Predicting Forest Fire Occurrences with Seasonal Forecast Data

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ABSTRACT

Forest fires are influenced by environment conditions. This paper examines the correlation between average fire season temperature and amount of precipitation to the number of forest fires started by lightning. It was determined that a strong correlation exists between these two parameters and number of forest fires. This correlation was then used to determine if the NCEP seasonal forecast could be used to predict the occurrence of forest fires. It was determined that this model appears to be useful, but adjustments need to be made for operational use.

Introduction

Forest fires can be a major threat to both the public and the forest itself. In the year 2000, over 8 million acres of land was burned due to wildfires. These wildfires can affect homes, tourism, and wildlife if these fires are severe and unhealthful to the forest. If conditions seem extremely favorable for wild fires, precautions such as prescribed burns can be implemented to try to reduce the risk of fires.

Local National Weather Service offices and the Storm Prediction Center (SPC) issue forecasts pertaining to the probability of forest fires during the fire season. Information such as fuel availability, temperature, moisture, and other variables are used to make these forecasts. However, a long-range forest fire forecast does not exist; therefore, we wanted to use the NCEP long-range ensemble forecast model to enhance the accuracy of the Forest Service's risk assessment for the upcoming fire season. This information could be used to determine areas most at risk, proper location of equipment, and funds needed to support firefighting operations.

Data Sources

The National Agricultural Decision Support System (NADSS) website was used to obtain observational data for western Wyoming (approximately –110º to 107º longitude). Twenty-two observation sites (*See Appendix A*), over the period of 1970–2000, were selected to represent the climate within this region. Sites were chosen based on data available and location, including elevation and environment. Average monthly temperature and precipitation was obtained for each site. Some months, or even whole years, had missing data due to a lack of observations during that time period. It was assumed that the information obtained from NADSS was reliable and accurate.

Fire information for the state of Wyoming was obtained from the Desert Research Institute via Jared Anderson. This information included number of lightning started fires and total acres burned for each respective year from 1970 to 1996. This data only includes fires located on Forest Service Land. This leaves a large amount of forest area and other fires started due to other factors not being represented within this study.

Forecast Output

For our forecast data, we used the NCEP global circulation ensembles for the period from 1979 to 1999. This forecast data is in the form of monthly average temperatures and precipitation. We used the average temperatures and precipitation during the forecast period from the different forecast runs at specific sites within our forecasting region.

We found that four grid points for the model were located within our forecasting region. Our grid points are located at 42.19º N, 106.88º W; 44.06º N, 106.88º W; 42.19º N, 108.75º W; and 44.06º N, 108.75º W. It was determined that each grid point contained approximately 1.87º latitudes and 1.87º longitudes.

Analysis Procedure

Yearly and climate information for our region was determined using observed data. Compiling all twenty-two observing sites together was used to determine the monthly average temperature and precipitation for the years 1970–2000.

We wanted to find if there was a relationship between temperature and precipitation to the amount of lightning started fires and acres burned during a year. To determine if the number of fires and acres burned in a year is related to temperature, the months April through September for 1970–1996 were used. We used these months since the fire season normally peaks between June and August. The monthly average temperature for these months (average season temperature) was then computed and compared to the amount of fires and acres burned for each respective year. No correlation was found for the average season temperature and the acres burned. However, when the number of fires per year was plotted against the average season temperature, it was found that a correlation existed (*See Figure 1*). This conclusion was based on the best-fit line and R^2 value pf 0.59.

To determine if a correlation between the total precipitation during a season existed with the number of lightning started fires and acres burned, they were plotted against one another.

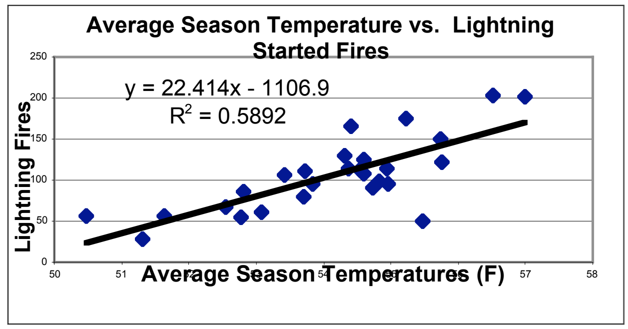

Figure 1. Average Season Temperature compared to Number of Lightning Started Fires

It was found that no strong correlation seemed to exist when taking the whole season's precipitation into consideration for either the number of fires or acres burned. However, a correlation between the total precipitation during the months of June and August for the number of lightning started fires was found (*See Figure 2*).

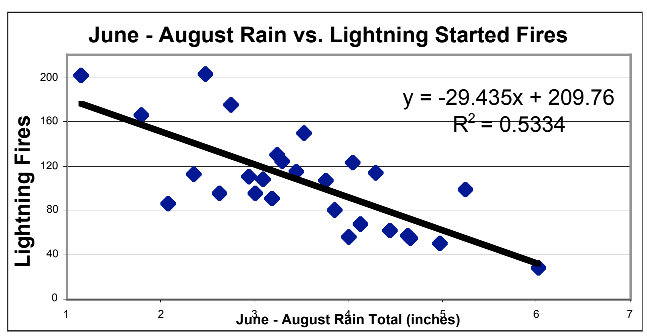

Figure 2. June through August precipitation compared to number of lightning started fires

Once correlations involving precipitation and temperature compared to the number of lightning-started fires were made, we wanted to determine if the model could be used to predict the number of forest fires per year. To do so, the four model grid points were averaged together to represent our region. When the model data was examined, it was found that it did not correspond to observed data. Differences between the model average temperature and observed average temperature were up to 12ºF in some cases. There was also a large discrepancy between the model precipitation and the observed precipitation data. To adjust for the discrepancy, we made an adjustment to the model's output temperatures and precipitation by calculating the difference between the observed data and the model output for each month during our forecast period. Next, we found the average of these differences from 1979 through 2000. This average difference was then added or subtracted, respectively, to each month to correct the model output (*See Table 1)*.

Table 1. Model corrections

	April	May	June	July	Aug.	Sept.
Temp.	-1.77	-0.65	1.40	6.23	6.49	4.07
Precip.	3.21	2.05	.07	-0.14	1.00	0.64

We then used the corrected model output data to try to predict the number of forest fires in each season. To do this, we input the corrected model output data into the equation we found by applying a best-fit line to our actual temperature and precipitation versus fires plots.

Results

Model Accuracy

As stated earlier, the model seemed to have significant biases. The largest discrepancies, over 6º, were found in temperatures for July and August. The precipitation bias did not seem to be as large. The largest correction, about one inch, was applied to August Precipitation. Even though April and May precipitation was not used, it was noticed that the model over predicted precipitation in these months on average between two and three inches.

Predictions from Average Season Temperatures

Using model averaged season temperatures, we found that across all years the average difference was only one; however, on a season-by-season basis, we see that the model does not perform as well as we would like it. During extreme years, one way or another, the model greatly overestimates or underestimates the number of fires (*See Table 2*). This can be seen in years 1984, 1987, 1988, and 1993. It is also worth noting that even though during 1988 the model under-predicted the amount of fires, it forecasted for more fires than normal. Though the model overestimated on some years, the model performed well during others.

Table 2. Number of lightning fires predicted from average season temperature

Year	Number of lightning fires	Predicted Number of Predicted fires	Differences
1979	96	100	-4
1980	130	101	29
1981	175	106	69
1982	55	106	-51
1983	62	90	-28
1984	57	128	-71
1985	125	101	24
1986	91	111	-20
1987	51	107	-56
1988	202	123	79
1989	115	119	-4
1990	150	112	38
1991	108	120	-12
1992	99	111	-12
1993	29	109	-80
1994	203	118	85
1995	68	102	-34
1996	166	107	59

Predictions from Average Season Temperatures

Using model precipitation output, we found the same trends as when we used temperature forecasts. The only difference being two additional extremes found during the years 1982 and 1996 (*See Table 3*).

Table 3. Number of lightning fires predicted from season precipitation

Year	Number of lightning fires	Predicted Number of Predicted fires	Differences
1979	96	104	-8
1980	130	144	-14
1981	175	109	66
1982	55	145	-90
1983	62	86	-24
1984	57	65	-8
1985	125	107	18
1986	91	126	-35
1987	51	94	-43
1988	202	41	161
1989	115	69	46
1990	150	91	59
1991	108	151	-43
1992	99	104	-5
1993	29	122	-93
1994	203	131	72
1995	68	102	-34
1996	166	52	114

Conclusions

From our data, we found that a correlation between the amount of precipitation versus the number of fires and averaged temperatures versus number of fires does exist in both cases. We feel this correlation is one of the biggest findings within our study, if not the biggest. This tells us that temperatures and precipitation are major factors in forest fires and can be used to assess fire probabilities.

Using this model as our forecasting tool appears to be our largest drawback. Over very large periods of time (years), the model appears to do very well. However, on a seasonal basis, the model does not perform to the standards needed for this type of forecasting. Since we need to be able to forecast on a seasonal basis, the model's inability to accurately forecast in this small of a time frame is the largest problem. Finding a better correction to compensate for the model bias seems to be a way to improve this method.

References

National Agricultural Decision Support System: http://nadss.unl.edu/datacenter/

High Plains Region Climate Center. Wyoming observing stations: http://hprcc.unl.edu/coop/location/WY_ACTIVE.html

Appendix A
Wyoming observing stations used

Name	Lat (d)	Lat (m)	Lon (d)	Lon (m)	Elevation (m)	Period of Record
Afton	42	44	110	56	1892.0	1/ 1/1957 - 4/29/2003
Basin	44	23	108	03	1170.0	1/ 1/1948 - 4/29/2003
Bedford 3 SE	42	52	110	55	1958.0	1/ 1/1975 - 4/29/2003
Big Piney	42	33	110	07	2079.0	1/ 1/1948 - 4/29/2003
Billy Creek	44	08	106	43	1516.0	1/ 1/1962 - 4/29/2003
Bitter Creek 4 NE	41	35	108	31	2048.0	1/ 1/1962 - 4/29/2003
Black Mountain	43	39	107	44	1718.0	1/ 1/1963 - 4/29/2003
Boysen Dam	43	25	108	11	1415.0	1/ 1/1948 - 4/29/2003
Buffalo	44	21	106	41	1423.0	1/ 1/1948 - 4/29/2003
Burgess Junction	44	46	107	32	2451.0	1/ 1/1960 - 4/29/2003
Cody	44	31	109	04	1539.0	1/ 1/1915 - 4/29/2003
Cora	42	56	110	00	2238.0	1/ 1/1979 - 4/29/2003
Dubois	43	34	109	38	2121.0	1/ 1/1948 - 4/29/2003
Farson	42	19	109	29	2067.0	1/ 1/1986 - 4/29/2003
Green River	41	32	109	28	1856.0	1/ 1/1915 - 4/29/2003
Jackson	43	29	110	46	1899.0	1/ 1/1948 - 4/29/2003
Jeffrey City	42	30	107	50	1926.0	1/ 1/1964 - 4/29/2003
Lake Yellowstone	44	33	110	24	2368.0	1/ 1/1948 - 4/29/2003
Rawlins Ap	41	48	107	12	2053.0	1/ 1/1951 - 4/29/2003
Snake River	44	08	110	40	2098.0	1/ 1/1948 - 4/29/2003
South Pass City	42	28	108	48	2390.0	1/ 1/1915 - 4/29/2003
Thermopolis 25 WNW	43	43	108	41	1736.0	1/ 1/1951 - 4/29/2003