

Effects of Fire on Sonoran Desert Plant Communities

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Abstract—The number of fires has increased during the past 45 years in the Sonoran Desert within the Tonto National Forest of central Arizona. The positive trend in the number of fires was consistent with an increase in the population of Maricopa County and an increase in traffic along major Sonoran Desert highways in the Tonto National Forest. The number of hectares burned did not change with increased population in Maricopa County or increased traffic along Sonoran Desert highways. However, number of hectares burned was influenced by the occurrence of two and three consecutive winters' precipitation. Overall plant density decreased as canopy cover increased on a time-since-fire (tsf) gradient. Native species most impacted by fires were saguaro (*Carnegiea gigantea*) and foothill paloverde (*Cercidium microphyllum*).

Introduction

Native Sonoran Desert plants lack fire-adapted characteristics, and their discontinuous spacing indicates that recurring fires were not significant in the long-term ecological history of the Sonoran Desert (Rogers 1986; Smith and others 1997). However, the changing fire regime in the Arizona Upland Subdivision of the Sonoran Desert has been an increasing concern during the past three decades. Increased fire occurrence could alter Sonoran Desert vegetation by removing several species, including the indigenous saguaro (*Carnegiea gigantea*) from plant communities (Cave and Patten 1984; Rogers and Steele 1980; Rogers 1985; Smith and others 1997; Wilson and others 2000). The spatial and temporal variation of fire in the Sonoran Desert appears to be highly sensitive to changes in climatic and anthropogenic activities. Climate and human activities influence fire regimes through their effects on fuel condition and fire ignition (DeBano and others 1998; Veblen et al. 2000). Precipitation and temperature govern the amount of vegetation that is produced and the moisture content of the fuels. Human activities often provide an ignition source to the fuels. The objective of this study is to determine which anthropogenic and climatic factors significantly influence the number of fires and number of hectares burned annually in the Sonoran Desert ecosystem, and determine the recovery of Sonoran Desert plant species on a time-since-fire (tsf) gradient.

Methods

Study Area

The study area consists of the Sonoran Desert ecosystem on the Tonto National Forest (TNF) in central Arizona. The

study area is typical of the Arizona Upland Subdivision (Shreve 1951), characterized by: saguaro, foothill palo verde (*Cercidium microphyllum*), creosote bush (*Larrea tridentata*), catclaw acacia (*Acacia greggii*), white thorn acacia (*Acacia Constricta*), mesquite (*Prosopis* spp.), bursage (*Ambrosia deltoidea*) and brittle bush (*Encelia farinosa*).

It generally extends from Phoenix north to Sunflower, and from the east side of Roosevelt Lake to Interstate Highway 17 on the west. Mean annual precipitation, during the past 45 years was 368 ± 19 mm of which 34% fell during winter (December-February), 18% during the spring (March, April and May), 22% during the summer (June-August), and 26% during the fall.

The number of fires and hectares burned were extracted from the Forest's individual fire reports. Population of Maricopa County and annual 24-hour traffic on State Highways 87 and 60 were used as anthropogenic factors that potentially affect the number of fires and hectares burned. The climatic factors consisted of seasonal and annual precipitation in the study area from 1953 through 2000 extracted from the National Oceanic Atmospheric Administration (NOAA) Climate Data Center records. The monthly totals from the Bartlett Lake, Stewart Mountain, and Roosevelt Lake Weather Stations were averaged to represent the Sonoran Desert moisture regime on the Tonto National Forest. Individual seasonal precipitation, combinations of seasons, and combinations of years of precipitation were used as variables affecting number of fires and number of hectares burned.

The anthropogenic and climatic factors were used as independent variables in a stepwise regression analysis to determine their power to influence the number of fires and hectares burned.

Table 1—A description of the study sites.

Study site	Year burned	Fire age category time-since-fire (tsf)	Time of year burned	Hectares burned
River Fire	1995	<5 years	July	3,845
Vista Fire	1993	5–15 years	May	36
Bush Highway Fire	1976, 1983, 1993, 1994	Repeat burns	May and June	40-200
Massacre Fire	1983	15–20 years	July	1,335
Siphon Fire	1979	20–25 years	June	283

Five previously burned sites were selected for determining the effects of fire on Sonoran plant communities. These were compared with adjacent unburned sites. The burned sites represent a stratum of time-since-fire of less than five years, five to ten years, ten to fifteen years, fifteen to twenty years, and twenty to twenty-five years (table 1). One site had repeated fires between 1976 and 1994.

A random-systematic design (Barbour and others 1999) was used to compare plant height, cover, and density between burned and control plots in the five burn sites. Five 100 m X 100 m (one hectare) homogeneous macro-plots were located within the burned area of each study site, and in adjacent control areas. Within each macro-plot, four randomly located 100 m transects were established. Canopy cover was measured by the line intercept method, in which the length of the intercept of canopy was measured for each species (Cox 1996). The height of each plant that intersected the line was recorded. The same 100 m line was used to form the center of a 2 m X 100 m belt transect. Density was estimated by counting the number trees, shrubs and perennial plants in the belt transects. The number of saguaro was counted within each 100 m X 100 m macro plot.

Results and Discussion

Climatic and Anthropogenic Influences on Sonoran Desert Fire Regimes

The annual number of fires increased sharply from 1955 through the early 1980s and stabilized somewhat from 1990 through 2000 (figure 1). The relationship between both human population and traffic, and the number of fires in the Sonoran Desert, was significant ($P = <0.05$); however, these factors were not significantly ($P = <0.05$) related to the number of hectares burned.

There was a significant increase ($P = 0.05$) in numbers of fires with increased annual precipitation, winter precipitation, two consecutive winters precipitation, three consecutive winters precipitation, and spring precipitation. However, summer precipitation, fall precipitation, and consecutive summer and winter precipitation did not have a significant relationship to the number of fires. Summer precipitation appears to have an inverse relationship to the number of fires, but the relationship was not significant.

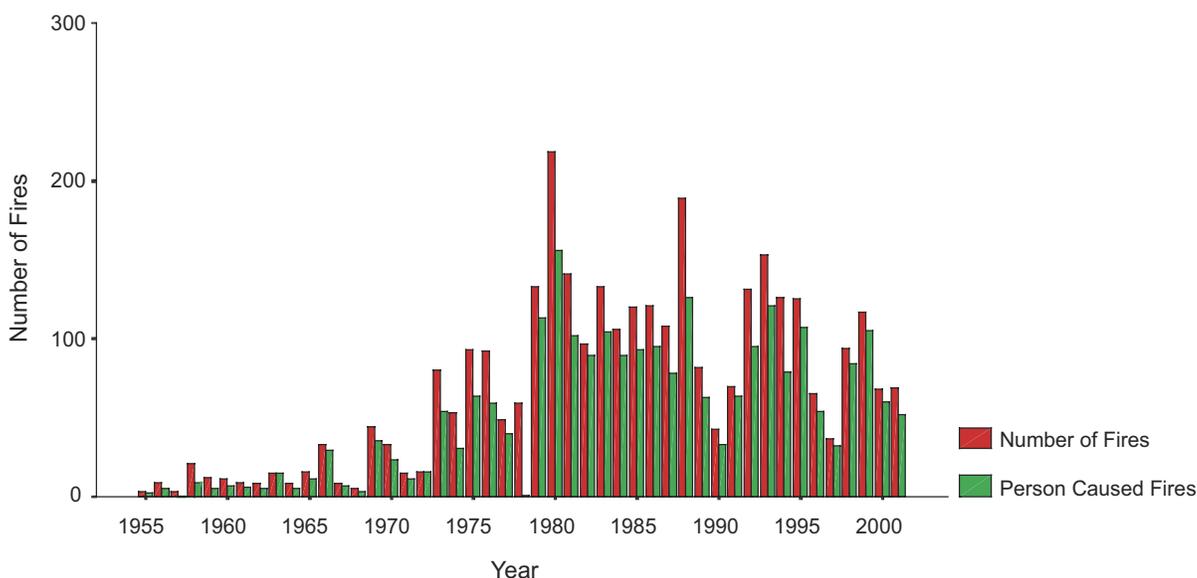


Figure 1—Total fires and person caused fires in the Sonoran Desert on the Tonto National Forest from 1955-2000.

The number of hectares burned increased with an increase in two and three consecutive winters' precipitation, and consecutive winter and spring precipitation; however, the number of hectares burned were not affected by the increase in population of Maricopa County or the increase in traffic on SH 87 and 60. The strongest variables for predicting the number of fires were "traffic" and "three consecutive winters' precipitation," while three consecutive winters precipitation was the strongest variable for predicting the numbers of hectares burned.

This study shows an interaction between the heavy anthropogenic activities, and arid early summer preceded by one to three consecutive wet winters. These conditions yield a vigorous fire season in late spring-early summer. The summer monsoons sharply reduce the incidence of fire in the Sonoran Desert by increasing fuel moisture and unfavorable fire conditions such as increased relative humidity.

Effects of Fire on Sonoran Desert Plant Communities on a Time Since Fire Gradient

The number of plant species decreased as time fire increased. However, canopy cover increased along the tsf gradient. The similarity of total canopy cover between the burned and control plots increased with time (figure 2). Canopy cover on the burned plots was 24% of the control plots on the River Fire (5 tsf) whereas the similarity of canopy cover between burned and controlled plots was 75% on the Siphon Fire (21 tsf). With this model one could predict that total ground cover would recover after approximately 28 years.

Saguaro and foothill paloverde were noticeably removed by fire from the burned plots in all but the Siphon Fire, which showed no significant difference in density of saguaro and a

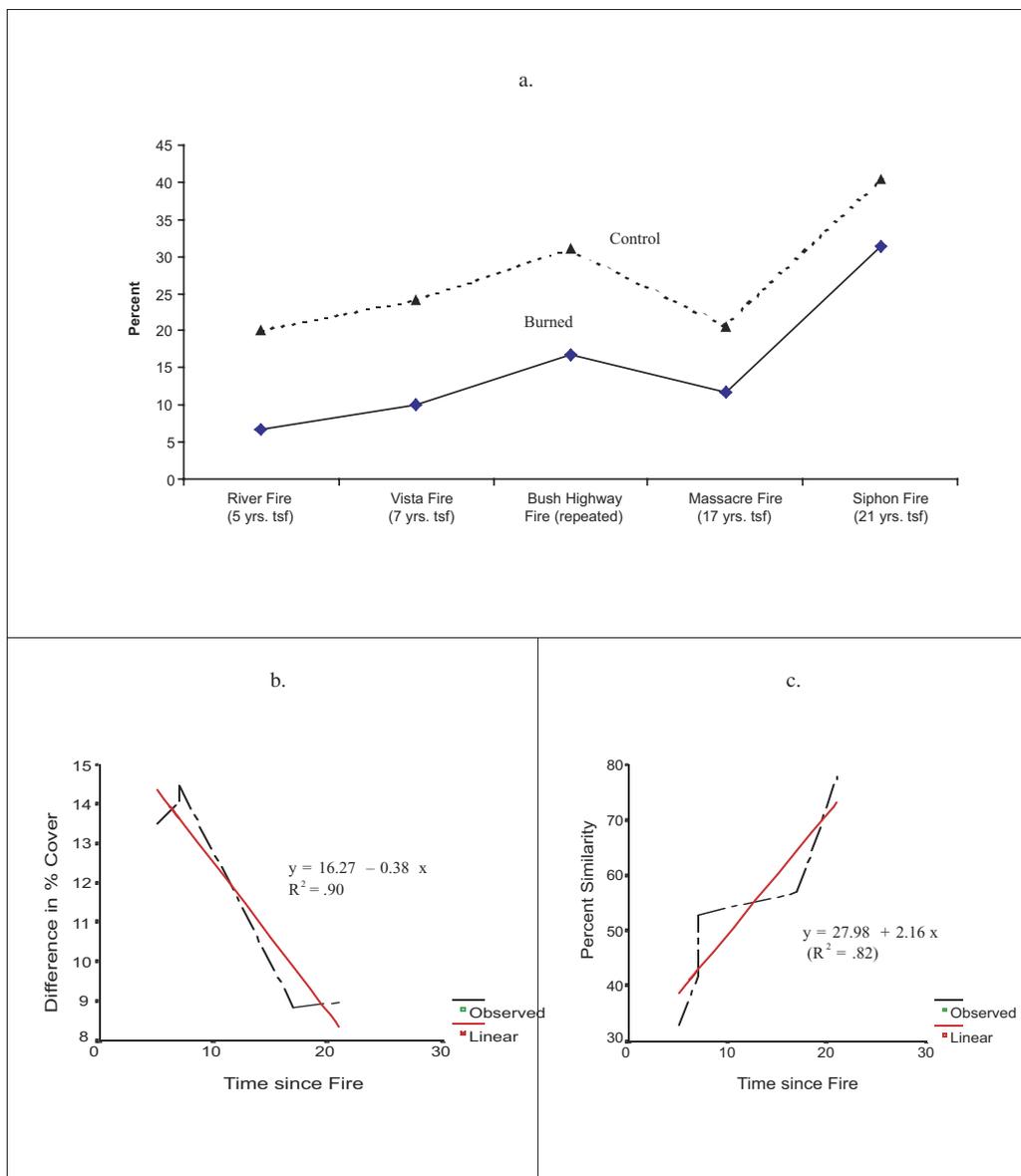


Figure 2—Canopy cover response to tsf. a. shows the canopy cover of burned and control plots; b. shows the difference in canopy cover between control and burned plots on a tsf gradient; c. shows the similarity between the burned and control plots on a tsf gradient.

small significant increase in density of foothill paloverde. It is difficult to conclude that saguaro has recovered on the Siphon Fire, since the pre-fire density is unknown and the recovery after fire is rare. However, 32 % of the saguaro in burned plots were <0.6 m in height. It takes 30 to 40 years for the saguaro to reach 1 m in height (Steenbergh and Lowe 1983; Pierson and Turner 1998). Therefore, plants that are 0.6 m should be 18 to 24 years old, within the time since the Siphon fire event. The 32% of the saguaro that were <0.6 m in height included plants that were a few centimeters up 0.6 m in height. Therefore, it is concluded that there was at least some recovery of saguaro on the Siphon Fire.

The Bush Highway Fire (repeated) appears to be the site most influenced by fire because of the loss of native Sonoran Desert vegetation. The highly significant increase in density and/or canopy cover of purple three-awn (*Aristida purpurea*) and senna (*Cassia Armata*), and the decrease in native species such as saguaro, foothill paloverde, white ratany (*Krameria grayi*), creosote bush (*Larrea tridentata*), and wolfberry (*Lycium berlandieri*) indicates that shrubs and nurse trees are being replaced with lower growing plants.

References

- Barbour, M. G.; J. H. Burk; W. D. Pitts; F. S. Gillam; M. W. Schwartz. 1999. Terrestrial plant ecology. 3d ed. New York: Adison Wesley Longman Inc.
- Cave, G. G.; D. T. Patten. 1984. Short-term vegetation responses to fire in the Upper Sonoran Desert. *Journal of Range Management*. 37: 491-96.
- Cox, G. W. 1996. Laboratory manual of general ecology. 6th ed. Dubuque, IA: Wm. C. Brown.
- DeBano, L. F.; D. G. Neary; P. F. Ffolliott. 1998. Fire's effects on ecosystems. New York: John Wiley & Sons.
- Pierson, E. A.; R. M. Turner. 1998. An 85-year study of saguaro (*Carnegiea gigantea*) demography. *Ecology*. 79: 2676-93.
- Rogers, G. F. 1985. Mortality of burned *Cereus giganteus*. *Ecology*. 66: 630-632.
- Rogers, G. F. 1986. Comparison of fire occurrence in desert and nondesert vegetation in Tonto National Forest, Arizona. *Madrono*. 33: 287-83.
- Rogers, G. F.; J. Steele. 1980. Sonoran Desert fire ecology. Technical Conference. M. A. Stokes; J. H. Dieterich. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.
- Shreve, F.; T. D. Mallery. 1964. The relation of Caliche to desert plants. Stanford, CA: Stanford University Press.
- Smith, S. D.; R. K. Monson; J. E. Anderson. 1997. Physiological ecology of North American sesert plants. New York: Springer.
- Steenbergh, W. F.; C. H. Lowe. 1977. Ecology of the saguaro II: Reproduction, germination, establishment, and survival of the young plant. Washington, DC: U.S. Department of the Interior, Park Service.
- Veblen, T. T.; T. Kitzberger; J. Donnegan. 2000. Climatic and human influences on fire regimes in ponderosa pine forests in the Colorado front range. *Ecological Applications*. 10: 1178-1195.
- Wilson, R. C.; N. G. Narog; B. M. Corcoran. 2000. Destructive wildfires in giant saguaro country Sonoran Desert, Arizona. Educational Bulletin 99-4. Desert Protective Council, Inc.