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An investigation of cumulative precipitation trends prior to Mississippi early season wildfires

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AN INVESTIGATION OF CUMULATIVE PRECIPITATION TRENDS PRIOR TO MISSISSIPPI EARLY SEASON WILDFIRES

By

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AN INVESTIGATION OF CUMULATIVE PRECIPITATION

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Mississippi's landscape is comprised of sixty-five percent forest and is a vital artery for the state economy. Each year, an average of 4,000 wildfires occur that burn more than 60,000 acres statewide. This study examines correlations of cumulative precipitation for Mississippi's nine physiographic regions during 1991– 2005 with total number of acres burned during peak wildfire season in Mississippi. Statistical analyses suggests that significant correlations exist between the cumulative precipitation at one, two, and three months prior to Mississippi's early wildfire season and the total number of acres burned and the total number of fires. These findings, in conjunction with ongoing Mississippi wildfire research, may be incorporated into a potential predictive fire risk model for the state of Mississippi.

DEDICATION

My time here at Mississippi State University as a graduate candidate is being dedicated to my Grandpaw, Wilton J. LeBoeuf , the late Theresa Grace LeBoeuf, and the late Dr. Leo Lynch.

Wilton J. Leboeuf, an honorable man with a fourth grade education has given me the best advice a granddaughter could ever ask for in her lifetime. With a Cajun accent he tells me, “Whatever you do sha, go to school and get your education. No one can ever take it away from you.” He left grade school to help support a family of eleven. His unending love, care, and support for his family and me are unconditional. To know him is to love him.

My grandmother’s life was taken by a heart attack at the age of forty-five years old. I know she is very proud of my success and accomplishments. One day, I will join her in heaven where I will listen to all her stories from her own childhood.

This research is also dedicated to the family and friends of Dr. Leo Lynch. He will be missed for his sense of humor and smiles he brought to the halls of Hilbun. My prayers are with him and his family during this time of hardship.

ACKNOWLEDGEMENTS

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I want to thank my parents for helping me through the roller coaster ride of graduate school. Without my mom, Linda Hernandez and my stepdad Rick Hernandez, I would not have made it this far. Last but not least, I would like to thank my fiancée for his utmost patience and love. It is the sweet little things that he does for me that keep me on my feet

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CHAPTER I

INTRODUCTION

Wildfires play an important role in habitat health, species diversity, carbon storage, biomass accumulation, and fuel loads reduction (Grala *et al.*2008). However, wildfires threaten human lives, property, wildlife, and timber resources (Gilreath 2006). While numerous studies have focused primarily on western wildfires, few have researched wildfires in the southeastern U.S. (Simard *et al*. 1985, Zhai *et al.* 2003, Goodrick and Hanley 2005, Brewer and Rogers 2006, Cooke *et al.* 2007, Dixon *et al.* 2008, Grala *et al.*2008). Wildfire frequency and temporality in the West differ from wildfires in the southeast U.S. In the west, wildfires begin in March and peak in July and August (Westerling *et al.* 2003). In the southeast U.S., there are two wildfire seasons: a winter/spring season (January – March), and a fall/winter season (September – December) (Grala *et al.* 2008). Grala *et al.* (2008) observed that the largest number of wildfires and the largest wildfire acreage burned occur during winter/spring wildfire season.

There are numerous causes of wildfires that can be sorted into the following three categories: natural fires, accidental and/or arson fires, and person-controlled fires (prescribed fires) (Zhai *et al.* 2003). Human-caused forest fires (including accidental/arson and prescribed fires) represent more than two-thirds of forest fires in the

U.S. (Zhai *et al.* 2003). Stephens (2005) indicated that among the ten U.S. Forest Serviceregions tested, the southeast region had the largest number of human caused wildfires. According to the Mississippi Forestry Commission (MFC), most wildfires in Mississippi are the result of human activity. The high percentage of human-caused fires in the southeast region and in Mississippi is a source of concern, particularly if antecedent landscape moisture conditions result in increased wildfire danger due to lower fuel moisture content during the early wildfire season.

A few studies have investigated climatic effects on wildfires in Mississippi (Zhai *et al* 2003, *Cooke et al* 2007, Cooke *et al.* 2007, Dixon *et al.* 2008, Grala *et al.* 2008), but these studies were primarily targeted towards wildfires that occur in the late summer. Fewer studies examined the causes of the early wildfire season, (Stephens 2005, Grala *et al.* 2008). These studies of the early wildfire season imply that differences in wildfire acreage burned and frequency may be due to changes in anthropogenic behavior. While this early wildfire season peak in the bimodal distribution may in fact result from changing anthropogenic behavior, this claim cannot be accepted unless the effects of antecedent climatic conditions are investigated for their potential influence on the early wildfire season. The primary objective of this research was to examine the potential role antecedent precipitation plays at various lag intervals as a driving variable that modulates wildfire acreage burned and frequency in the early wildfire season in Mississippi. Understanding relationships between antecedent climatic conditions and wildfire size and frequency in the early wildfire season has the potential for enhancement of current fire potential models in Mississippi developed by Cooke *et al.* (2007).

To test the importance of antecedent climatic conditions on the early wildfire season in Mississippi, the effects of antecedent climatic conditions on wildfires in the early spring season were analyzed by correlating climatic data with wildfire occurrence and wildfire size data for the month of February over a 15-year time period (1991–2005). Climate effects fire potential through precipitation, evaporation, wind, and lightning (Pye *et al*., 2003). The climate-related variables that affect the severity of the wildfire season are those that affect soil moisture content, vegetation density, and the moisture content of vegetation (NCDC, 2009).

The impact of early season wildfires is an important economic issue, particularly for wildfires that affect forested land. The U.S. is comprised of more than 750 million acres of forestland (SAF 2009). An average of four million acres of the U.S.'s landscape burns each year as a result of wildfires (USFA 2009). Currently, the Mississippi landscape is comprised of more than sixty-five percent forestland. Suitability of Mississippi landscapes for forest and other vegetation types varies by topographic position, soil type, and microclimate. Results of investigations by Pillai *et al.* (2009) for Normalized Difference Vegetation Indices (NDVI) correlations with wildfire acreage burned revealed that physiographic regions reduced within-class variance of the correlations. Consequently, physiographic regions were used as summary strata for correlation of antecedent moisture conditions with early season wildfire characteristics for this investigation.

Cumulative precipitation and evaporation variables used in models developed by Cooke *et al*. (2007) for late season wildfire potential are based on a January 1 calibration date for water budget calculations each year. Investigations by Leopold (1974) suggest that the concept of a water year (October – September) may be a better calibration basis that reflects the hydrologic season. This water year concept was used for this study of antecedent moisture conditions by calculating cumulative precipitation beginning on October 1.

Wildfire data for this project were obtained from The Mississippi Forestry Commission for the 15-year study period. Precipitation data for the study period were obtained from the National Climatic Data Center (NCDC) through their online database.

CHAPTER II

LITERATURE REVIEW

Wildfire impacts human safety, ecological processes, and air quality. Numerous models exist that help estimate current, and future wildfire danger, potential, and behavior. This review focuses on investigation of wildfire research specific to wildfire potential modeling, which integrates climate fuels, and anthropogenic variables to describe conditions that favor wildfire if an ignition source is available. National, regional, and Mississippi wildfire research was reviewed and general wildfire characteristics were documented at both national and regional scales. Wildfire studies in the southeastern U.S. were compared with research in the western U.S. and the bimodal nature of Mississippi wildfires was reviewed. The role of antecedent moisture at various temporal lags prior to known peaks in acreage burned and fire frequency was investigated and summarized by physiographic regions. The use of a water year for calibrating cumulative landscape moisture was reviewed as an alternative to existing Mississippi wildfire potential model water budget indices that begin calibrations on January 1 of each year.

General Characteristics and Causes of Wildfires, National and Regional

Wildfires are described by the U.S. Department of Agriculture (USDA) as an unplanned fire requiring suppression action, as contrasted with prescribed fire with prepared fire lines enclosing a designated area, under prescribed meteorological conditions (USDA 1956). Wildfires are also explained by the USDA as a free-burning fire unaffected by fire suppression measures. Millions of acres of land in the United States are burned by wildfires annually, including Hawaii and Alaska. As a result, billions of dollars in damage are incurred in a given year (USDA 2006). Wildfires result in the loss of the timber crop in the West and in Mississippi, often pose danger to human safety, and adversely affect air quality. However, wildfires are a natural ecosystem process that has been used to improve wildlife habitat, improve range, help prepare sites for planting or seeding, control undesirable understory species, reduce the hazardous accumulation of fuel, improve access, and improve visibility for recreation (Mobley *et al*. 1981). Prescribed burning is a common technique used to manage the ecological composition of forests in both western forests and southeastern U.S. forests (Mobley and Balmer 1981). These prescribed burns are primarily implemented during the early wildfire season in Mississippi and can sometimes escape and become wildfires. The spatial and temporal distributions of wildfires, particularly summer wildfires, are affected by varying climatic conditions in the western and southeastern portions of the U.S.

The behavior of climatic variables influence wildfire frequency in the western U.S. and the southeastern U.S. Western wildfire research has identified temperature, precipitation, wind, humidity, and the location of lightning strikes as deterministic factors that modulate the frequency of western wildfires (Westerling *et al.* 2003). The findings of Cooke *et al.* (2007) and (Grala *et al.* 2007) illustrate that late season wildfires in Mississippi are affected by climate. In Mississippi, Cooke *et al.* (2007) identified *P-E* (precipitation minus evaporation*)* as a driving variable for fire potential models. While Mississippi's early wildfire season has the highest wildfire frequency, this is also a period of surplus rainfall. Although January and March is a period when the state allows prescribed burning, reduction burns of deadfalls, agricultural field burns, and fire in burn barrels (Grala *et al.* 2007), it is not clear whether frequency of anthropogenic causes of wildfires vary enough year-to-year to explain the differences in wildfire peak for frequency and size observed over this 15-year period. The effect of precipitation on Mississippi's early wildfire season needs to be investigated to understand the relationship between precipitation and wildfire frequency.

The Bimodal Nature of Mississippi Wildfires

The combined effects of climate, land use changes, landscape fragmentation, management practices, vegetation succession, and spread of invasive species, since the beginning of Euro-American settlement, have led to widespread change in fire regimes across the United States. Hence, an increase in acreage burned and frequency has been observed (Westerling, *et al.* 2003). In Mississippi, more than 60,000 acres are burned annually as a result of wildfires. With more than 65% of Mississippi's landscape maintained as forest cover, a better understanding of the role of climatic variables that affect the early wildfire season is needed (Grala, 2008).

The distribution of wildfires in the West and in Mississippi differ on a temporal scale. Wildfires in the west generally occur during a single wildfire season that begins in March and peaks in August (Westerling *et al.* 2003). Mississippi has two distinct wildfire seasons. Grala *et al.* (2008) illustrated a bimodal distribution of the wildfire (Fig. 2.1). Grala *et al.* (2008) seasonal differences in wildfire characteristics from 1991 through 2005. Their findings illustrated that the first peak in wildfire frequency was most likely due to anthropogenic factors rather than climatic conditions. Few studies have investigated the temporal nature of climatic variables that influence the bimodal distribution of wildfires in Mississippi.

Role of Antecedent Lag in Climatic Variables in Wildfire size & Frequency

Precipitation, seasonal variation in the availability of flammable fuels, and the incidence of human ignition sources interact to play a dominant role in the seasonal patterns of wildfires (Brewer and Rogers 2006). Recent research is beginning to yield a better understanding of the nature of historical wildfires in Mississippi using atmospheric teleconnections as a predictor for wildfires, and the probability of wildfire locations as a function of population densities (Cooke *et al.* 2007, Dixon *et al.* 2008, Grala *et al.* 2008, Pillai *et al.* 2009). To date, the only climatic variables in Mississippi that have been

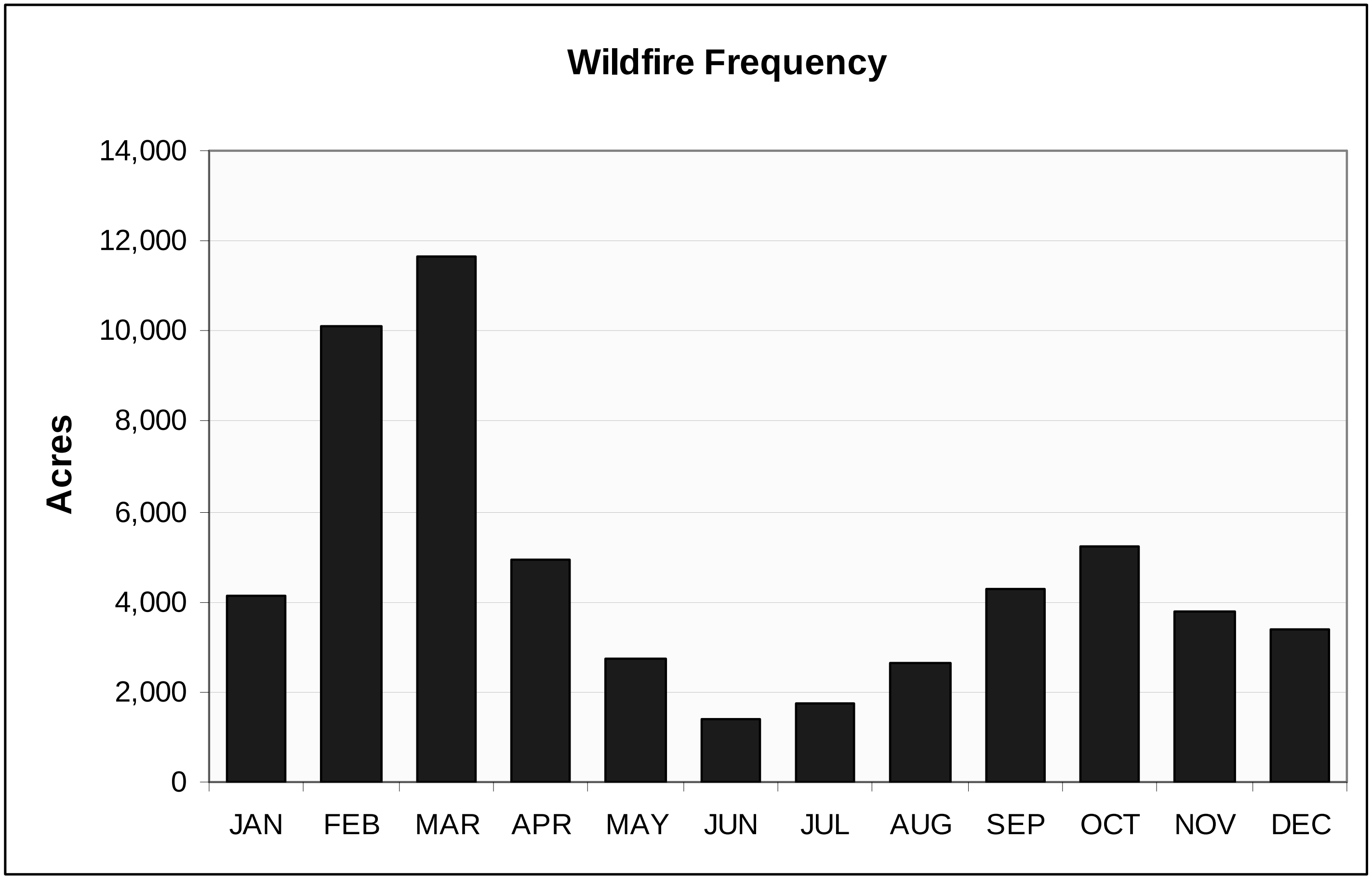


Fig. 2.1. Wildfire Frequency from 1991-2005.

analyzed for early wildfire season included the average precipitation for the Holly Springs National Forests in northwest Mississippi (Brewer and Rogers 2006), average that drive landscape level water budget estimates (Cooke *et al.* 2007). Of the previously mentioned climate variables, cumulative precipitation has yet to be investigated.

The work of Dixon *et al.* 2008 showed significant correlations exist between teleconnection indices and wildfire occurrence, total acres burned, and average acres burned. The aforementioned variables resulted in statistically significant (α =0.05 and α = 0.10) correlations with teleconnection index values from six months prior to Mississippi's early wildfire by temporal lags. As much as 50% of the variance was explained by the independent variables (r = -0.5) Pillai *et al.* (2009) found similar results with NDVI values prior to Mississippi's early wildfire season. Their findings illustrated significant correlations (α = 0.05, r = -0.399) between NDVI and the average acres burned and average number of wildfires in Mississippi from 1991-2005. Pillai *et al.* (2009) examined temporal lag effects for Mississippi landscape strata. Results of their analysis indicated that NDVI values are negatively correlated with wildfire frequency and size in various physiographic regions. Pillai *et al.* (2009) found significant correlations between NDVI and the nine physiographic regions in Mississippi by temporal lags. The fact that correlations were significant only for certain physiographic regions imply that conditions within each physiographic region are important as analytical strata for testing antecedent precipitation.

Role of Landscape Stratification

A physiographic region is described by the United State Geological Survey (USGS) as a broad-scale subdivision based on terrain texture, rock type, and geologic structure and type (USGS 2003). The decision to use physiographic regions as a stratum to test correlations helps mitigate effects due to the Modifiable United Area Problem (MAUP) (O'Sullivan and Unwin 2003). MAUP is an analytical artifact of choosing an area or strata that, if too large, results in loss of information specificity, and if too small, results in the loss of general pattern variation across the landscape. Physiographic regions were used to reduce the source of variance in wildfire size and frequency correlations with precipitation due to landscape conditions that maintain homogeneity among various physiographic units in Mississippi. The physiographic regions were applied to provide a representation of relatively homogeneous conditions related to wildfires (Pillai *et al.* 2009). The physiographic regions of Mississippi were developed from a variety of historical sources by Mississippi Automated Resourced Information Systems (MARIS 1994) by including forest habitat regions, soil associations, and major land resource areas. Mississippi's landscape was partitioned into the following physiographic regions, Black Prairie, Coastal Zone, Delta, Jackson Prairie, Loess Hills, North Central Hills, Pine Belt, South Central Hills, and the Tombigbee Hills.

Only two previous studies (Pillai *et al.* 2009, and Grala *et al.*, 2008) have summarized wildfires by physiographic regions in Mississippi. Pillai *et al.* (2009) analyzed fifteen-years of values of seven-day NDVI composites Advanced Very High

Resolution Radiometer (NOAA-AVHRR) satellite. Physiographic regions in Mississippi were used in Pillai's *et al.* (2009) study as summary strata to test NDVI as a potential indicator of wildfire size and frequency. They found statistically significant (α =0.01 and α = 0.05, r = -0.388) correlations between NDVI and fire size and fire frequency for several physiographic regions of Mississippi. Grala *et al.* (2008) findings illustrated that the southern physiographic regions had the highest percentage of area burned from 1991-2005. An investigation of antecedent meteorological variables by physiographic regions subsequent to early wildfire season may provide a better understanding of the acreage burned and fir frequency in Mississippi by a water year.

Water Year

As defined by Leopold, a water year is the 12-month period October 1, for any given year through September 30, of the following year for all locations (Leopold 1974). A water year was used so that one hydrologic season (that is, the fall and winter, which generally are more alike in weather than are successive years) may be included. The calendar break of January 1 used in current fire potential models for Mississippi (Cooke *et al.* 2007) is arbitrary in that it has no weather or hydrologic meaning thus it is often avoided (Leopold 1960). This thesis research utilized a water year as opposed to a calendar year in order to develop a better profile of the precipitation trends graphically prior to Mississippi's early wildfire season. For statistical analysis, it was expected that beginning the cumulative precipitation summarization period at this time would provide a

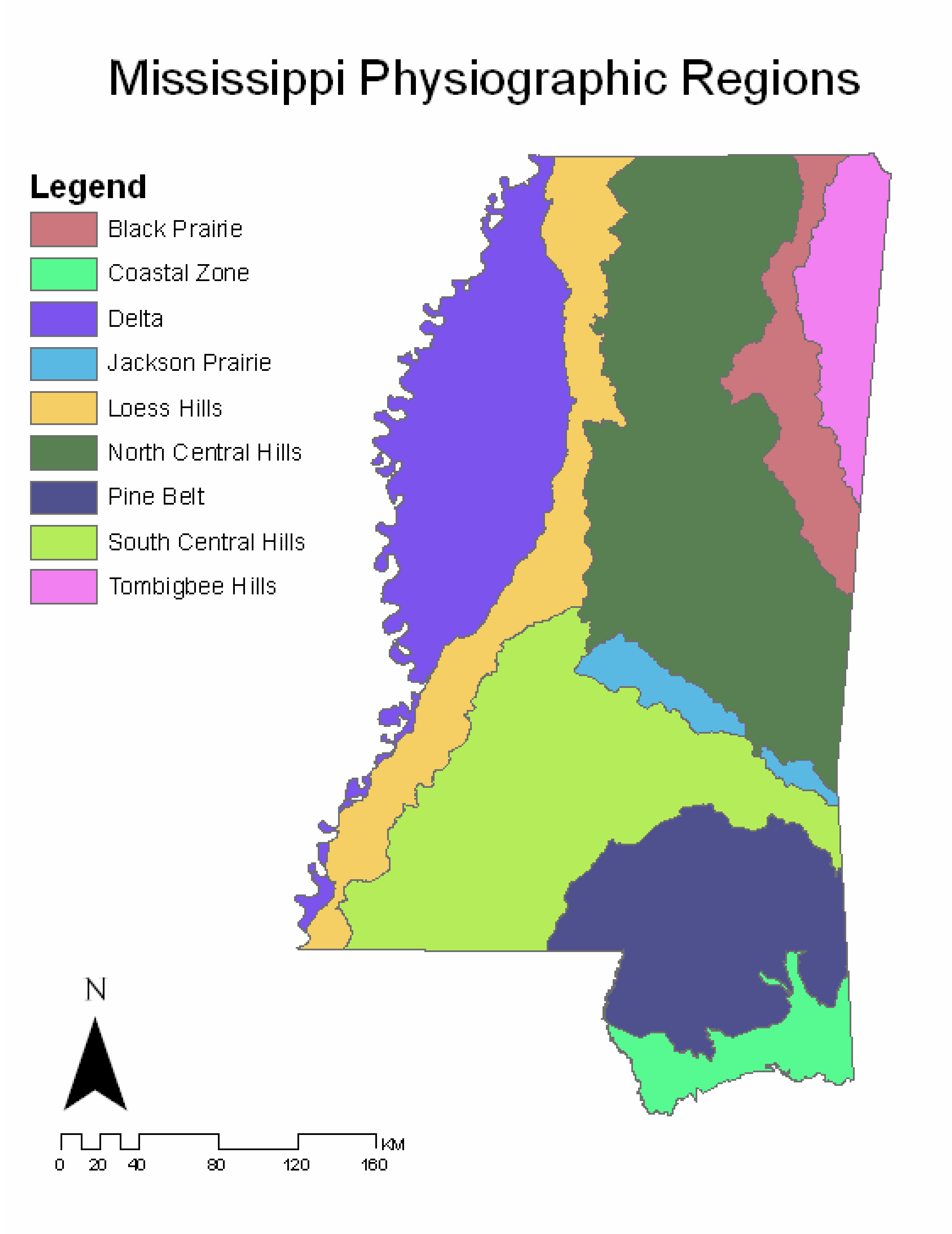


Fig. 2.2. The spatial physiographic regions of Mississippi.

better understanding of whether cumulative precipitation deficit or surplus is a modifier of average wildfire size and wildfire frequency for Mississippi's early season wildfires.

Precipitation is one of the many climatic variables considered in quantifying the characteristics of wildfires. Antecedent meteorological variables needed for fire potential models in Mississippi are not clear (Cooke *et al*. 2007) for the early wildfire season in Mississippi. For this reason, precipitation was investigated by means of the physiographic regions in Mississippi to gain a better understanding of precipitation trends leading up to early wildfire season in the state.

CHAPTER III

RESEARCH OBJECTIVES

The primary objective of this research was to investigate cumulative antecedent precipitation at various temporal lags as a driver of acreage burned and wildfire frequency for early season wildfires in Mississippi. The landscape of physiographic regions was used to stratify homogeneous landscape conditions as a response to precipitation.

The secondary objective of this research was to determine the role of a water year as a calibration method for future potential wildfire models for the early wildfire season in Mississippi. The final objective was to develop a climatic database for total precipitation per physiographic region from 1991-2005.

CHAPTER IV

METHODS

Data Preparation

Wildfire data used in this study were obtained from the Mississippi Forestry Commission and included all wildfires in Mississippi that required the activation of at least one fire department crew. The data included the latitude and longitude of wildfire point locations between January 1, 1991 and December 31, 2005. Other attributes included the year, month, and day the wildfire occurred, the cause of the fire, and the size of the wildfire. The dataset did not include prescribed fires or structure fires.

Precipitation Data and Inherent Errors

The total monthly precipitation for the study period was obtained through the National Climatic Data Center (NCDC 2009). Since the antecedent precipitation for 1991 included November and December of 1990, precipitation data from 1990 were also obtained. Precipitation data were extracted from the cooperative station observations (COOP) and Automated Surface Observing Systems (ASOS). A network of 11,000 COOP sites and 800 ASOS sites exist nationwide. One hundred and twenty-nine COOP sites and 13 ASOS sites were used in Mississippi (Figure 4.2). The spatial distribution of ASOS and COOP stations has random observation locations. The implementation of

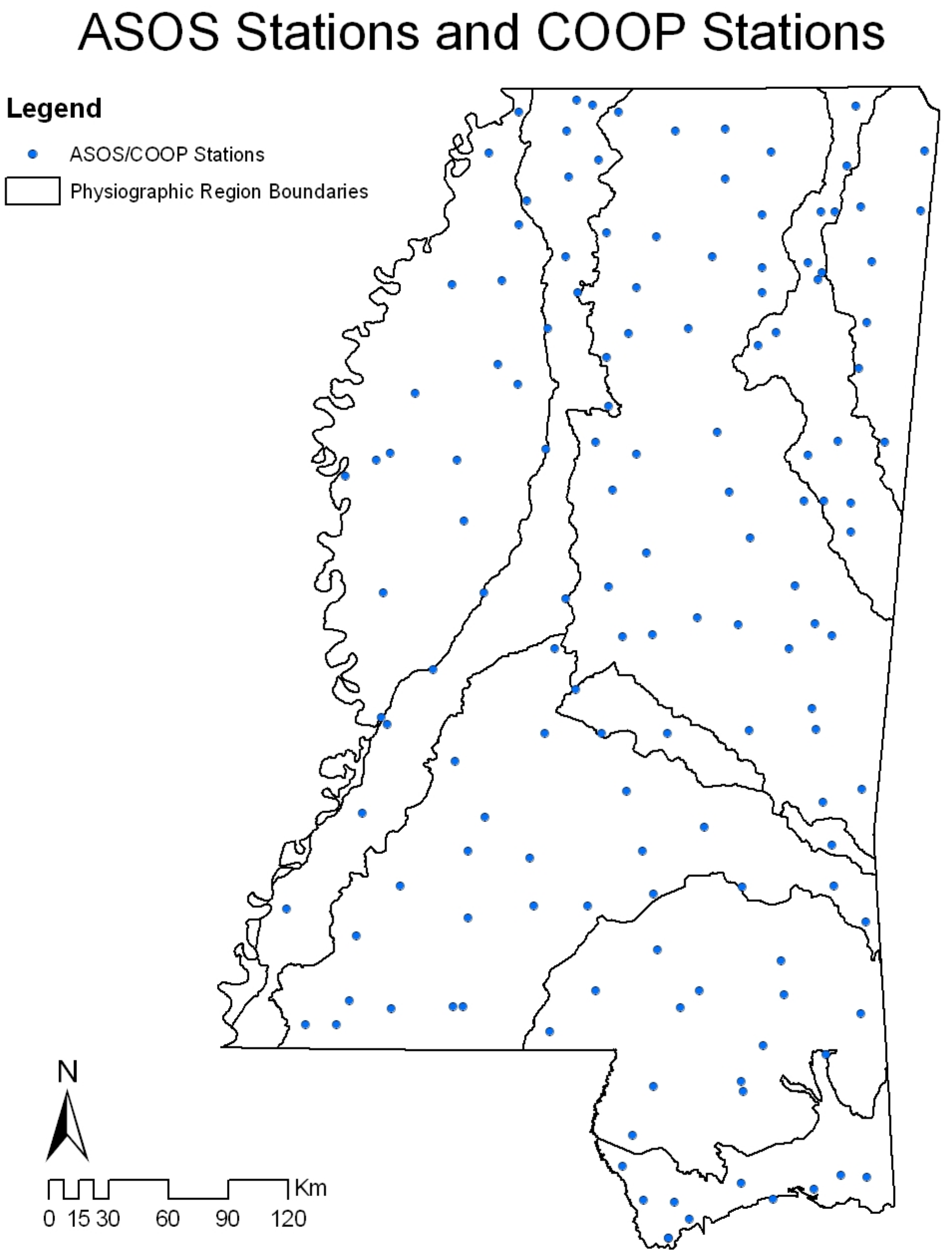
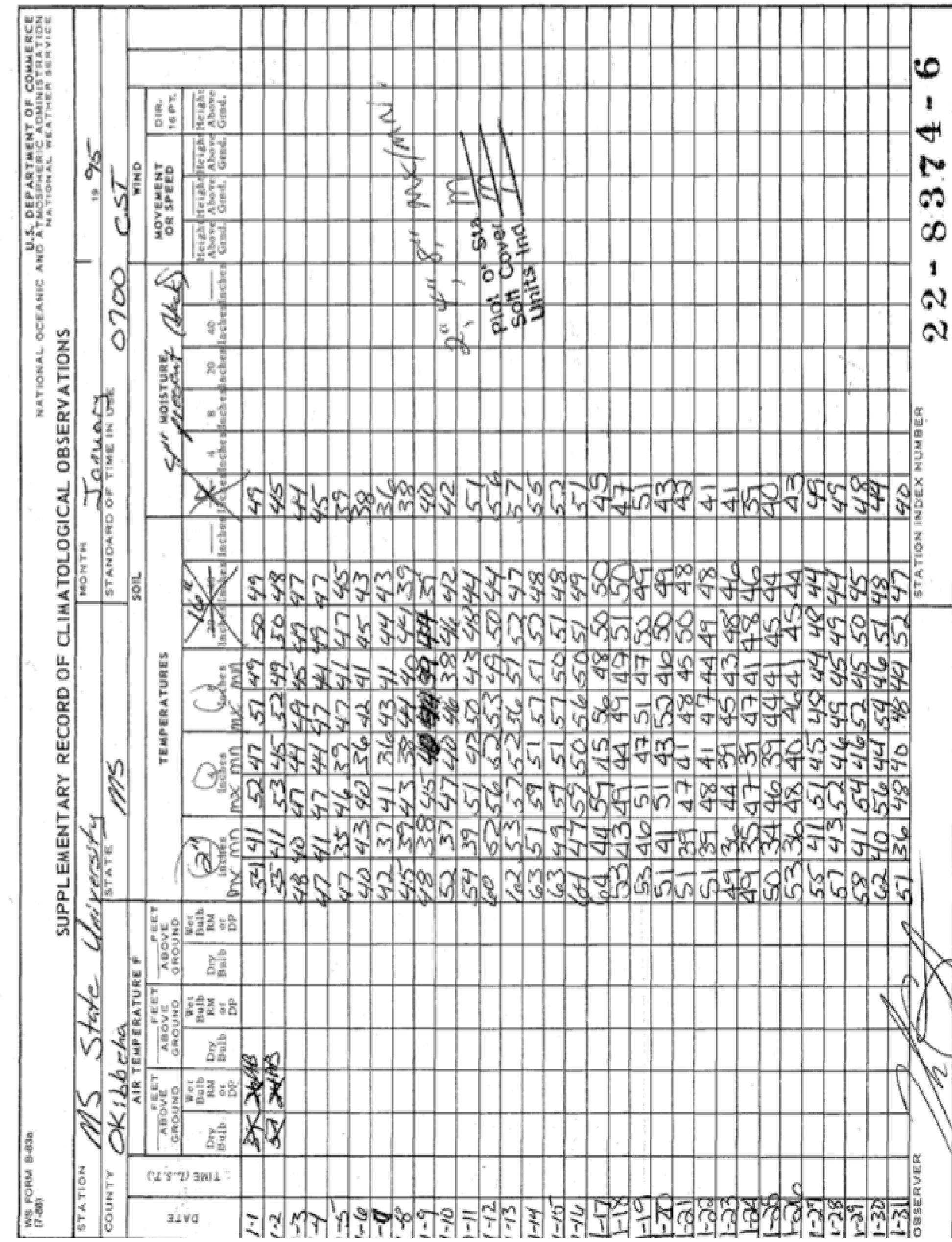


Fig. 4.1. The spatial distribution of ASOS and COOP weather observation station per physiographic region.

ASOS stations was a joint effort of the National Weather Service (NWS), the Federal Aviation Administration, and the Department of Defense. The ASOS observation stations have served as the nation's primary weather observing network (NWS 2009). COOP stations are the secondary weather observation sites used to enhance the quantity and quality of the observation network. Volunteers or contractors are part of the COOP program sponsored by the NWS. Volunteers do not have to complete any form of training to become an observer. Therefore, observer error may exist within the dataset and is considered an uncontrollable error. A second uncontrollable error was noted in the early records of the COOP observation stations. Original climate data were recorded on a National Weather Service form called a Weather Service B-92 form (Fig. 4.3) and was sent to NCDC each month and was converted into an electronic format. Early records of precipitation were manually recorded and later converted to a digital format. Through the digital conversion process, illegible handwriting may have resulted in the misrepresentation of the 24-hour precipitation records.

Data obtained by NCDC had missing records at various times and locations. Making necessary modifications to eliminate missing records created the most accurate representation of Mississippi's rainfall in a given month for a physiographic region. Missing values in the dataset were labeled as -*9999*. When a record was missing from either an ASOS or a COOP station, the precipitation record from the nearest observation station was used. Data from the nearest station were imported and used to replace the missing data record. The same technique was applied to all records that had missing records for the study period. Precipitation was summed by physiographic regions for



WS FORM B-92a (7-88)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SUPPLEMENTARY RECORD OF CLIMATOLOGICAL OBSERVATIONS

STATION MS State University

MONTH January 19 95

COUNTY Oktibbeha

STATE MS

STANDARD OF TIME IN USE 0700 CST

STATION INDEX NUMBER 22-8374-6

Fig. 4.2. The National Weather Service B 92 form.

each month (180 months) of the study period. The total precipitation data were aggregated for each physiographic region.

Pearson's Product Moment Correlation

Pearson's product moment correlation coefficient (r) computation was used to determine if a relationship exists between antecedent precipitation anomalies and subsequent wildfire frequency and acreage burned during the early wildfire season in Mississippi. The correlation statistic represents the degree of linear relationship between two variables. A relationship is considered significant if the probability of the observed test statistic ($\alpha = 0.01$ and $\alpha = 0.05$) is equal to or less than the test level. Smaller p values allude to more consistent correlations (Wilks 2006). Pearson's product moment correlation coefficient provides no explanation at all about the relationship between the variables in any physical or causative sense (Wilks 2006).

The correlation statistic (r) was used to correlate the cumulative precipitation leading up to the early peak in wildfires with acreage burned and wildfire frequency in Mississippi. The correlations were tested by lag times. Lag one was defined by the total precipitation for January and February. Lag two was defined by the total precipitation for December of the previous year, January, and February. Finally, lag three was defined by the total precipitation for November and December of the previous year, January and February.

Sample Variance

The population sample variance estimated for the sample data was used to assess overlap between means for each physiographic region around the mean to visually assess the degree of overlap among regions. The sample variance has a divisor of n-1 yielding, on average, the correct value for the population variance (Wilkes 2006). Dividing by n alone will underestimate the population variance. Although the computation can be easily derived, it often leads to a value well out of the range of the observations. It proves difficult to interpret. Wilkes (2006) explains the sensitivity of a large spread of samples effects the variance of the dataset. A very large data value will exert a strong influence on the mean, and that difference will be magnified by the squaring process (Wilkes 2006). The primary objective of this study was to determine if significant correlations existed between antecedent rainfall, acreage burned and wildfire frequency per physiographic region in Mississippi. The methods presented in this research provide a reasonable approach to test the significant correlations.

CHAPTER V

RESULTS

During the study period tested, Mississippi experienced the most predominate peak in wildfires in the winter/spring months The increased number of wildfires in the winter/spring months caused February and March to experience the most acres burned state-wide. Correlations between antecedent cumulative precipitation and wildfire acreage burned and wildfire frequency proved to be significant in the early wildfire season in Mississippi at various lag times for various physiographic regions.

Seasonality of Wildfires

Mississippi has an average of approximately 4,000 wildfires each year that require at least one fire department crew to extinguish the wildfire. During the study period, January 1990 – December 2005, Mississippi experienced 56,034 wildfires. In the 15-year study period, 46% of the total number of wildfires occurred in the winter/spring months and 29% of the wildfires occurred in the fall/winter months in Mississippi. The number of acres burned in the early wildfire season coincides with the increased frequency of wildfires during January through March. Although previous studies indicated anthropogenesis as the primary cause of wildfires, this study provided statistically significant correlations between wildfires and a climatic variable.

General Effects of Climate on Early Wildfire Season

Cumulative precipitation was inversely correlated with Mississippi's early wildfire season (Fig. 5.1 and Fig. 5.2). Statistically significant correlations, via Pearson's product moment correlation coefficient, existed between precipitation at various lags prior to the early wildfire season in Mississippi. The size and frequency of wildfires during the early wildfire season in Mississippi were correlated with the cumulative rainfall at lag one, two, and three for various physiographic regions.

Effects of Cumulative Precipitation at Various Lags by Physiographic Regions

Significant correlations, via Pearson's product moment correlations coefficient, were found in the majority of the hilly physiographic regions in Mississippi. Correlations at the $\alpha = 0.01$ and $\alpha = 0.05$ were tested for acreage burned and wildfire frequency. In both instances, all four of the hilly physiographic regions were significant at lag one. As much as 60% of the variance can be explained by the independent variables ($r = -0.772$). Statistically significant correlations were found for lag one, two, and three for 75% of the hilly physiographic regions.

Wildfire Correlations between Acreage Burned and Cumulative Precipitation

Statistically significant correlations between the cumulative precipitation subsequent to acreage burned and wildfire frequency prior to February resulted in statistically significant correlations for most of the hilly physiographic regions at lag one,

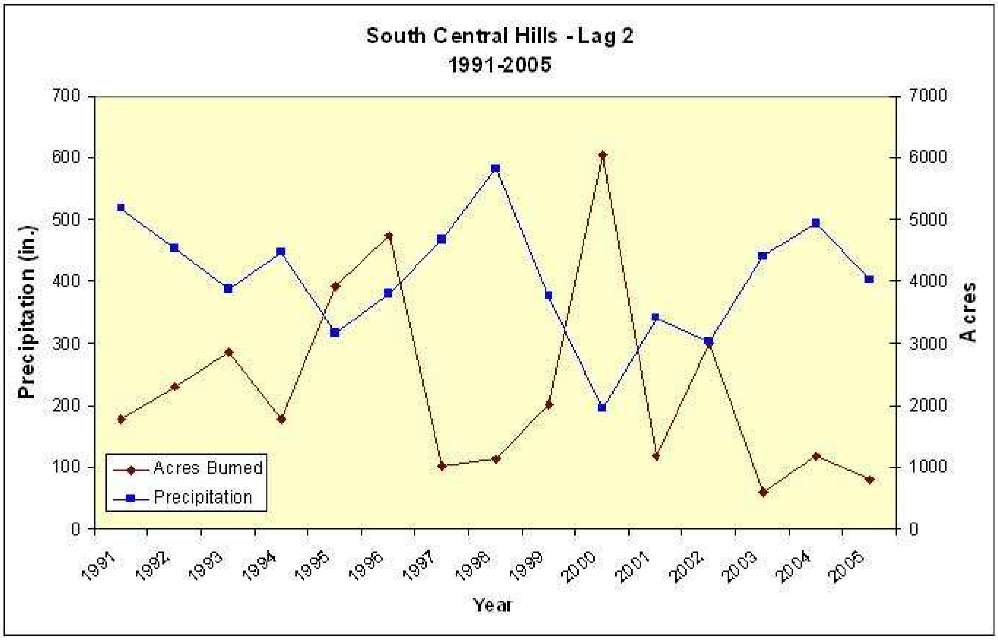


Fig. 5.1. Inverse Relationship between acres burned and wildfires at lag 2 for the South Central Hills

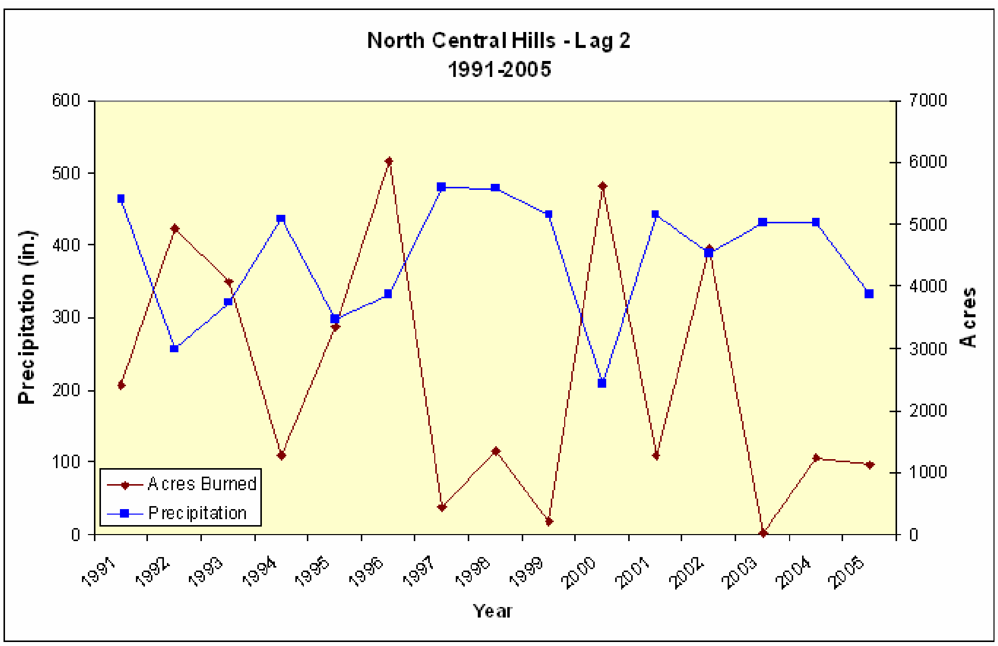


Figure 5.2. Inverse Relationship between acres burned and wildfires at lag 2 for the North Central Hills.

two, and three (Table. 5.1). As much as 60% of the variance was explained by the independent variable (r = -0.819).

Wildfire Correlations between Wildfire Frequency and Cumulative Precipitation

Correlations between wildfire frequency and cumulative precipitation were similar to the correlations between acreage burned and antecedent precipitation prior to February at lag one, two, and three per physiographic region (Table 5.2). Statistically significant correlations were observed in the hilly physiographic regions when correlating wildfire frequency and cumulative precipitation prior to February. Pearson's moment correlation coefficient was used to test the significance at the ($\alpha = 0.01$ and $\alpha = 0.05$) level.

Role of Physiographic Regions

The stratification of the physiographic regions affected the statistical significance among the varying physiographic regions in Mississippi. Significant correlations were found between the physiographic regions when statistically tested with the cumulative precipitation at various lags and wildfire acreage burned and frequency. Significant correlations between antecedent precipitation and wildfire acreage burned and frequency were found primarily among the hilly physiographic regions. Conversely, physiographic regions with flat or gentle relief were poorly correlated with antecedent precipitation.

Table. 5.1. Pearson's *r* correlations between acreage burned and cumulative precipitation at various temporal lags by physiographic region. Relationship with *p* values ≤ 0.05 are in bold, and those ≤ 0.01 are also shaded gray.

Physiographic Region		**No Lag**	**Lag 1**	**Lag 2**	**Lag 3**
Black Prairie	***r***	-0.597	**-0.783**	-0.566	-0.637
	p	**0.019**	**0.001**	**0.028**	**0.011**
Coastal Zone	***r***	-0.432	-0.260	-0.257	-0.232
	p	-0.260	0.350	0.356	0.405
Delta	***r***	-0.372	-0.493	-0.503	-0.541
	p	0.172	0.062	0.056	**0.037**
Jackson Prairie	***r***	-0.494	-0.457	-0.418	-0.418
	p	0.062	0.087	0.121	0.121
Loess Hills	***r***	**-0.642**	**-0.720**	-0.612	**-0.689**
	p	**0.010**	**0.002**	**0.015**	**0.004**
North Central Hills	***r***	-0.612	**-0.770**	-0.596	**-0.651**
	p	**0.015**	**0.001**	**0.019**	**0.009**
Pine Belt	***r***	-0.485	-0.194	-0.142	-0.161
	p	0.067	0.488	0.613	0.567
South Central Hills	***r***	**-0.772**	**-0.763**	**-0.771**	**-0.778**
	p	**0.001**	**0.001**	**0.003**	**0.001**
Tombigbee Hills	***r***	-0.639	**-0.692**	-0.460	-0.564
	p	**0.010**	**0.004**	0.084	**0.028**

Table 5.2. Pearson's *r* correlations between wildfire frequency and cumulative precipitation at various temporal lags by physiographic region. Relationship with *p* values ≤ 0.05 are in bold, and those ≤ 0.01 are also shaded gray.

Physiographic Region		Lag 0	Lag 1	Lag 2	Lag 3
Black Prairie	***r***	-0.521	**-0.719**	-0.374	-0.506
	p	**0.046**	**0.003**	0.170	0.054
Coastal Zone	***r***	-0.316	-0.081	-0.066	-0.207
	p	0.251	0.774	0.815	0.460
Delta	***r***	-0.278	-0.394	-0.455	-0.549
	p	0.317	0.147	0.088	**0.034**
Jackson Prairie	***r***	-0.545	-0.503	-0.482	-0.562
	p	**0.036**	0.056	0.069	**0.029**
Loess Hills	***r***	-0.638	**-0.694**	-0.567	**-0.645**
	p	0.010	**0.004**	**0.028**	**0.009**
North Central Hills	***r***	-0.640	**-0.737**	-0.547	-0.583
	p	0.010	**0.002**	**0.039**	**0.022**
Pine Belt	***r***	-0.563	-0.128	-0.102	-0.157
	p	**0.029**	0.651	0.718	0.577
South Central Hills	***r***	**-0.819**	**-0.707**	**-0.688**	**-0.713**
	p	**0.000**	**0.003**	**0.007**	**0.003**
Tombigbee Hills	***r***	-0.556	-0.611	-0.277	-0.393
	p	**0.031**	**0.016**	0.317	0.147

CHAPTER VI

DISCUSSION

The antecedent precipitation trends inversely affected the acreage burned and wildfire frequency. As cumulative precipitation decreased, the acreage burned and wildfire frequency increased. All tested variables were described as a negatively inverse relationship in this research. The significant inverse relationships in this study provided declarative correlations between climate and the early wildfire season in Mississippi. Pearson's product moment correlation coefficient statistic at $\alpha = 0.01$ and $\alpha = 0.05$ resulted in significant correlations with as much as 60% of the variance explained by the independent variables ($r = -0.72$, $\alpha \leq 0.01$), between cumulative precipitation with acreage burned and wildfire frequency in February by physiographic regions.

Within the hilly physiographic regions of Mississippi, significant correlations were found between cumulative precipitation with acreage burned and wildfire frequency. However, significance at $\alpha = 0.01$ at lag two explained less than 25% of the variance in the Loess Hills and the North central Hills ($r = -0.547$). Although significant at $\alpha = 0.05$ exist at lag one and three, there were no statistically significant correlations at lag two. Further research may yield an explanation. Numerous studies nationwide stress that the primary cause of early season wildfires are anthropogenic and that modification of size and frequency are due to human activity differences. This study, along with Dixon *et al.* (2008) and Pillai *et al.* (2009), shows that significant correlations exist between climate and wildfire acreage burned and frequency pointing to antecedent climatic conditions as a potential driving variable even when surplus rainfall patterns are observed.

Further research could investigate precipitation by rate, the number of rain free days, and potentially by summarizing precipitation by Bailey's Ecoregions and Omernik's Ecoregion. The significant correlations in the hilly physiographic region may be affected by landscape topography.

Physiographic Regions and Soil Drainage

Physiographic regions were successfully used as a stratum to test significant correlations between acreage burned and wildfire frequency in Mississippi. The majority of the hilly physiographic regions in Mississippi during the 15-year study showed statistically significant correlations with antecedent cumulative precipitation trends in the early season wildfires. Few significant correlations were found in remainder of the physiographic regions in the state. The landcover within the physiographic regions may help provide additional clues to correlative significance.

The hilly physiographic regions are predominately comprised of deciduous and evergreen trees. Soils within the hilly physiographic regions can be described by porous particulates allowing for water to easily drain. Although the early wildfire season is climatologically described by a period of surplus rainfall, high porosity soils can lead to a high drainage rate in the hilly physiographic regions. Relationships between type and amount of vegetation growing on a variety of soils may be related to wildfire frequency and are a likely source of uncontrolled variation in the fire data.

Hydrologic Year used as a Potential Recalibration Method

Precipitation trends prior to early wildfire season in Mississippi were not modified by using cumulative precipitation calibrated for a water year. Because significant correlations existed between acreage burned and wildfire frequency for February and at lag one within the calendar year, recalibration by a water year may not be necessary. Although antecedent moisture conditions were significant in a calendar year, other variables that affect the intensity of the early wildfire season may need to be recalibrated by a water year. The interactions of variables including the time of green-up, number of freezing days, and/or temperature may need to be recalibrated by a water year.

CHAPTER VII

CONCLUSIONS

The primary objective to test antecedent moisture conditions at various temporal lags as a driver of acreage burned and wildfire frequency with the early wildfire season in Mississippi was achieved. Statistically significant correlations exist between antecedent precipitation trends with acreage burned and wildfire frequency for early season wildfires at various lags. The secondary objective to test the usefulness of a water year as a calibration method for future potential wildfire models was also achieved. The role of physiographic regions was successfully used to stratify homogenous landscape conditions as a response to precipitation. The use of temporal lags was inconclusive in this study and did not prove to be necessary for cumulative precipitation. However, the interaction of various climatic variables by temporal lags may be important to correlate by a water year. The results of this study do not indicate the necessity to recalibrate the current wildfire potential model for Mississippi by a water year. Significant correlations found at month to month correlations and at lag one proves to be adequate within the calendar year. The final objective was also achieved. A climatological database for total precipitation was derived for the 15-year study period for each physiographic region.

The significant correlations found in this study provide the groundwork for further research in Mississippi's early wildfire season. Methods in this study can be applied to other climatic variables including wind, heating degree days, time of green up, and dewpoint temperature. Time series analysis of precipitation could provide enhanced information in wildfire potential models in Mississippi. Identifying the significant correlations of additional variables and variable interactions are necessary before this knowledge can be incorporated into future wildfire potential models for the state of Mississippi.

Future analytical studies should focus on summarizing the variables by different landscape partitioning techniques such as Omernick and Bailey's ecoregions. Studies summarized by these ecoregions may yield different results as compared to current findings. Once the studies have been summarized by different landscape features, then the potential wildfire models for Mississippi can be compared.

Another important aspect of future studies may incorporate the number of heating degree days that occur prior to the ignition of a wildfire on Mississippi's landscape. A threshold may be derived from this research and furthermore, one can determine the amount of plant desiccation that may occur. When a plant enters a desiccation phase, the moisture from the plant is evaporated and hence becomes a potential for the early wildfire season.

Understanding the characteristics of climatic variables that enhance the potential for wildfires can be used in wildfire management. Though the earth goes through climatic heating and cooling cycles, wildfires could become more frequent if temperatures increase through the next decade. Studies have already acknowledged an increase in wildfires in the west and research implies that these trends will continue

(Covington 2000; Pierce et al. 2004; Westerling et al. 2006). Therefore, climate is a very important aspect of wildfire seasons nationally, regionally, and statewide. Unusually warm and/or early springs and longer, drier summers lead to extended fire seasons, but it is unclear if these are due to global climate change or regular cyclic climate teleconnections (Westerling et al. 2003; Keeley 2004). Wildfires are both a hazard to forests and a danger to people. The use of teleconnections indices, in conjunction with ambient conditions of moisture, temperature, wind, and ongoing drought, should provide a better forecast of coming months as opposed to just a measure of previous months. Fire risk models are available nation-wide, however these models do not account for localized effects that may play a part in the wildfire seasons per state or per region.

This study enhances the information relevant to Mississippi fire regimes, and if incorporated into existing regional fire potential models, can help fire managers plan effective strategies for wildfire mitigation. These strategies might include optimization of allocation of precious fire fighting personnel and equipment that can result in reductions in fire size and decrease in the negative economic impacts due to wildfires in Mississippi and the southeastern region.

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