

Reevaluating size-density relationships for ponderosa pine stands grown in northeast California: preliminary results

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Abstract - We re-measured tree diameter and mortality on 121 ponderosa pine and Jeffrey pine plots since 2005 and mainly during last fall. Tree density and quadratic mean diameter were plotted in a log-log scale to reevaluate the size-density trajectory for these species grown in northeast California. An objective is to determine whether Oliver's limiting SDI of 365 has been held after 20 years stand development. Results confirmed the limiting SDI of 365 for ponderosa pine stand *IF* bark beetle is presence. Otherwise, stands could reach the SDI of 500 before heavy mortality occurs; managed plantations seem to reach a higher SDI than unmanaged natural stands prior to the heavy mortality. Mechanism for this phenomenon is unknown and must be tested in the future.

Introduction

In fall of 2009, we completed re-measurements on almost all ponderosa pine permanent plots established by US Forest Service research scientists from Pacific Southwest Research Station, personnel from Pacific Southwest Region (R5), and researchers from the former Weyerhaeuser Company across northeast California. The common purpose of the original plot establishment was mainly to determine the growth and yield of even-aged ponderosa pine or Jeffrey pine plantations in the region, although the specific objectives might vary for each installation. Therefore, these re-measured plots vary with various management treatments (Table 1). Some were studied for stand density manipulations. Some were for the effect of understory vegetation control, with no, partial, and/or completely control of competing vegetation. Others were purely for constructing a yield table, usually, they were not replicated. Most studies were established in plantations from zero to 77 years old on the establishment year. Eleven plots were in the natural stands ranging from 42 to 87 years old. Because most plots were established around 1970, 40-years data provided some other information that was not expected from the beginners besides growth and yield.

One of unexpected results that couldn't obtain with short-term experiments was the difference in natural self-thinning among different stands. In 1995, Bill Oliver, a former Principal Silviculturist at the Pacific Southwest Research Station examined a self-thinning rule in even-aged ponderosa pine stands using these growth and yield plots. Applying the principle of "Reineke's stand density index (1933)" he found that self-thinning started when stand density index reached 230, "a zone of imminent mortality" and significant mortality occurred when SDI reached 365. This value was well-below the maximum SDI of 500 used in Region 5 in the past or 429 used in Region 6 for the Forest Vegetation Simulators. However, Oliver (1995) argued that a SDI of 365 was the result of increased bark beetle activity during contemporary drought. Conventional self-thinning rules only included inter-tree competition as a cause.

Recent review of maximum stand density index for ponderosa pine in northern California indicated that maximum SDI could have been higher than 365 as Oliver (1995) proposed. With the latest measurements available for some plots used to develop the original trajectory, we found that some test plots measured after 2004 grew beyond the maximum SDI line for a given stand density regardless of site quality and climate. Therefore, we revisited this question by re-measuring those plots used in the Oliver's paper (1995) across the region and by adding some plantation data available to us in California. We would address the question whether Oliver's rule (1995) is still holding after 20 years stand development.

Self-Thinning Theory

The self-thinning rule describes a relationship between size and density of organisms including even-aged plant populations. Because the slope of relationship was found to be $-3/2$ by Yoda et al. (1963), it is also called the $-3/2$ power rule or "Yoda's law." While ecologists were celebrating this discovery, people found that a forester had introduced the rule for forest stands 30 years earlier (Reineke 1933). He called it Stand Density Index, which is calculated:

$$SDI = TPA * (D/10)^{1.605}$$

Where: TPA = number of trees per acre, D = average stand diameter at breast height in inches.

Note that Reineke used a slope for the maximum stand density line of 1.605. A slope of 1.77, however, has been found to be a better fit for ponderosa pine data set in this region (Oliver and Powers 1978, DeMars and Barrett 1987).

Method

We re-measured dbh, mortality, and condition for trees in 40 plots located at 12 sites in 2009, 20 plots in the Initial Spacing Study at Challenge Experiment Forest in 2007, 60 plots at 3 sites in 2005, and one plot at Dockwell in 2000 (Table 1). Previous measurements usually included dbh and tree condition for all trees in the plot, height and height at live crown for all or 25% sampling trees in the plot. The inventories were usually conducted every five years since the plots were established. Among these plots, plots at Adin Pass, Antelope Mountain, Dockwell, Edson Creek, Hog Lake, Jelly Camp, Joseph Creek, Show Plantation, Sugar Hill, and Washington Mountain were established by Region 5 personnel and transferred to PWS later on. Plots at KC Reservoir, Prattville, and Spaulding Butte were established by Weyerhaeuser researchers and transferred to PSW after the company terminated the project in 1987. The rest plots were established by William Oliver at PSW, except the BMEF (Blacks Mountain Experiment Forest) plot that was established by other PSW scientists. The plots have been appropriately maintained and each tree was numbered with a metal tree tag.

Results and Discussion

Results indicated that stands at all sites, if not in all plots, experienced mortality (Table 1, Figure 1). The highest SDI reached over 200, which is close to 230 defined as a threshold for a zone of imminent bark beetle mortality, in at least one of plots at each site, suggesting that we should include all plots in our analysis.

After we add data collected after Oliver (1995) constructed his figure, we found that many plots passed over the line of limiting SDI of 365 established by Oliver (Figure 1). The SDI in some plots reached as high as 579 and yet a massive mortality has not occurred in these plots. The size-density trajectories seem topped off when the stand SDI reached 500 in some plots.

Because the SDI of 365 is the result of increased bark beetle activity, we re-analyze the size-density trajectories by eliminating the plots in which 25% and more trees are Jeffrey pine; the species is not as sensitive to bark beetle as ponderosa pine (Figure 2). We found that only a few plots passed over the line of the SDI of 365 at Antelope Mountain, Challenge, KC Reservoir, and Prattville. All plots but one at Challenge did not show mortality after they passed the line. Preliminary results also indicated that all plots that passed the SDI of 365 are plantations. The natural stands did not reach this line because of either their slow growth (Adin Pass) or heavy mortality (Edson Creek). A hypothesis that plantation trees with early intensive management can grow at higher SDI without mortality could be tested with some plantations established on forest industrious lands in the region.

Higher than the SDI of 365 without heavy mortality can be explained as bark beetle absence in the plots at Prattville and Challenge. The heavy mortality occurred with normal competition in the high density plots when the SDI reached 500 at both sites. More interesting, we have observed that trees were killed by bark beetles at the natural stands at Challenge although mortality caused bark beetle around the Prattville plots was not observed.

We do not have explanation for a single plot at Antelope Mountain, in which mortality was heavy, caused by both competition and bark beetle. Yet, SDI was still 572 although it was 637 in 2002 and 584 when the plot was established in 1991. This is a very small plot (0.19 acre) and is surrounded by treated stand or road. Therefore, a "dilute" effect might have occurred.

Next Step

I will include some data collected from LOGS plots at Blue Mountains and Lookout Mountain in 2009. The measurements were funded by other projects. I hope to measure some intensively managed plots and natural stands. I am seeking for help from the coop to re-measure the Chester, Ponderosa, and Jaws Garden of Eden sites. If the help is not available, I will write a manuscript up based on the current available data.

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Table 1. Geographic information, site index, stand history, and plot characteristics of ponderosa and Jeffrey pine established in the past across northeast California.

Location	No. plots	Site index	PIPO/ others	Lat. (N)	Long. (W)	Elev. (ft)	Stand History	Establishment year			Latest measurements			Max. SDI at site	
								Year	TPA	QMD	Age	Year	TPA		QMD
Adin Pass	1	70	100:0	41.21	120.56	5200	N	1957	122	6	61	2009	109	14.4	207
Antelope MT	4	90-105	mixed	40.34	120.56	6000	P	1991	156-518	10.7-15.9	64	2009	62-396	12.3-21.3	572
BMEF	1	72	0:100	40.44	121.08	6000	N	1957	700	2.2	55	2009	600	8.2	425
Challenge	20	120	100:0	39.28	121.13	2650	P	1968	122-1212	0	3	2007	101-1010	6.0-16.1	501
Dockwell	1	85	100:0	41.39	121.42	5200	N	1968	160	9	42	2000	150	15.4	321
Edson Creek	3	130	100:0	41.2	121.56	3900	N	1972	41-66	18.1-19.3	87	2005	39-49	26.7-28.6	314
Elliot Ranch	15	120	100:0	39.04	120.45	3880	P	1969	68-548	7.0-10.0	20	2009	18-108	17.5-33.9	428
Hog Lake	1	65	99:1	41.35	121.03	4900	N	1944	256	6.5	61	2009	194	13.8	345
Jelly Camp	1	60	26:74	40.48	121.16	5400	N	1962	203	7.5	77	2009	192	12.4	281
Joseph Creek	3	55-75	100:0	41.37	120.2	5600	N	1974	184-283	7.5-9.5	62	2009	72-111	13.9-16.8	328
KC Reservoir	1	105	98:2	41.18	122.17	4000	P	1972	242	9.8	35	2009	163	18.1	465
Prattville	3	90-110	100:0	40.12	121.11	4700	P	1971	100-433	4.2-6.2	15	2009	100-342	13.1-16.9	579
Show Plantation	3	130	100:0	41.19	121.59	3900	P	1972	60-156	13.4-17.8	53	2005	51-90	20.4-25.8	332
Spaulding Butte	3	70-80	mixed	41.32	121.09	4650	P	1972	268-525	4.2-5.6	52	2009	92-256	11.7-14.0	337
Sugar Hill	6	75-85	mixed	41.5	121.18	5400	P	1958	43-300	5.5-7.8	27	2009	43-300	12.7-23.0	489
Trough Spring	54	80	100:0	39.17	122.4	4200	P	1970	193-1193	0.9-1.9	11	2005	193-1120	3.4-10.1	339
Washington MT	1	65	100:0	41.28	120.58	5200	N	1963	120	7.5	42	2009	109	14.6	213

Stand history: N = natural stand; P = plantation.

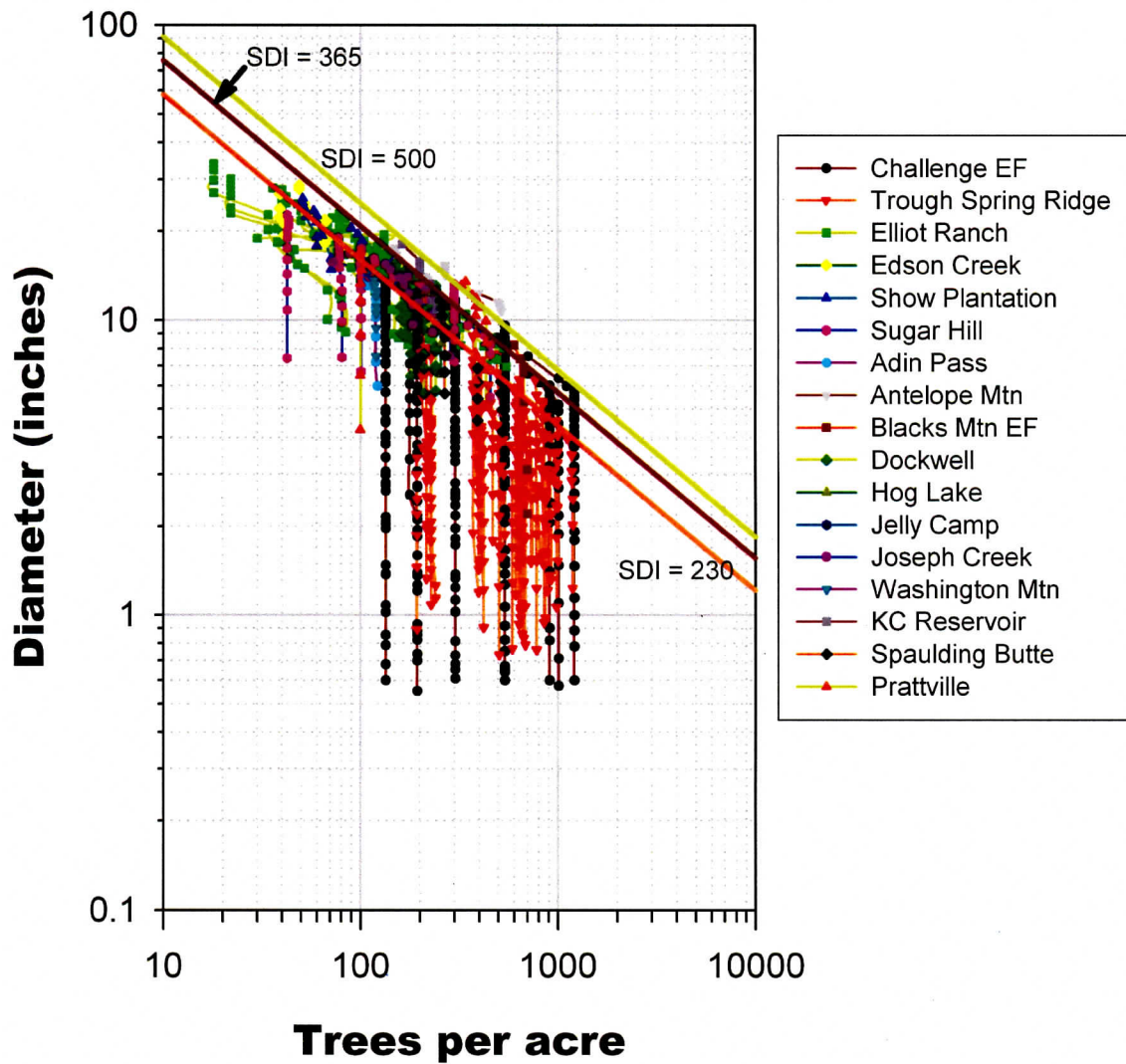


Figure 1 – Size-density trajectory based on 121 ponderosa pine and Jeffrey pine plots across northeast California. The three lines are when SDI= 230, defined as a threshold of the zone of imminent bark beetle mortality, SDI=365, a limiting SDI and SDI=500, a line which characterizes the current data in the figure.

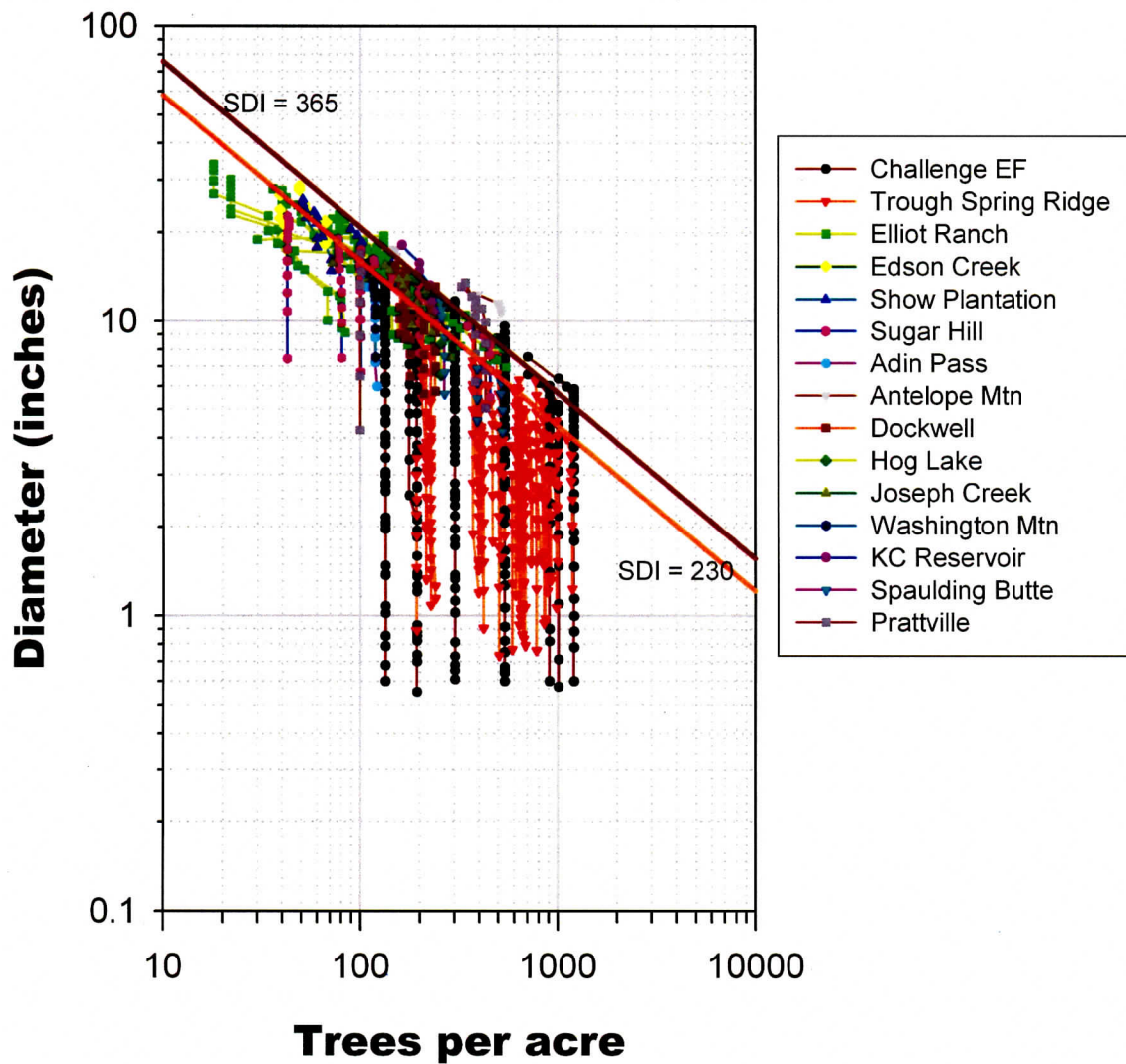


Figure 2 – Size-density trajectory based on only ponderosa pine plots across northeast California. The three lines are when SDI= 230, defined as a threshold of the zone of imminent bark beetle mortality, SDI=365, a limiting SDI.