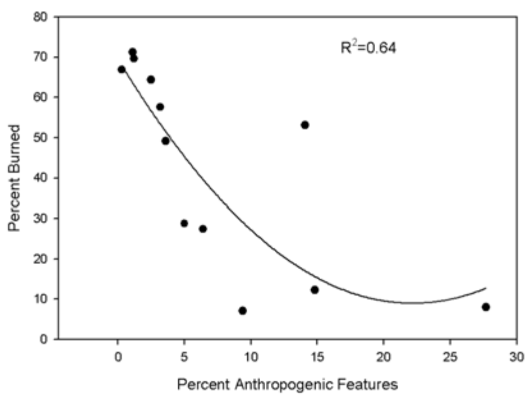

Figure 5. Quadratic regression plot showing the relationship between percent of landscape burned and percent of landscape with anthropogenic features.

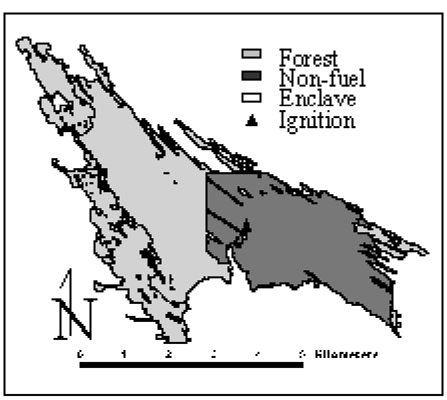

Figure 6. Fire simulation maps for 1990 forest features imbedded within 1920 fuels (Forest) and 1990 non-fuel (industrial, transportation, agriculture) features imbedded within 1920 fuels (Non-fuel).

Table 2. Average burn rates for fire simulations on 1990 forest and 1990 non-fuel features imbedded within 1920 fuel model.

Location	Fire area (ha)	Avg. burn rate (ha/hr)
Central KSC forest	2,663	15
Central KSC non-fuel	1,022	6

6. DISCUSSION AND CONCLUSION

Under average meteorological conditions, the ability of fire to spread across the KSC/MINWR and CCAFS landscapes has been reduced since the early 1900's. Scrub and flatwoods communities (the primary terrestrial fuel) in Florida are well adapted to fire and other natural disturbances (Abrahamson 1984a,b; Myers 1990, Schmalzer and Hinkle 1992a,b). Historically, frequent lightning ignitions maintained natural scrub in a low, open structure and flatwoods as open savannas (Robbins and Myers 1989). Development of Cape Canaveral Air Force Station beginning in the early 1950's and of Kennedy Space Center beginning in 1962 resulted in increased fire suppression. Fire suppression continued until 1981 on KSC and 1990 on CCAFS when prescribed burning was implemented to reduce dangerous fuel levels and restore habitat for native species (Adrian and Farinetti 1995; Schmalzer et al. 1999). Facilities and infrastructure for the space program substantially increased landscape fragmentation.

The combination of anthropogenic disturbance and fire suppression allowed dense pine forests to establish in pine flatwoods communities (Duncan et al. 1999). Fire suppression and hydrologic alteration also allowed mesic forest species to spread into marshes where frequent fire previously hindered tree establishment (Duncan et al. 1999). These forests replace the native flammable grasses and act as firebreaks because of the linear ridge-swale topography that run the entire length of many landscapes. Fire suppression has altered vegetation structure of long unburned scrub communities so they no longer burn readily except under the most extreme fire conditions (Schmalzer et al. 1994, Schmalzer and Adrian 2001).

Anthropogenic features such as roads and industrial areas have increased since 1920. These features, while not as dense and widespread as outside the federal property boundaries, still fragment remaining fuels. We found that a small amount of anthropogenic development significantly reduced fire extent in all regions of KSC/MINWR/CCAFS. As little as 10 percent anthropogenic landcover reduced fire extent by 50 percent from 1920 levels. Isolating the effect of both non-fuel and forest features on fire spread reveals that forest alters fire spread but not as much as non-fuel features.

In the southeast anthropogenic influences such as arson and escaped controlled burns have caused a shift in peak acreage burned from the historic mid-summer to current spring maximum (Florida Division of Forestry 2003). The majority of fires (frequency) on KSC/MINWR are natural summer lightning ignitions (F. Adrian, MINWR, personal communication), and KSC is a secured area so arson fires are not a major factor in its fire regime. This study was possible because historic fuels data were available and our study location was a controlled environment retaining summer lightning ignitions with a high ratio of native fuels to anthropogenic development.

This study used empirical historic and current fuel maps combined with spatial fire modeling techniques to perform a change detection of fire extents from baseline historic conditions. We conclude that the ability of fire to spread across a pyrogenic system in the southeastern United States has decreased through time. Anthropogenic factors such as agricultural and industrial development have been critical influences causing fragmentation of native fuels, altering fire extent and fire patterns.

We found that anthropogenic features directly replacing flammable fuels have had a disproportionate effect on reducing fire size. This has profound implications for land managers unaware that relatively few anthropogenic features can greatly alter spatial fire behavior.

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