APPLYING MESONET WIND CLIMATOLOGY TO OKLAHOMA PRESCRIBED BURNS

Jeffrey Zuczek

National Weather Center Research Experience for Undergraduates, Norman, Oklahoma
Cornell University, Ithaca, New York

Dr. Mark Shafer

Oklahoma Climatological Survey, Norman, Oklahoma

ABSTRACT

Since 2001, twelve prescribed burning associations have been enacted in the state of Oklahoma. These burn associations perform a variety of tasks, such as the control of invasive plant species. The Eastern Red Cedar tree is especially notorious in Oklahoma for breaking up pastures and wildlife habitats. Prescribed burning is also a major tool used by farmers for crop preparation, via the controlling of invasive weeds. The benefits achieved from prescribed burning in Oklahoma are vast.

A burn must be carried out in a safe and predictable manner in order to reap its environmental benefits. Understanding prevailing weather conditions is a must when it comes to burning. This study specifically focuses on winds that exist during the time of burn. Wind climatology, via Oklahoma Mesonet data that extends from January of 1994 through May of 2008, is used to predict the likelihood of having several consecutive favorable burn days. A three-pronged criterion was developed to determine the constraints of a "favorable burn day" that is based primarily on information gathered from officials of the individual burn associations. A resulting burn calendar shows both daily and monthly trends of favorable burn days for February, March, and April. These specific months are desired by the burn associations for a variety of reasons, such as burning before native birds begin to nest and when relative humidities are still low. The daily burn calendars present a weak downward trend in the data. This trend suggests that of the three months considered in this study, February is the most favorable month to conduct prescribed burns. Monthly burn calendars, however, show a more pronounced downward trend. They present clear evidence that the frequency of favorable burn days declines from February through April. These results suggest that from a purely climatological perspective, it is wise to conduct burns earlier, rather than later.

1. INTRODUCTION

Lunsford and Wade (1989) define prescribed burning as "[t]he controlled application of fire to wildland fuels in either a natural or modified state, under specified environmental conditions which allow the fire to be confined to a predetermined area and at the same time produce the intensity required to attain planned resource management objectives." It is both a premeditated and safe process.

The practice of prescribed burning is important for a variety of reasons. The control of invasive plant species, such as Eastern Red Cedar, is a state-wide issue. Dobberstein (2007) acknowledges that the Eastern Red Cedar tree is invading Oklahoma at a rate of 726 acres a day. He further describes that the ramifications of this epidemic are numerous. Such ramifications include the destruction of wildlife habitats and the creation of health issues from the tree's associated pollen. In general, prescribed burning helps to reduce ground fuel that could normally be used by wildfires, while at the same time, recycling nutrients back into the soil. Prescribed burning is also a practice used to maintain plant diversity and native wildlife. Weir and Bidwell (2005) assert that "prescribed burning is the key land management tool used to restore and maintain native plant communities to their former diversity and productivity for livestock production and wildlife habitat. Without fire, native plant communities become dysfunctional and unproductive. Research has clearly shown that there is no substitute for fire."

For the purpose of this study, it is necessary to determine who performs prescribed burns in the state of Oklahoma. Dobberstein (2007) explains that farmers and ranchers use this tool to prepare their land for crop and hay production. Weir and Bidwell (2005) acknowledge that prescribed fire (or burn) associations are the main governing bodies responsible for performing prescribed burns in Oklahoma. Throughout the course of this study, I will refer to them as burn associations. Weir and Bidwell (2005) define these burn associations as "a group of landowners and other concerned citizens that form a partnership to conduct prescribed burns." In essence, burn associations are a cooperative led by citizens who believe that burning is absolutely necessary for land maintenance. As of 2008, the Oklahoma Prescribed Fire Council's website lists a total of 12 burn associations located in the state.

The purpose of this climatological study is to pinpoint a favorable time scale for conducting prescribed burns in Oklahoma. This study will concentrate strictly on wind climatology in determining when favorable conditions exist to burn. Focus is placed on constructing both daily and monthly burn calendars to ascertain if any trends exist. Section 2 presents the primary methodology of this experiment. It begins with the surveying of some of Oklahoma's burn associations as well as the development of wind criteria used to define a favorable burn day. A spatial comparison between two Mesonet stations is also made to determine if location influences the classification of favorable burn days. Section 3 presents the results. This section includes both daily and monthly burn calendars. Also constructed are year-to-year burn calendars to diagnose the reliability of this study's findings. The final section interprets the results and findings.

2. DATA AND METHODOLOGY

a. Guidance from Oklahoma Burn Associations

The primary data source for this project is the Oklahoma Mesonet. The Mesonet's monthly time series data ranges from January 1994 through May 2008 and consists of 120 automated stations. Specific variables of interest for this study are 10-meter surface wind speeds, 10-meter wind direction standard deviations, and 10-meter wind gusts.

To determine what conditions constitute a "favorable burn day," it was necessary to contact those officials who regularly perform these burns. The Oklahoma Fire Council's website as well as an article by Dobberstein (2007), allude to the many burn associations which are native to Oklahoma. Of the twelve that are currently listed on the Oklahoma Fire Council's website, only four were contacted via phone and email; the remaining eight either did not have contact information, have gone defunct since their start-up, or did not follow up to inquiries. The resulting associations that were of help to this study were Cimmaron Range Preservation Association, the Roger Mills Prescribed Burn Association, the Cross Timbers Prescribed Burn Association, and the Big Pasture Prescribed Burning Association. Focus is therefore placed on the counties and inclusive Mesonet stations in which these associations conduct their burns. Counties of concern include Alfalfa, Northern Woodward, Woods, Roger Mills, Beckham, Lincoln, Comanche, Cotton, Jefferson, Kiowa, and Tillman. One Mesonet station was chosen in each county to represent that county. An exception for Woods County exists. Alva would have been the station of choice, but it has relocated during the history of the Mesonet. It is necessary to choose a station that has had a consistent location during its lifetime. Freedom's Mesonet station was chosen for this reason. Therefore, the respective Mesonet stations used in this study include Cherokee, Woodward, Freedom, Cheyenne, Erick, Chandler, Medicine Park, Walters, Waurika, Hobart, and Tipton.

It is important to classify both temporal and physical thresholds that are used to classify a favorable burn day. These thresholds are based on information gathered from the burn associations as well as relevant literature and other sources. Appendix A presents data collected from interviews with the four prescribed burning associations. As evident, a general consensus exists in many of the categories. February, March, and April are the months primarily used to burn by the associations. For time of day, 9:00am-4:00pm received a nearly unanimous consensus. For the purpose of defining what truly is a favorable burn day based on wind parameters, it is necessary to inquire about the associations' own standards. The interviews with the four burn associations relayed a 4-20 mile-per-hour range in average wind speed during time of burn, as well as the need for a steady wind direction, and therefore low variance. In relation to wind gust speeds during the time of burn, the consensus was for an upper limit of 20 miles-per-hour.

b. Other Relevant Sources

The information obtained from the burn associations parallels relevant prescribed burning literature and other contacted sources. Porter (1997) notes that a burn should not be conducted while wind direction is variable. He designates a 5-15 mile-per-hour range in wind speed during the time of burn. White and Hanselka (1990) also pose the 5-15 mile-per-hour threshold for wind speed. They further acknowledge that wind direction should be consistent throughout the burn, though they do not provide a range (in degrees) of variation from the wind direction that was present at ignition. Wade and Lunsford (1989) mention that wind speeds for fire-weather forecasts are taken at a height of 20 feet. They describe that the minimum wind speed at this height for burning is approximately 6 miles-per-hour and the maximum is about 20 miles-per-hour. For the purpose of this study, the Oklahoma Mesonet measures surface winds at 10 meters (roughly 30 feet). John Weir, a research associate with the Natural Resource Ecology and Management who has conducted 710 prescribed burns in the last 20 years, also provided the 5-15 mile-per-hour wind speed threshold. In addition, he notes that you can prepare for up to and including a 45-degree change in wind direction and less than 20 mile-per-hour gusts during the time of burn.

c. Wind Criteria Development and Testing

Coupling both the information from Oklahoma's burn associations as well as the relevant literature and other contacts, a favorable burn criteria model was developed. A 5-15 mile-per-hour average wind speed range along with an upper limit of 20 miles-per-hour for wind gusts was chosen. Wind direction variation was set at an average of 30 degrees or less to allow for some variability. The real predicament for this study was how to determine what actually constitutes a favorable burn day. In other words, what distinguishes one day from another in how favorable it is to burn? For example, if on a certain day average wind speeds fell within the 5-15 mile-per-hour threshold, wind gusts were less than 20 miles-per-hour during the time of burn, but the wind direction was highly variable, should this day be discarded completely from the study, or accepted? For the purpose of this study, and due to the good degree of consensus between burn associations and other sources, we have defined a favorable burn day as one in which meets *all* the model criteria. Therefore this fictional day would be completely discarded from the study.

To test at first whether or not the data is supportive of these stringent thresholds, Woodward and Hobart stations are run through the model. Figures 1 and 2 represent Woodward and Hobart stations' wind profiles respectively.

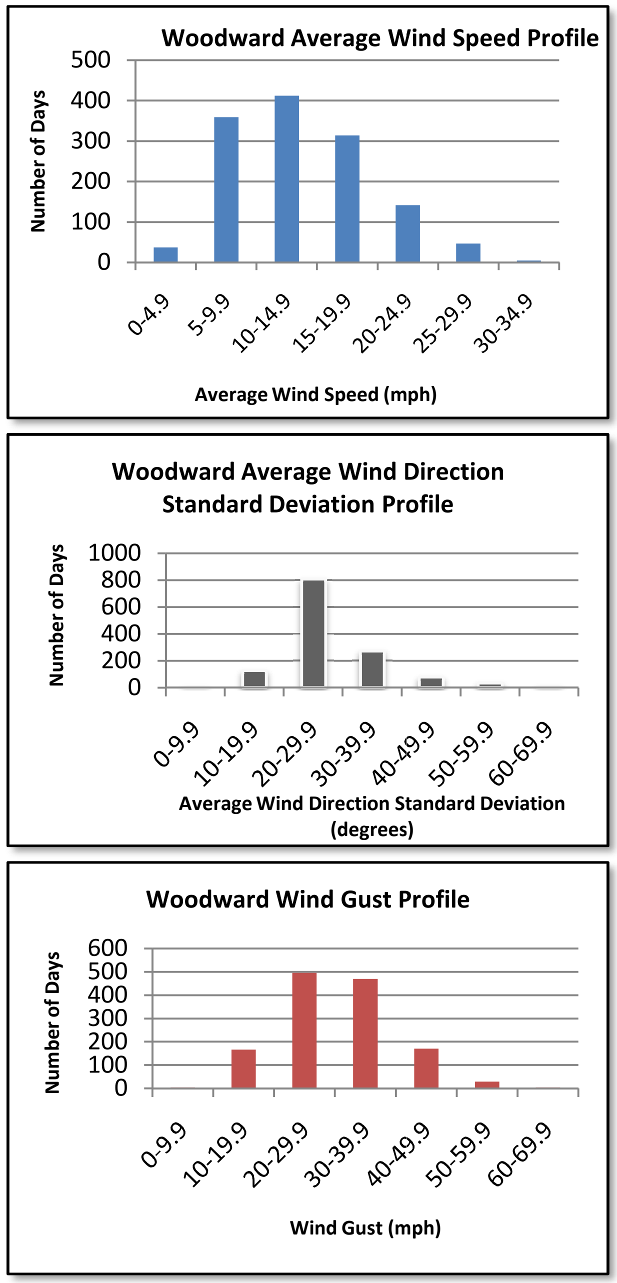


Figure 1: Woodward Mesonet Station's wind profile extending from 1994-2008 for the months of February, March, and April.

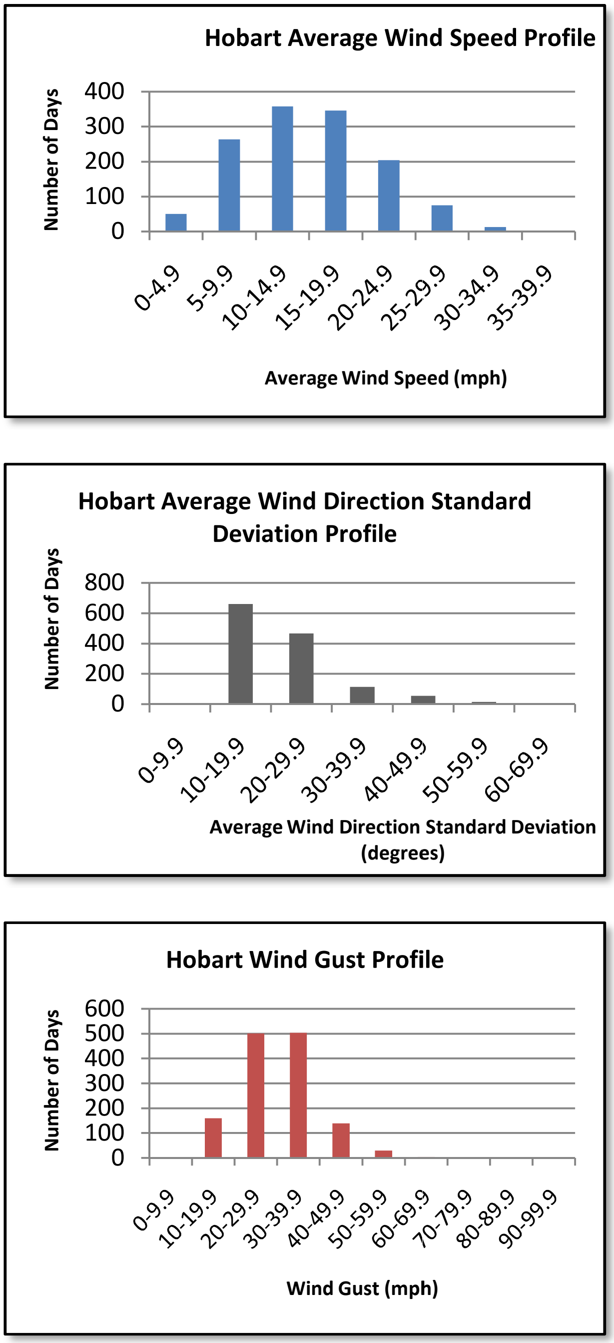


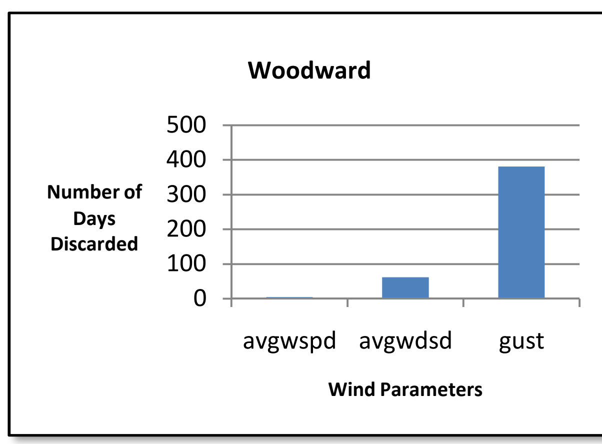
Figure 2: Hobart Mesonet Station's wind profile extending from 1994-2008 for the months of February, March, and April.

Both stations reasonably meet the criteria for average wind speed between 5-15 miles-per-hour and average wind direction standard deviation less than or equal to 30 degrees. The 20 mile-per-hour wind gust upper limit, however, discarded many of Woodward and Hobart's days. This cannot be avoided since this specific criterion was unanimous from all sources and considered a necessity for predictable burns. The majority of burn associations even noted that if gusts exceed 20 miles-per-hour, then they will actually stop the burn.

This test run demonstrates that the criteria developed to classify a favorable burn day are reasonable. The criteria is representative of the burn association's own standards, the consensus of the majority of the literature on this subject, as well as other contacted sources such as John Weir and Michael D. Porter.

d. Spatial Comparison of two Mesonet stations

To ascertain if a single burn criterion is discarding many of the model days, it is important to look at those days which only meet two of the three criterions. We can then assess if there is any correlation among stations for a single burn criterion that is not being met. To obtain a representative measure of the data, it is also important to incorporate the spatial variability of the stations. This approach allows a spatially accurate diagnosis of the wind parameter that is failing the model and therefore causing those days that only meet one or two of the criterions to be thrown out. The two stations chosen are Woodward's Mesonet station, located in Northern Woodward County in north-western Oklahoma, and Chandler's Mesonet station, located in Lincoln County in central Oklahoma. Figure 3 provides the comparison between these two stations.



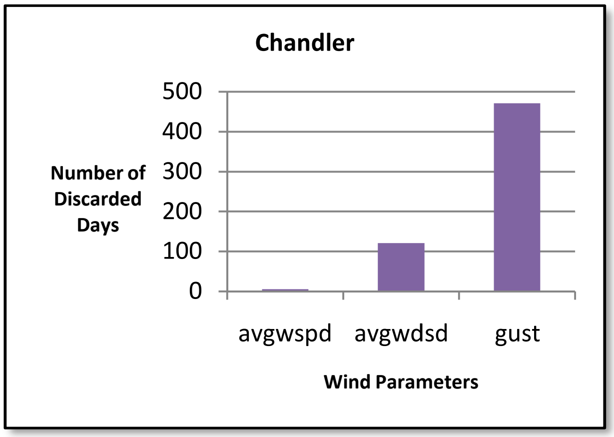


Figure 3: Spatial comparison between Woodward and Chandler Mesonet Stations. Parameters include Average Wind Speed (avgwspd), Average Wind Direction Standard Deviation (avgwdsd), and Gusts. The Comparison includes Oklahoma Mesonet data extending from 1994-2008 for the months of February, March, and April.

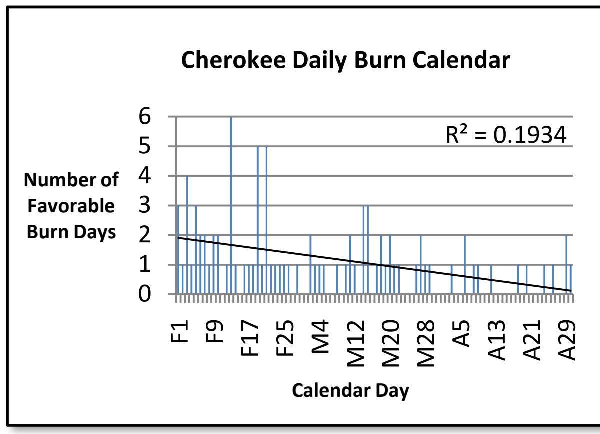
As is evident, Woodward and Chandler stations both show that the number of discarded days is highest for the gust criterion in the model. This parallels the previous testing for Woodward and Hobart stations which suggested that the criterion for less than 20 miles-per-hour gusts may be a problem. In this comparison, wind gusts single-handedly are responsible for discarding many of the days present in the Mesonet data set. Unfortunately, this criterion is one in which nearly all of the burn associations agreed on. To reiterate, for gusts that exceed 20 miles-per-hour, most burning associations said that they would completely stop the burn. Therefore, this criterion is upheld since the target audience for this research is primarily the burning associations themselves.

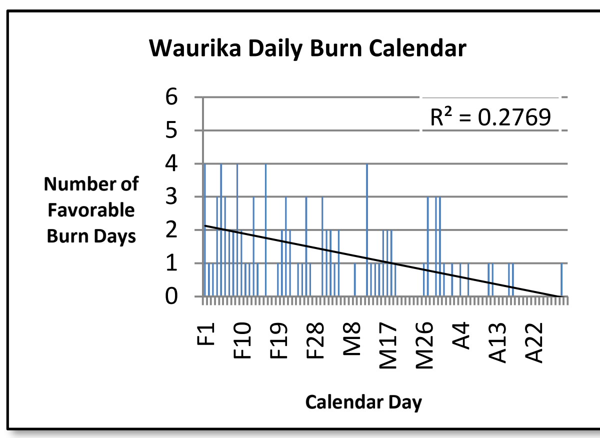
When comparing Woodward and Chandler's Mesonet stations, it is interesting to note their overall similarity. Despite the fact that Chandler is located in a denser vegetative part of the state, where it is reasonable to expect that wind directions may be more variable, their burn characteristics are much the same. This may suggest that favorable burn days, as classified in this study, may be independent of station location and overall topography.

3. RESULTS

a. Daily Burn Calendars

Daily burn calendars were constructed to ascertain if any trends exist in the number of favorable burn days (those days satisfying all model criteria). Figure 4 presents two arbitrarily selected Mesonet stations along with a composite daily burn calendar comprised of all eleven Mesonet stations. This allows a comparison between the trends shown in individual stations and any trend observed in a composite calendar of all eleven Mesonet stations. Appendix B consists of daily burn calendars for all eleven Mesonet stations considered in this study. Each histogram portrays all calendar days from February 1- April 30. Each calendar day serves as a bin for holding the total number of favorable burn days that have existed on that specific day throughout the history of the Mesonet. The maximum possible number of favorable burn days for a specific calendar day is therefore 15, since the Oklahoma Mesonet data set comprises the 15 years from 1994-2008.





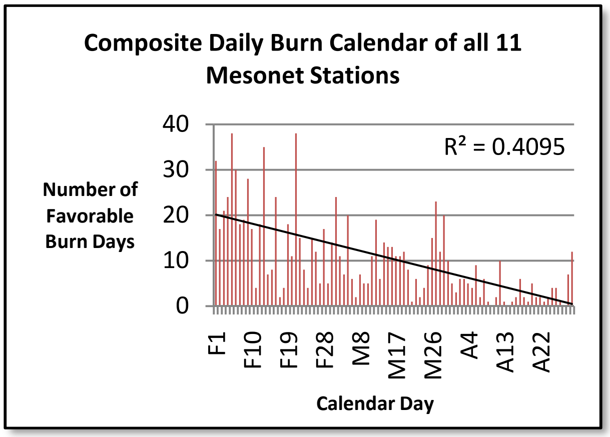


Figure 4: Daily burn calendars for Cherokee and Waurika Mesonet Stations, along with a composite daily burn calendar of all eleven Mesonet stations used in this study. Calendars extend the1994-2008 history of the Oklahoma Mesonet for the months of February, March, and April.

As is evident, a slight downward trend exists in all three histograms. Though these trend lines do not represent an adequate fit to the data, they suggest that the number of favorable burn days may decline from February through April. It is possible that these trend lines do not accurately match the data since not all calendar days have favorable burn days associated with them throughout the fifteen years of the data set. This would serve to hinder any viable trends.

b. Monthly Burn Calendars

To alleviate the trend issue of various calendar days having no favorable burn days in association, monthly burn calendars were developed. Instead of looking at calendar days individually, lumping each month's favorable burn days together accurately shows evidence of temporal trends. Figure 5 presents two arbitrarily selected Mesonet stations that are coupled with an integrated monthly burn calendar of all eleven Mesonet stations considered in this study. Appendix C consists of monthly burn calendars from all eleven Mesonet stations.

A more pronounced and striking downward trend exists in these calendars. This is evident from the high r-squared values present in the histograms. This evidence strongly suggests a decline in favorable burn conditions from February through April. Therefore, one can more accurately say, based on wind climatology, that days with favorable burning conditions are more frequent earlier on in this three-month period.

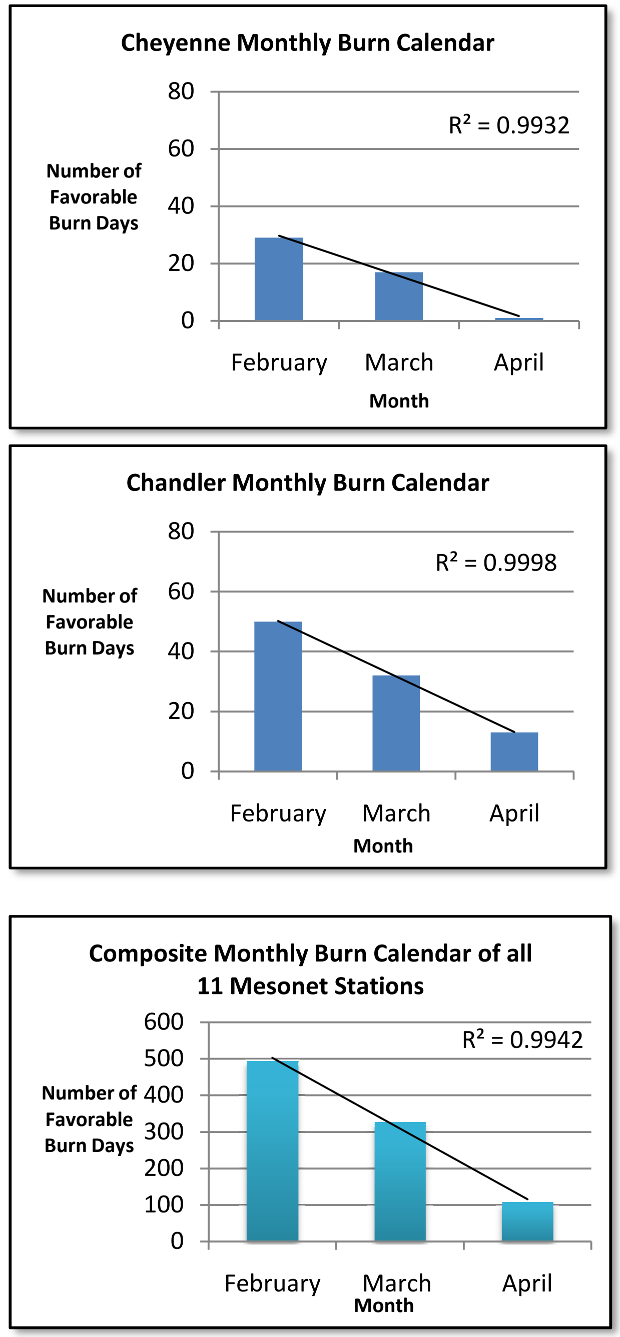
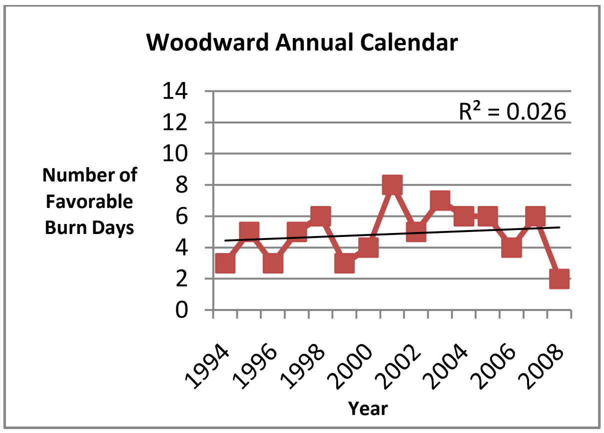
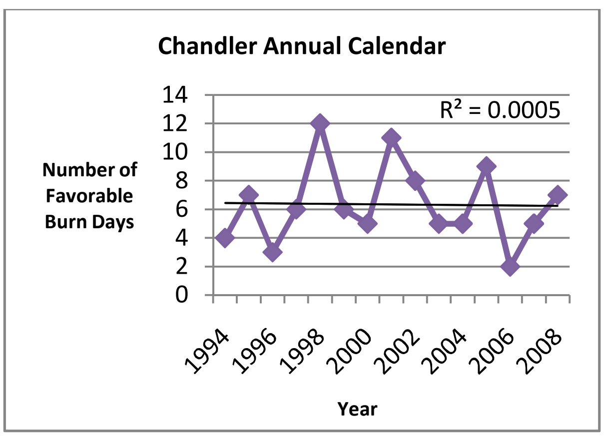


Figure 5: Monthly burn calendars for Cheyenne and Chandler Mesonet Stations along with a composite monthly burn calendar of all eleven Mesonet Stations. Calendars extend the 1994-2008 history of the Oklahoma Mesonet for the months of February, March, and April.

c. Analyzing Year-to-Year Trends in the Data

It is important to determine if there are any annual, or year-to-year, trends in the data. This allows a proper diagnosis of the reliability of the results. Potential questions that burn associations, or others who burn in the state of Oklahoma, may pose include: Can we assume that the decline in the frequency of favorable burn days from February through April will hold for this upcoming year? Is the number of favorable burn days increasing or decreasing by year? Is there a good consensus in how many favorable burn days we can expect per year? All of these questions try to ascertain whether or not a year-to-year trend exists in favorable burn days. Figure 6 presents two annual calendars from Woodward and Chandler Mesonet stations, as well as a total composite annual calendar of all eleven Mesonet stations used in this study.





These graphs plot the number of favorable burn days (those days meeting all three criterion) for each year of Oklahoma's Mesonet, only for the months of February, March, and April. If, for instance, there was an apparent downward trend, this would primarily suggest that the number of favorable burn days is decreasing with time throughout the history of the Mesonet.

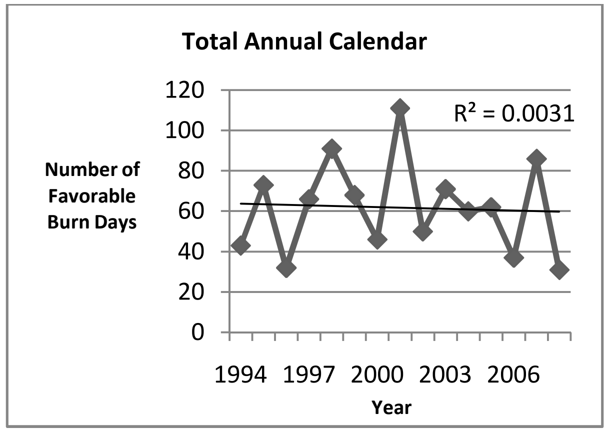


Figure 6: Annual calendars for Woodward and Chandler Mesonet stations along with a Total Calendar comprising all eleven Mesonet stations used in this study. Annual Calendars extend the 1994-2008 history of the Oklahoma Mesonet for the months of February, March, and April.

Therefore, those results would not be considered reliable since there may be little favorable burn days to plan for in years to come. However, this study's results show little presence of any trend in a year-to-year temporal scale. This suggests that the number of favorable burn days is not increasing or decreasing throughout the history of the Mesonet. It is reasonable to expect that the number of favorable burn days is stagnant from year-to-year. The yearly average for the number of favorable burn days for all eleven Mesonet stations during February, March, and April, is 61.8 days, with a population (all eleven Mesonet stations) standard deviation of 22.1 days. Those who conduct prescribed burns can expect about 5-6 favorable burn days on average from year-to-year during February, March, and April.

4. CONCLUSIONS

The daily burn calendars that were constructed show evidence of only a slight downward trend in the frequency of favorable burn days extending from February 1- April 30. This suggests that the number of favorable burn days may decline over this three-month period. The primary reason this trend does not accurately fit the data is that some calendar days were never associated with any favorable burn days throughout the 1994-2008 history of the Oklahoma Mesonet. Those days reporting zero favorable burn days were responsible for disguising any evident trends in the data. To adjust for this, calendars constructed on a monthly time scale were developed. These calendars presented a more striking and conclusive downward trend in the frequency of favorable burn days throughout this study's three-month period.

The overall conclusion of this study, based primarily on the monthly burn calendars, is that the frequency of favorable burn days declines from February 1-April 30. It is therefore a wise decision to burn earlier, rather than later, since the likelihood of burning on a favorable burn day is greater.

The absence of any year-to-year trend in favorable burn days over this three-month period bolsters the reliability of the results. The nearly horizontal trend lines present in the year-to-year histograms demonstrate that favorable burn days are neither increasing nor decreasing throughout the history of the Oklahoma Mesonet. These results can therefore be used as a climatological basis for prescribed burning decision-making in years to come.

5. ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. ATM-0648566. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

It is important to mention and thank those sources who contributed vital information to this study. First and foremost, members of Oklahoma's burn associations, including Verlin Hart of the Cross Timbers Prescribed Burn Association, Shelly Oliphant of the Cimmarron Range Preservation Association, Gregory Allen of the Roger Mills Prescribed Burn Association, and Al Bennett of the Big Pasture Prescribed Burning Association, all provided their time and information to this study. In addition, John Weir, a research associate at Oklahoma State University, also provided in depth information in regard to favorable prescribed burning conditions. Mr. Michael D. Porter with the Samuel Roberts Noble Foundation also provided pertinent information to this study.

Special thanks to Dr. Mark Shafer for support and guidance throughout this study as well as Mrs. Daphne LaDue for organizing the National Weather Center REU Program.

6. REFERENCES

Bidwell, T.G., J.R. Weir, Oklahoma Cooperative Extension Service, cited 2005: Prescribed Fire Associations. [Available online at http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-2819/NREM-2880web.pdf]

Bidwell, T.G., J. D. Carlson, S. Conrady, S. D. Fuhlendorf, R. E. Masters, J. Waymire, J. R. Weir, 2003: Using Prescribed Fire in Oklahoma. Oklahoma Cooperative Extension Service Tech. Rep. E-927, 36 pp.

Dobberstein, J., 2007: 'Burn Associations' Hot Topic. *Tulsa World*, 18 April.

Hanselka, C. W., L. D. White. Texas Parks and Wildlife Department and Texas Agricultural Extension Service: Prescribed Range Burning in Texas. [Available online at http://www.tpwd.state.tx.us /publications/pwdpubs/media/pwd_bk_w7000_0196.pdf]

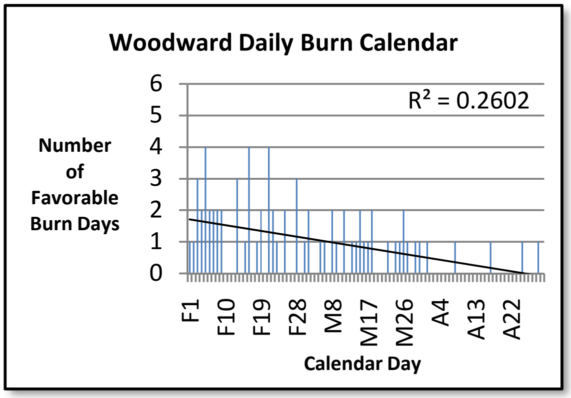
Lunsford, J. D., and D. D. Wade, 1989: A Guide for Prescribed Fire in Southern Forests. Georgia Forestry Commission Tech. Rep. R8-TP 11.

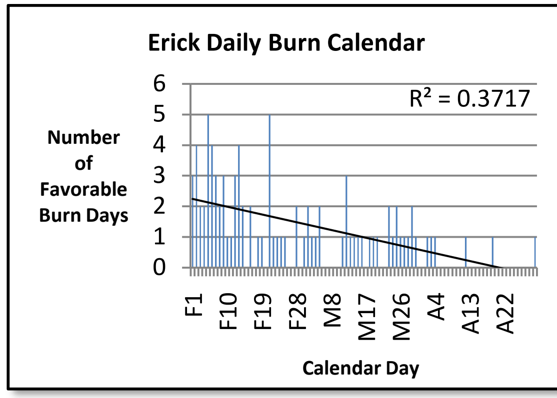
Porter, M. The Samuel Roberts Noble Foundation, cited 2000: Hot to Conduct a Prescribed Burn. [Available online at http://www.noble.org/ag/Wildlife/prescribedburn/Index.html]

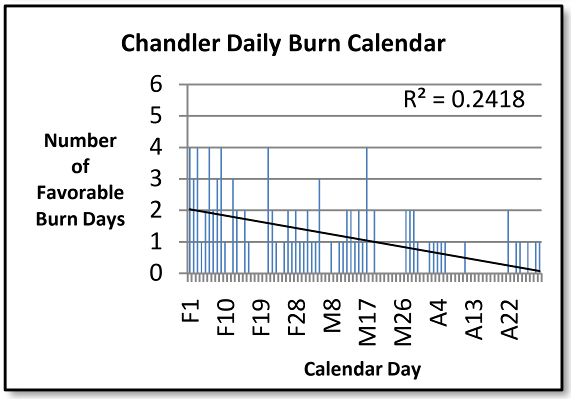
Appendix A: Information surveyed from Oklahoma's Prescribed Burning Associations

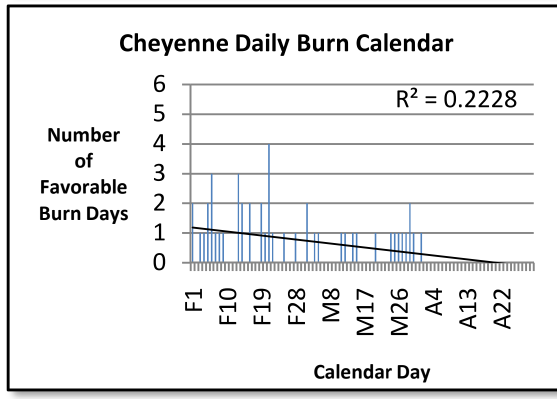
	Time of Year	Time of Day	Wind Speeds	Wind Direction variation	Gust
Cross Timbers Prescribed Burn Assoc.	February 1-April 30	9:00am-4:00pm	4-15 mph	≤ 20 deg.	< 20 mph
Cimarron Range Preservation Assoc.	late February, March, April	9:00am-4:00pm	4-20 mph	Site specific	≤ 20 mph
Roger Mills Prescribed Burn Assoc.	February 1-April 15	9:00am-4:00pm	≤ 20 mph	Site specific; usually 10-20 deg.; some 30 deg. +	< 20 mph
Big Pasture Prescribed Burning Assoc.	February, March, occasionally early April	10:00am-3:00pm	< 20 mph	Site specific; prefer consistent wind direction during burn	< 20 mph

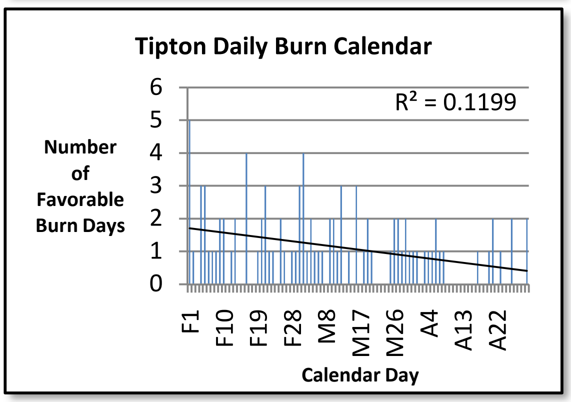
APPENDIX B: Daily Burn Calendars

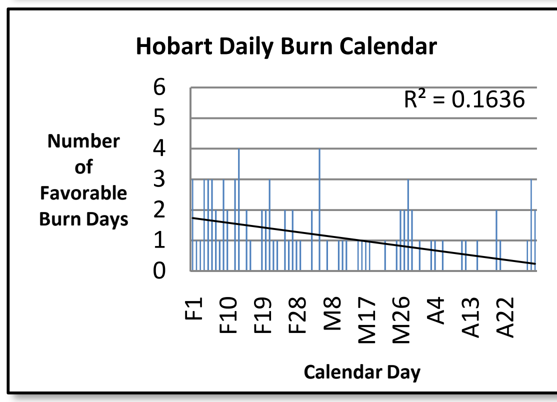


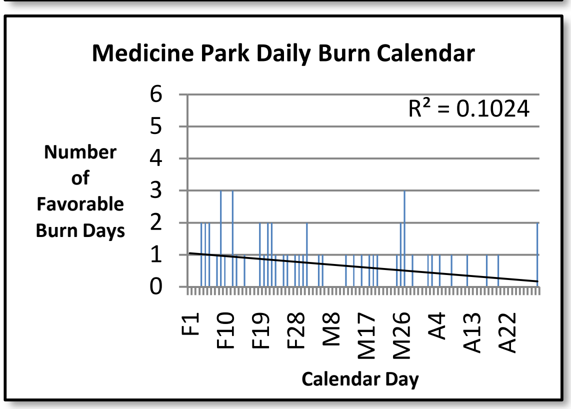


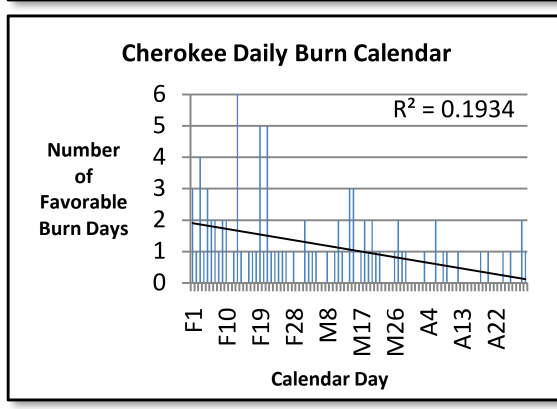


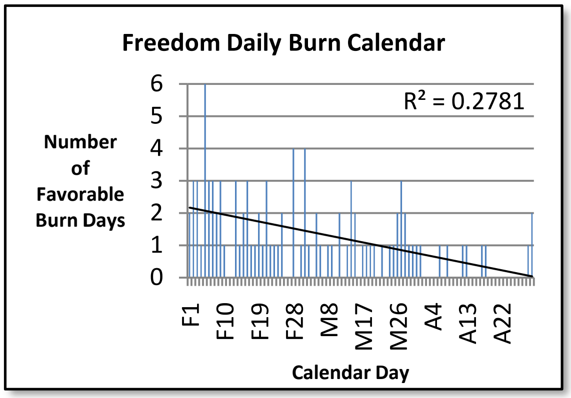


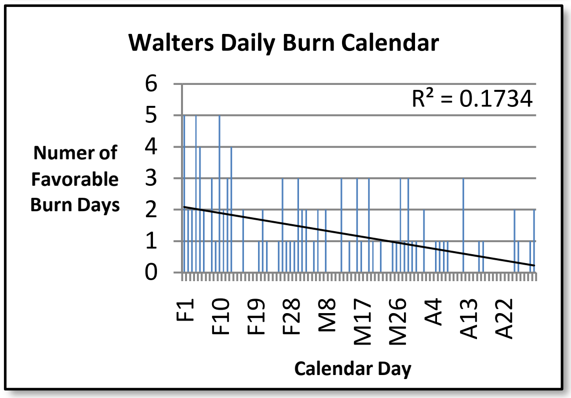


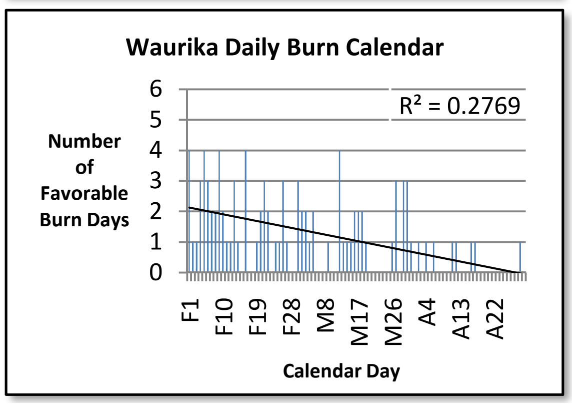


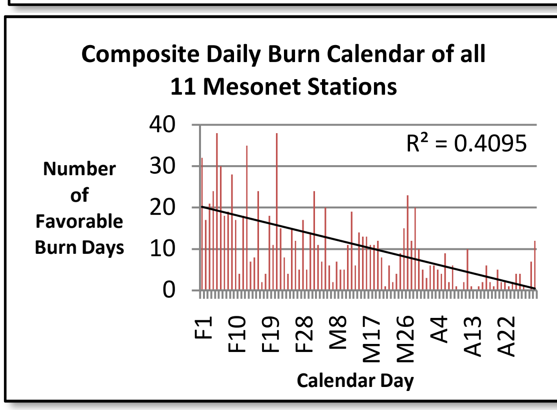




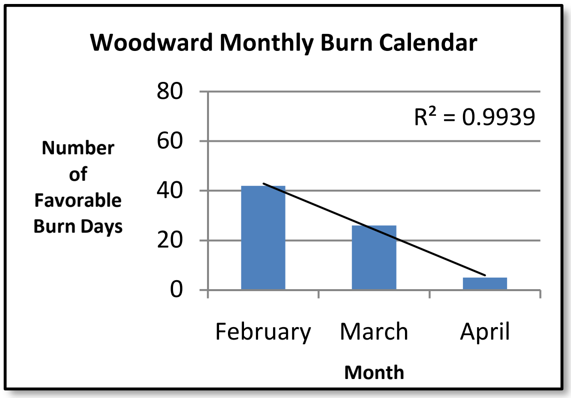

Freedom Daily Burn Calendar
Number of Favorable Burn Days
6
5
4
3
2
1
0
R² = 0.2781
F1
F10
F19
F28
M8
M17
M26
A4
A13
A22
Calendar Day

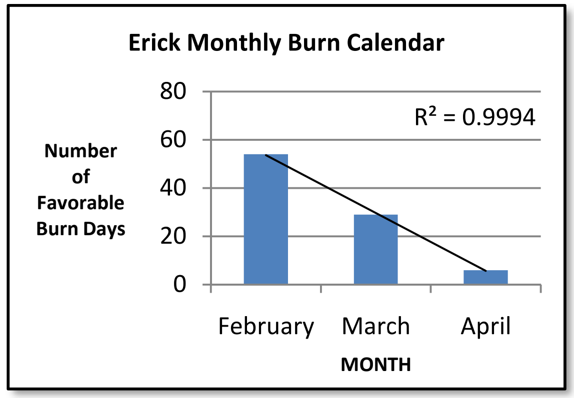

Walters Daily Burn Calendar
Numer of Favorable Burn Days
6
5
4
3
2
1
0
R² = 0.1734
F1
F10
F19
F28
M8
M17
M26
A4
A13
A22
Calendar Day

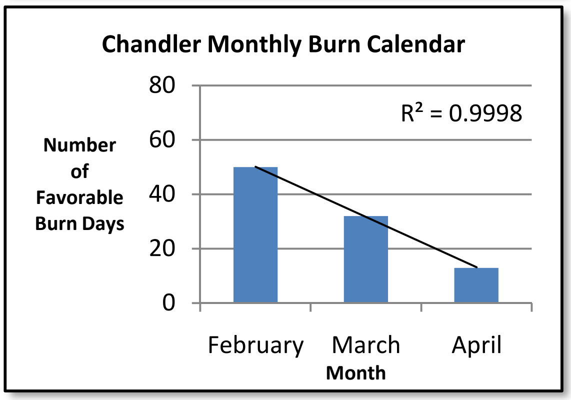

Waurika Daily Burn Calendar
Number of Favorable Burn Days
6
5
4
3
2
1
0
R² = 0.2769
F1
F10
F19
F28
M8
M17
M26
A4
A13
A22
Calendar Day

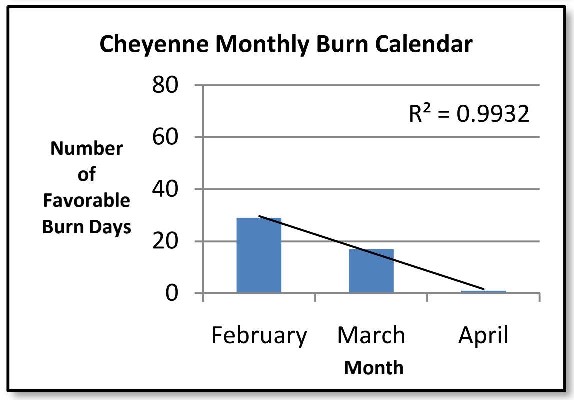

Composite Daily Burn Calendar of all 11 Mesonet Stations
Number of Favorable Burn Days
40
30
20
10
0
R² = 0.4095
F1
F10
F19
F28
M8
M17
M26
A4
A13
A22
Calendar Day

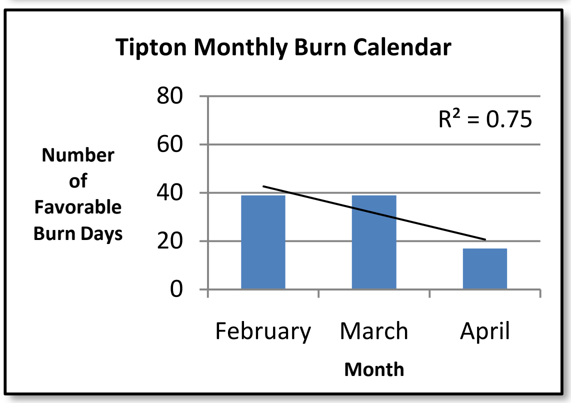
APPENDIX C: Monthly Burn Calendars

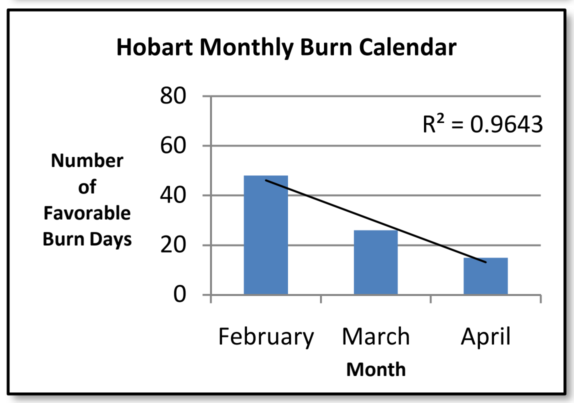


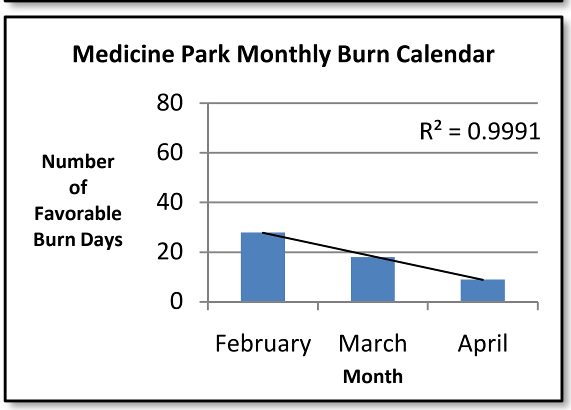


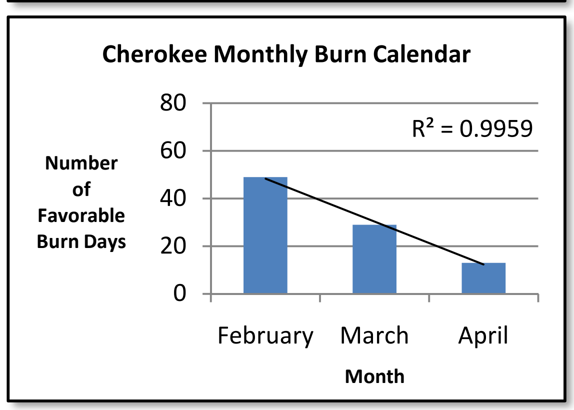


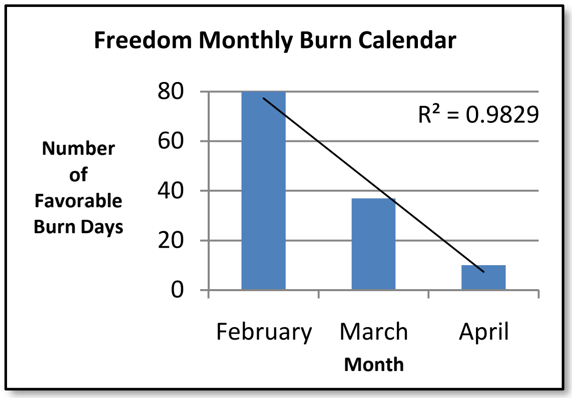


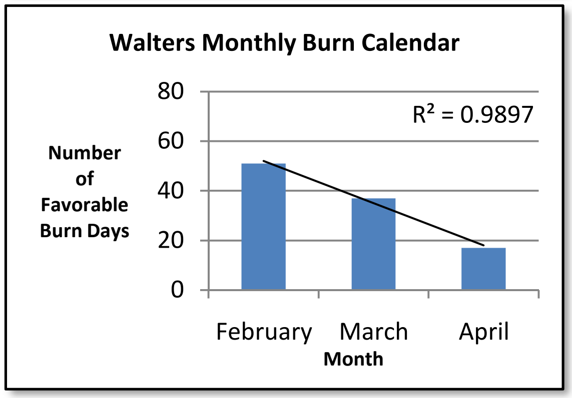


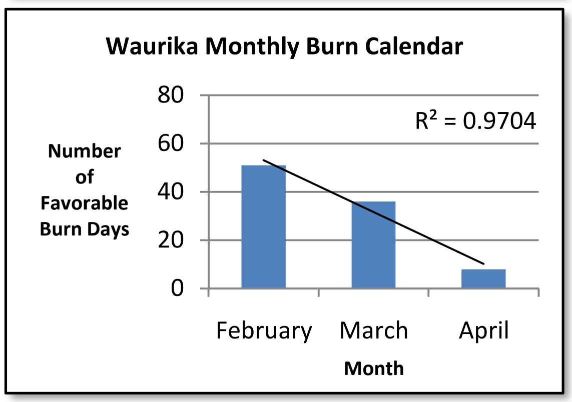


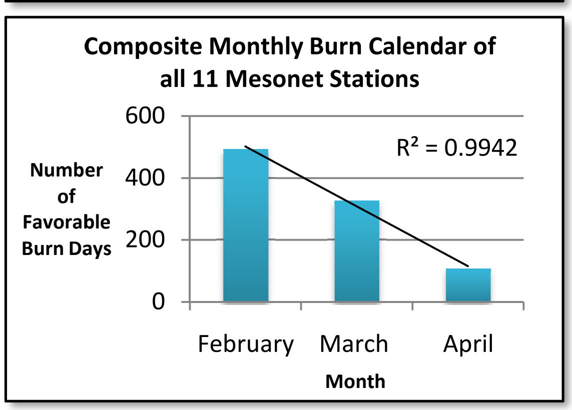





Freedom Monthly Burn Calendar
Number of Favorable Burn Days
80
60
40
20
0
R² = 0.9829
February
March
April
Month


Walters Monthly Burn Calendar
Number of Favorable Burn Days
80
60
40
20
0
R² = 0.9897
February
March
April
Month


Waurika Monthly Burn Calendar
Number of Favorable Burn Days
80
60
40
20
0
R² = 0.9704
February
March
April
Month


Composite Monthly Burn Calendar of all 11 Mesonet Stations
Number of Favorable Burn Days
600
400
200
0
R² = 0.9942
February
March
April
Month