Effects of Blue Oak Canopy on Annual Forage Production[1]

J. Michael Connor[2] Bob L. Willoughby[3]

Abstract: *Production of annual forage was compared at four sites under four blue oak (*Quercus douglasii*) canopy levels (0, 25, 50, and 75 percent), over 5 years, at the University of California Sierra Foothill Research and Extension Center in Yuba County, California. Long-term annual precipitation averages 28.5 inches. Significant differences in herbaceous forage production occurred among years, with the highest rainfall season being the most productive and the drier years generally being less productive. There was a significant (approximately 100 percent) difference in production among sites. The effects of canopy cover varied from year to year; canopy significantly depressed forage yield in 2 of the 5 years. High rainfall years appeared to favor herbaceous plant growth under the higher canopy levels.*

Clearing of blue oaks (*Quercus douglasii*) from northern California hardwood rangelands has been shown to increase the production of forage for livestock (Jansen 1987; Johnson and others 1959; Kay 1987; Murphy and Crampton 1964). However, forage enhancement due to clearing is not consistent throughout the state, and at other California locations, higher herbage levels have been found under oak canopy (Duncan and Clawson 1980; Duncan and Reppert 1960; Frost and McDougald 1989; Holland 1973, 1980). Bartolome and others (1994) found no difference in forage yield due to oak canopy.

Duncan and Clawson (1980), Kay (1987), and Menke (1987) discussed reasons for the variable effects of oak canopy on forage growth throughout the state. These include tree density, climate, and soil factors. McClaran and Bartolome (1989) identified mean annual precipitation as a factor influencing the relationship between forage yield and oak canopy; they reported reductions in forage production due to oak canopy only where mean annual precipitation is greater than 20 inches.

Kay (1987) demonstrated that increased forage yield due to blue oak clearing continued only for a limited time (15 years). He also showed that naturally open grasslands produced more forage than areas with trees, suggesting that cleared areas will return to a forage production level that is higher than that under canopies.

Oak woodlands are valuable for wildlife habitat and protection of soil and water quality. Because oak management practices have long-term implications, and because canopy effects vary widely, it is important to determine the long-term results of oak clearing under specific conditions. The objective of this study was to compare herbaceous forage production under a range of blue oak canopy levels, across a number of sites, in the northern Sierra Nevada foothills.

Methods

The study was located in the northern Sierra Nevada foothills at the University of California Sierra Foothill Research and Extension Center in Yuba County, California. The study area supports a mosaic of small open grasslands, savannas, and dense oak woodlands. Woody species are mostly blue oak, interior live oak (*Quercus wislizenii*), and foothill pine (*Pinus sabiniana*). Common grasses include *Bromus hordeaceus*, *B. madritensis*, *B. diandrus*, *Lolium multiflorum*, *Avena barbata*,

---

[1]An abbreviated version of this paper was presented at the Symposium on Oak Woodlands: Ecology, Management and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

[2]Superintendent, University of California Sierra Foothill Research and Extension Center, 8279 Scott Forbes Rd., Browns Valley, CA 95918.

[3]Farm Advisor Emeritus, University of California Cooperative Extension, 2279 Del Oro Ave., Oroville, CA 95965.

Elymus caput-medusae, and *Cynosurus echinatus*. Important forb species are filaree (*Erodium* spp.), *Trifolium hirtum*, and *Geranium molle*. Jansen (1987) further describes the common species.

Four study sites were selected; each provided areas of open grassland (0 percent canopy) and blue oak canopy of approximately 25 percent, 50 percent, and 75 percent in reasonable proximity (*table 1*).

Table 1—Study site description

Site	Elev.	Slope	Slope aspect	Soils[1]	Stems[2]	Basal area	Avg. DBH[3]
	ft	*pct*			*per acre*	*ft²/acre*	*in.*
1 – Lewis	700	25	West	Sobrante-Las Posas very rocky loams	25-306	37-139	14
2 – Scott	1,350	18	South	Auburn-Las Posas-Argonaut rocky loams	32-64	27-72	14
3 – Koch	1,150	20	NW	Auburn-Sobrante very rocky loams	57-209	45-110	12
4 – Schubert	600	40	South	Sobrante-Auburn very rocky loams	40-139	32-47	10

[1]Herbert, F.W. and Begg, E.L. (1969)
[2]Low end of the range represents 25 percent canopies, high end = 75 percent canopies.
[3]Average stem diameter at breast height

Almost 4 miles separate the most distant sites. Precipitation was recorded at 600 feet elevation at a location central to the four study sites. Annual and seasonal precipitation during the 5 years of the study are presented in *figure 1*. Long-term (1962 to 1995) mean annual precipitation is 28.5 inches.

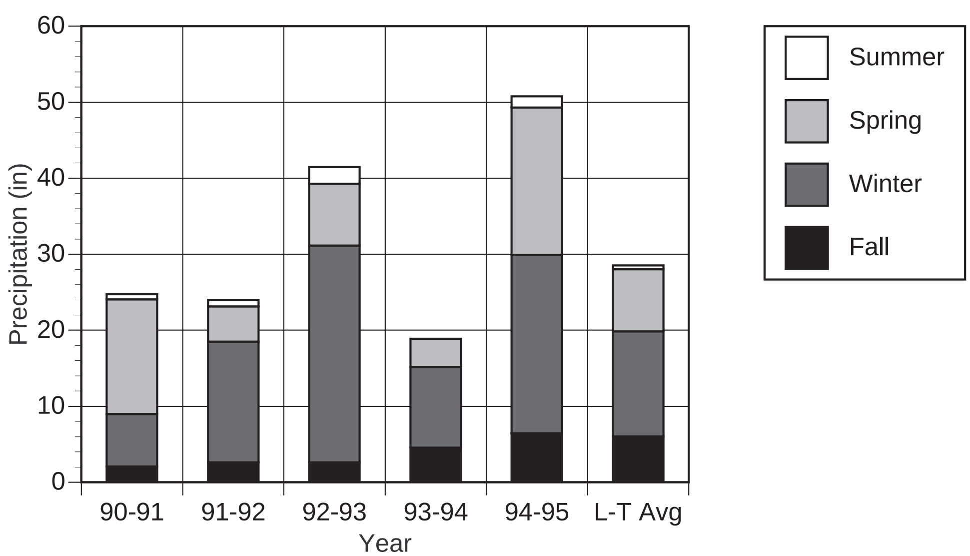

Figure 1–Annual and seasonal precipitation for the years 1990-91 to 1994-95 and the long- term average (L-T Avg).

In fall 1990, before leaf fall of blue oak, four plots at each study site were selected to represent canopy levels of 0, 25, 50, and 75 percent. Canopy levels were estimated by measuring the shaded area within the plot at midday and by use of a spherical densiometer. Canopies were almost exclusively blue oak; interior live oak and foothill pine were rarely encountered. The 16 plots averaged 0.24 acre with a range of 0.1 to 0.4 acre.

Each fall, for the years 1990 through 1994, twelve wire cages to prevent grazing were placed in each plot. Cages were made from woven wire field fencing and were 3 feet by 5 feet by 2 feet high. Each was held in place with four 3/8-inch steel reinforcing bars. These subplots were located by following a stratified random procedure. In the 25 percent canopy plots, 25 percent of the cages were placed under canopy; in 50 percent canopy plots, 50 percent of the cages were under canopy; and in the 75 percent canopy plots, 75 percent of the cages were under canopy. Areas of 0.5 m were hand clipped from within each subplot at peak standing crop each year. The clipped material was air dried and weighed to estimate herbaceous forage production. Cages were removed after clipping in the spring, to allow grazing by cattle, and were relocated to different subplots the following fall using this same procedure. Data were analyzed by analysis of variance as a split plot in time. The 12 subplots in each plot were pooled for analysis. This analysis allows examination of interaction effects for site by year and canopy by year. It does not allow investigation of site by canopy interaction or the three-way effects, site by canopy by year. Where statistical significance for main effects was indicated ($P < 0.05$), mean separation was tested at the 5 percent confidence level using Tukey's procedure.

Results and Discussion

Sites

Forage yield differed significantly ($P < .01$) among the four sites (*table 2*). The most productive site, with an average yield of 2052 pounds per acre, provided twice the yield of the least productive site. Sites intermediate in productivity differed significantly from either of the extremes, but not from each other. The large difference among four sites located within 4 miles of each other demonstrates the large variability in forage production in oak woodlands. Yield differences were consistent over years and do not appear to be related to the obvious physical factors: elevation, slope, or slope aspect. Soil differences based on the mapped descriptions also do not explain the variation in yield among sites. Soils in the study area are variable and are made up of associations of several soils series. Variations within mapped associations can be considerable and may be partially responsible for the differences among sites (Herbert and Begg 1969).

Table 2—Forage yield by site

Site	Elevation	Average forage yield
	feet	*pounds/acre*
2 – Scott	1,350	2,052 a
1 – Lewis	700	1,644 ab
4 – Schubert	600	1,225 bc
3 – Koch	1,150	1,020 c

[1]Values in the same column followed by different letters are significantly different ($P < 0.05$)

Years

Forage yield varied significantly ($P < 0.01$) from year to year (*table 3*). Much of the difference in yield appeared to be related to differences in yearly precipitation totals. The year-by-canopy level interaction was also significant ($P < 0.01$), but this interaction had little effect on the forage yield rank among years. The 1994-95 growing season had the highest precipitation observed during the study period (50.7 inches, 178 percent of normal) and produced the most forage over all canopy levels (average 1975 pounds per acre). The 1990-91 and 1993-94 growing seasons, years with generally the lowest rainfall (87 and 66 percent of normal, respectively), ranked either lowest or next to lowest in forage yields over all canopy levels. These two seasons had the lowest forage yield, approximately 1100 pounds per acre. The 1991-92 growing season was unusual in that it produced relatively high forage yields in spite of annual precipitation of only 24.0 inches (84 percent of normal). That season was intermediate in ranking over all canopy levels and was statistically similar in forage yield to the 1992-93 season which received 145 percent of normal rainfall. The 1991-92 season may demonstrate the importance of even distribution of moisture throughout the growing season. Substantial rainfall was received during each 2-week period from the middle of October to the end of April. Rainfall exceeded 1 inch during most of these 2-week periods, and it exceeded 0.6 inch during every 2-week period but one. Pitt and Heady (1978) included rainfall pattern as important in determining forage yield. George and others (1988) recognized rainfall pattern as a factor in forage growth, but credited temperature, described by degree days, as being of more importance.

Table 3—Forage yield by year

Year	Normal precipitaion	Average forage yield[1]
	pct	*pounds/acre*
1990-91	87	1,100 c
1991-92	84	1,694 b
1992-93	145	1,522 b
1993-94	66	1,136 c
1994-95	178	1,975 a

[1]Values in the same column followed by different letters are significantly different ($P < 0.05$)

Canopy Level

The effect of blue oak canopy on forage yield varied among years as indicated by the significant interaction between year and canopy level. An apparent increase in yield over all years for open grassland compared to canopy was not consistent among years or statistically significant *(table 4)*. Yield significantly decreased with increasing canopy during the 1990-91 rainy season, and open grassland was more productive than tree-covered plots in 1992-93. No significant differences due to canopy were found during the other 3 years of the study. Results of previous research suggest that a negative effect of blue oak canopy on yield would be expected in the northern California foothills (Jansen 1987; Johnson and others 1959; Kay 1987) and in locations with more than 20 inches mean annual precipitation (McClaran and Bartolome 1989). The results of the current study agree with Jansen (1987) who found yield at peak standing crop to be significantly

Table 4—Forage yield by canopy level and year

Year	Normal precipitation	Canopy level			
		0 pct	25 pct	50 pct	75 pct
	pct	*pounds/acre*			
1990-91	87	1,557 a	1,178 b	816 c	848 c
1991-92	84	1,651 a	1,872 a	1,702 a	1,551 a
1992-93	145	1,704 a	1,316 c	1,467 bc	1,599 ab
1993-94	66	1,255 a	1,147 a	1,061 a	1,082 a
1994-95	178	1,989 a	1,877 a	1,993 a	2,041 a
Average		1631 a	1478 a	1408a	1424 a

[1]Values in the same row followed by different letters are significantly different (P <0 .05)

higher in open grassland than under blue oak canopy in half of the 6 years reported in his study. We could not consistently match the finding of Kay (1987) who reported 26 percent more production in open grassland than in tree-covered (about 75 percent tree canopy) areas. The significant differences in forage yield that occurred in 2 of the 5 years of this study do not allow us to report a consistent effect of canopy level on forage yield. This supports the contention of Passof and others (1985) that canopy levels up to 40 to 60 percent do not depress forage production.

Kay (1987) suggested that the improved forage yield he found when blue oak trees were cleared from a site was greatest in dry years. Jansen (1987) did not report the same finding, and the current study does not clarify the question of whether canopy effects are greatest in dry years. The 1994-95 season, the year of highest precipitation, resulted in relatively high levels of forage under canopy compared to open grassland. On the other hand, the 2 years with significant differences in forage yield between open grassland and tree-covered areas (1990-91 and 1992-93) included both a relatively dry year (87 percent of normal precipitation) and a wet year (145 percent of normal).

Forage production varied less among years at the low canopy levels. The difference in forage yield between the most and least productive years was more than 1175 pounds per acre for the 50 percent and 75 percent canopy levels compared to only 730 pounds for the 25 percent canopy and the open grassland. Kay (1987) reported even larger differences in the yearly variation between open grassland and tree-covered areas. He noted that this difference in yield is an important factor to the livestock producer. Not only is stable forage production valuable, but forage produced in low forage years is relatively more valuable, per pound, than that produced in a high production year.

Conclusion

In this study, the effect of blue oak canopy on forage yield varied among sites and years. We did not find a consistent effect of oak canopy levels, up to 75 percent canopy, on herbaceous forage production. The presence of canopy appeared to increase variability of forage production among years, which is of considerable importance to livestock producers. Forage yield varied among years and was apparently related to annual precipitation. Yield varied greatly among sites located in relative proximity (approximately 4 miles apart), demonstrating the large variability of forage response in oak woodlands.

Acknowledgments

This research was partially supported by University of California Sierra Foothill Research and Extension Center grant number 84 and by a Renewable Resources Extension Act grant.

References

Bartolome, J.W.; Allen-Diaz, B.H.; Tietje, W.D. 1994. **The effect of *Quercus douglasii* removal on understory yield and composition.** Journal of Range Management 47(2): 151-154.

Duncan, D.A.; Clawson, W.J. 1980. **Livestock utilization of California's oak woodlands.** In: Plumb, Timothy R., technical coordinator. Proceedings of the symposium on ecology, management and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 306-313.

Duncan, D.A.; Reppert, J.N. 1960. **A record drought in the foothills.** Misc. Paper 46. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 6 p.

Frost, W.E.; McDougald, N.K. 1989. **Tree canopy effect on herbaceous production of annual rangeland during drought.** Journal of Range Management 42(4): 281-283.

George, M.R.; Raguse, C.A.; Clawson, W.J.; Wilson, C.B.; Willoughby, R.L.; McDougald, N.K.; Duncan, D.A.; Murphy, A.H. 1988. **Correlation of degree-days with annual herbage yields and livestock gains.** Journal of Range Management 41(3): 193-197.

Herbert, F.W., Jr.; Begg, E.L. 1969. **Soils of the Yuba area, California.** Davis: Department of Soils and Plant Nutrition, University of California; 170 p.

Holland, V.L. 1973. **A study of vegetation and soils under blue oak compared to adjacent to open grassland.** Berkeley: University of California; 369 p. Ph.D. dissertation.

Holland, V.L. 1980. **Effect of blue oak on rangeland forage production in central California.** In: Plumb, Timothy R., technical coordinator. Proceedings of the symposium on ecology, management and utilization of California oaks; 1979 June 26-28. Claremont, CA: Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 314-318.

Jansen, H.C. 1987. **The effect of blue oak removal on herbaceous production on a foothill site in the northern Sierra Nevada.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 343-350.

Johnson, W.; McKell, C.M.; Evans, R.A.; Berry, L.J. 1959. **Yield and quality of range forage following 2,4-D application on blue oak trees.** Journal of Range Management 12: 18- 20.

Kay, B.L. 1987. **Long-term effects of blue oak removal on forage production, forage quality, soil and oak regeneration.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinators. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 351-357.

McClaran, M.P.; Bartolome, J.W. 1989. **Effect of *Quercus douglasii* on herbaceous understory along a rainfall gradient.** Madrono 36(3): 141-153.

Menke, J.W. 1987. **Hardwood range management.** In: Plumb, Timothy R.; Pillsbury, Norman H., technical coordinator. Proceedings of the symposium on multiple-use management of California's hardwood resources; 1986 November 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 342.

Murphy, A.H.; Crampton, B. 1964. **Quality and yield of forage as affected by chemical removal of blue oak.** Journal of Range Management 17: 142-144.

Passof, Peter C.; Clawson, W. James; Fitzhugh, E. Lee. 1985. **Preliminary guidelines for managing California's hardwood rangelands.** Oakland: Division of Agriculture and Natural Resources, University of California; 92 p. Available from Cooperative Extension, University of California; Oakland, CA: publication 21413.

Pitt, M.D.; Heady, H.F. 1978. **Responses of annual vegetation to temperature and rainfall patterns in northern California.** Ecology 58: 336-350.