

WOOD AND UNDERSTORY PRODUCTION UNDER A RANGE OF PONDEROSA PINE STOCKING LEVELS, BLACK HILLS, SOUTH DAKOTA

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Abstract. - Stemwood and understory production (kg ha^{-1}) were estimated during 3 nonconsecutive years on 5 growing stock levels of ponderosa pine including clearcuts and unthinned stands. Stemwood production was consistently greater at mid- and higher pine stocking levels, and understory production was greater in stands with less pine; however, there were no differences in total (stemwood + understory) production. Based on loss of productivity, there is no argument that small clearcuts and unthinned stands should not be included in site plans. They contribute significantly to community structure, particularly to plant and animal species richness.

Key words: *ponderosa pine, growing stock levels, stemwood production, understory production.*

Forage and timber are 2 important products derived from ponderosa pine (*Pinus ponderosa*) forests. These commodities are, however, competitive. As tree parameters (basal area, density, or canopy cover) increase, forage in the understory decreases. As a result, studies on overstory-understory relationships have been rigorously pursued (Ffolliott and Clary 1982).

Ponderosa pine is the dominant tree in the Black Hills of South Dakota and Wyoming. Well adapted to the environment of the Black Hills, this pine produces regular seed crops in a moist regime that favors seedling establishment. Harvested or burned stands are typically replaced by dense stands of pine seedlings which eventually form crowded thickets (Boldt and Van Duesen 1974). Relationships between overstory and understory have been investigated in the Black Hills (Pase 1958, Bennett et al. 1987, Uresk and Severson 1989). The primary objective in an earlier publication (Uresk and Severson 1989) was to develop linear or curvilinear models to describe relationships between overstory and understory. In a later publication we reported responses of individual understory species to changes in the pine overstory (Uresk and Severson 1998).

The purpose of this paper is to compare relative quantities of wood and forage produced under a range of tree stocking levels. Data were collected from 5 different growing stock levels

of ponderosa pine ranging from no trees to unthinned stands. Two size classes at the beginning of the study in 1974 included pine saplings (7.6-10.2 cm dbh) and poles (15.2-17.9 cm dbh). Results of this study will enable managers to contrast wood and forage production and develop a better understanding of site productivity. Preliminary results were provided by Severson and Boldt (1977).

STUDY AREA AND METHODS

This study was conducted in the Black Hills on the Black Hills Experimental Forest, about 30 km west of Rapid City, South Dakota. The experimental forest encompasses approximately 1375 ha and ranges in elevation from 1620 to 1800 m. Average annual precipitation is 600 mm, of which 70% falls from April to September. Temperature averages 30-90 °C, and the growing season ranges from 80 to 140 d. Soils are primarily gray wooded, shallow to moderately deep, and derived from metamorphic rock. The environment of the Black Hills is described by Boldt et al. (1983). Vegetation of the experimental forest is dominated by the *Pinus ponderosa*/*Arctostaphylos uva-ursi* habitat type as described by Hoffman and Alexander (1987) and Thilenius (1972). Mean fire interval for the Black Hills between 1388 and 1900 was $16 \text{ yr} \pm 14 \text{ (s)}$ (Brown and Sieg 1996).

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We sampled 5 growing stock levels (GSL) of ponderosa pine including small clearcuts and unthinned stands (Uresk and Severson 1989, 1998). These were numerically designated 0, 5, 14, 23, and unthinned (UT). Growing stock indicates all living trees in a stand. Growing stock level is the basal area ($\text{m}^2 \text{ ha}^{-1}$) of a stand adjusted to account for differences in average size of trees left in the stand after thinning. Therefore, the numerical designation of GSL approximates but does not necessarily equal the basal area. Three replications of each of the 5 GSLs were established in each of 2 size classes of pine, saplings and poles. Each replication in the sapling stands was 0.10 ha, and pole stands were each 0.20 ha, established in a completely randomized design. Thirty stands were sampled for both size classes. Basal areas of unthinned pole stands ranged from 37 to 40 $\text{m}^2 \text{ ha}^{-1}$ in 1981; unthinned sapling stands ranged from 27 to 33 $\text{m}^2 \text{ ha}^{-1}$. Plots were initially thinned in 1963 except 0 level, which was cleared in 1966. We rethinned plots and removed seedlings at 5-yr intervals to maintain original GSLs.

Production of understory vegetation was measured during August 1974, 1976, and 1981 on six 15-m randomly placed transects per plot (Uresk and Severson 1989, 1998). Twelve 30 x 61-cm quadrats were randomly located along each transect in 1974 and 1976. These data indicated that an increase in number of quadrats would provide a better estimate of minor plant species. Therefore, in 1981 we systematically located 25 circular plots measuring 0.125 m^2 each along 5 of the transects. Current annual growth of all herbage was harvested at ground level for each species. All leaves and terminal portions of twigs to the 1st node were clipped on shrubs, also by species, after which we oven-dried the material at 60°C for 48 h and then weighed it. Weights were averaged and expressed as mean per plot for data analyses.

Total aboveground biomass production was estimated during August 1974, 1976, and 1981. Tree growth was estimated immediately post-treatment 1963 and in 1968, 1973, 1978, and 1983. Data for each specified year represent average annual growth over the interval period; that is, wood production data for 1974 is the average annual production from 1968 to 1973; for 1976, from 1973 to 1978; and 1981, from

1978 to 1983. To facilitate comparisons with understory production, we converted wood volume to oven-dried wood weight by applying locally developed models (Myers 1960, 1964). Wood volume was first converted to dry weight with the following model: $W = 25.0688(V) - 3.0096$, where W is the oven-dried weight of merchantable bole in pounds and V is the corresponding volume in cubic feet, $r^2 = 0.98$. Once these values were obtained, we used the following equations to obtain oven-dried wood weight: $V = 0.002297 D^2H - 1.032297$ for D^2H to 6700; $V = 0.002407 D^2H - 2.257724$ for D^2H larger than 6700 where D = diameter at breast height (dbh) outside bark (inches) and H = height in feet. Diameter breast high for both sapling and pole plots in 1974 at the beginning of the study ranged from 7.6 to 19.9 cm per site. Hence, comparisons are annual increments, on an oven-dried basis, of total aboveground understory (graminoids, forbs, and shrubs) and stemwood of ponderosa pine (bark, branches, and needles excluded).

Years and stand types were analyzed separately using 1-way analysis of variance. Heterogeneous variances precluded simultaneous analysis. Significantly different means were separated using Tukey-HSD. Those data sets exhibiting heterogeneous variances were analyzed via post-hoc pair-wise permutation tests with type I error maintained for each set of tests using a Bonferroni adjustment (Miller 1981, Meilke 1984). All statistical inferences were made at a probability level of 0.05.

RESULTS

Generally, understory production was highest where no trees were present and decreased with increasing GSL. It was least in unthinned stands (Table 1; see also Uresk and Severson 1989). More specifically, GSLs 0 and 5 produced significantly more understory than GSLs 23 and UT, but GSL 14 was often comparable to both groups. Understory production tended to be greater in sapling stands than in pole stands, but differences were not significant (Uresk and Severson 1998).

Annual stemwood production was generally low in GSL 5 (Table 1) and in clearcuts. Production in these 2 levels was often lower than GSLs 14, 23, and UT. No differences were evident among the 3 higher GSLs. No differences in wood production were noted in 1981 pole

TABLE 1. Annual stemwood and understory production (kg ha⁻¹, oven-dried) sampled at 3 different years in sapling and pole-sized ponderosa pine stands each managed at 5 different growing stock levels.

Year	Category	Growing stock level (GSL)				
		0	5	14	23	UT ¹
Sapling-sized stands						
74	Understory	1112 ^{a2}	1152 ^{ab}	555 ^{bc}	397 ^c	98 ^c
74	Stemwood	0 ^a	475 ^b	1193 ^{bc}	1304 ^c	1626 ^c
74	Total	1112	1627	1748	1701	1748
76	Understory	2006 ^a	2200 ^a	1295 ^{ab}	767 ^b	340 ^b
76	Stemwood	0 ^a	552 ^{ab}	1646 ^c	2032 ^c	1348 ^{bc}
76	Total	2006 ^{ab}	2752 ^{ab}	2941 ^a	2799 ^{ab}	1689 ^b
81	Understory	2449 ^a	2279 ^a	1476 ^{ab}	952 ^b	333 ^b
81	Stemwood	0 ^a	807 ^{ab}	1964 ^c	2023 ^c	1348 ^{bc}
81	Total	2449 ^{ab}	3086 ^{ab}	3440 ^a	2974 ^{ab}	1681 ^b
Pole-sized stands						
74	Understory	997 ^a	625 ^b	386 ^{bc}	202 ^c	73 ^d
74	Stemwood	0 ^a	998 ^a	1647 ^c	1834 ^c	1543 ^{bc}
74	Total	997 ^a	1622 ^{ab}	2034 ^b	2036 ^b	1616 ^{ab}
76	Understory	1931 ^a	1522 ^{ab}	1179 ^{ab}	756 ^{bc}	112 ^c
76	Stemwood	0 ^a	836 ^b	1733 ^c	1991 ^c	1022 ^{bc}
76	Total	1931 ^{ab}	2359 ^a	2912 ^a	2747 ^a	1135 ^b
81	Understory	2551 ^a	1618 ^b	1121 ^b	640 ^c	41 ^d
81	Stemwood	0 ^a	934 ^b	1891 ^{cd}	1949 ^d	1022 ^{bc}
81	Total	2551	2552	3012	2588	1063

¹ Unthinned stands
² Numbers within rows followed by different letters are significantly different (*P* = 0.05).

stands, again despite a range of no production in GSL 0 to 1949 kg ha⁻¹ in GSL 23. Pole stands tended to produce more wood than sapling stands at GSL 5 and UT, but amounts were nearly similar at other GSLs.

Differences in combined production of wood and understory were generally similar among GSLs (Table 1). Exceptions were in 1981 sapling stands where total production was higher in GSL 14 (3440 kg ha⁻¹) than in UT (1681 kg ha⁻¹) and in 1976 pole stands where GSLs 5, 14, and 23 (2359-2912 kg ha⁻¹) produced more than UT (1135 kg ha⁻¹). Although not significant, there was a tendency for lower production values in GSLs 0 and UT compared with intermediate levels. Relative contributions of wood and understory to total production changed as GSL increased. More understory than wood was produced at GSLs 0 and 5, but wood production was greater in the remaining 3 higher GSLs (Table 1).

DISCUSSION

Increases of ponderosa pine, even at minimal levels, will reduce the amount of understory and therefore the available forage produced. This is particularly important for livestock and elk (*Cervus elaphus*) since graminoids and forbs are among the 1st species to decrease and even disappear under increased levels of pine (Uresk and Severson 1998). Forage for mule deer (*Odocoileus hemionus*) and white-tailed deer (*O. virginianus*) is not as dramatically affected. Although several forbs and shrubs present in open stands decrease in abundance, others, such as bearberry manzanita (*Arctostaphylos uva-ursi*) and cream peavine (*Lathyrus ochroleucus*), maintain levels or even increase under a mid-range of pine stocking levels (Uresk and Severson 1998). Stemwood production is significantly curtailed at lower stocking levels, and a stand is not fully stocked until levels approach 14 m² ha⁻¹. Others have

reported that it is about $9 \text{ m}^2 \text{ ha}^{-1}$ (Clary et al. 1975). The lack of significance among fully stocked stands indicates that unthinned stands: as defined herein, produce as much stemwood as those stocked at lower levels ($14\text{--}23 \text{ m}^2 \text{ ha}^{-1}$).

It is impractical to recommend a stocking level of ponderosa pine that "optimizes" all forest outputs in the Black Hills. If commodities such as livestock and timber production were the only considerations, intermediate stocking levels would likely offer an acceptable balance. However, recent emphasis on ecosystem management, an approach that considers ecosystem health, maintenance of natural systems, and economic and social needs, mandates that all facets of the forest system be considered. Arguments have been presented that suggest a range of ponderosa pine stand stocking levels are necessary to maintain a viable forest ecosystem.

Uresk and Severson (1998), for example, noted that while floristic diversity in pine stands was greatest at lower GSLs, total floristic diversity was greater if all stocking levels, including 0 and UT, were present. Similarly, many wildlife species including white-tailed deer, turkey, and small birds use a range of forest structures within the pine community (Rumble and Anderson 1993, Mills et al. 1996, Sieg and Severson 1996). This study supports the results of Clary et al. (1975), who found that lower pine stocking levels produced maximum forage for livestock while intermediate levels produced more wood fiber.

There was a tendency for less total production on clearcuts and unthinned stands because of the absence of wood production on the former and lack of understory and decrease in wood growth on the latter, but significant differences were rare; hence, there is no strong argument (based on loss of productivity) that these levels should not be included in site plans. Their value is magnified by contributions they make, in concert with other stands, to community structure, particularly plant and animal species richness. We therefore suggest that forest managers focus not on specific stocking levels to maximize forest productivity but rather on how a variety of stocking levels could be arranged in spatial and temporal mosaics to optimize community structure.

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