COLLEGE OF AGRICULTURE & LIFE SCIENCES
Cooperative Extension

AZ1397

Revised 10/14

Guidelines for Thinning Ponderosa Pine for Improved Forest Health and Fire Prevention

Tom DeGomez

Past land management practices have often resulted in ponderosa pine stands that are overly dense and prone to catastrophic wildfire or bark beetle outbreaks (Covington and Moore 1994a, 1994b; Kolb et al. 1994). Landowners and property managers in the Southwest now are faced with determining appropriate ways to prevent these potentially stand-replacing events. The best way to reduce wildfire threat, drought damage and attack by bark beetles is to lower stand density through mechanical thinning. This publication will help those landowners with little or no experience to determine existing stand density and choose an appropriate method to select trees for removal where needed.

An additional benefit from reducing stand density is that remaining trees will grow more rapidly than when in an over-stocked condition. A century of research has shown that tree diameters increase at a faster rate in stands with lower densities, and ponderosa pine is no exception (Ronco and Edminster 1985). Thinning can greatly increase under story plant density in ponderosa pine forests (Moore and Diter 1992, Covington et al. 1997). Herbaceous plant growth, both grasses and forbes, typically increases when additional light reaches the forest floor.

A potential drawback to thinning may be the perception that the properties scenic beauty will be spoiled. Brown and Daniel (1986) found, in their study of predicting scenic beauty in ponderosa pine stands, that less dense (more open) stands had greater scenic value. The major components of higher preference were the increase in herbaceous plant growth and the remaining mature trees. (Refer to Figures 1a-e for a visual representation of various basal areas in a ponderosa pine stand with even-aged management.)

AT A GLANCE

- Preventing a stand-replacing event is best accomplished through tree thinning.
- Lower stand densities result in greater individual tree growth and vigor.
- Lower stand densities promote greater plant diversity in the understory.
- Determining stand conditions is the first step.
- Formulating a plan to improve stand conditions.
- Thinning around individual trees can improve individual tree health, thus reducing the likelihood of damage from bark beetles, fire or drought.

How to determine stocking rate (trees per acre) and basal area (BA)

Using sub-sampling methods

Sub-sampling with 1/20th acre plots (radius of 26.3') will provide a good estimate of total number of trees and basal area per acre without measuring every tree on the property.

Laying out the first 1/20th acre sub-sample plot

Using a map of the property, select a representative point on the property sufficiently distant from edges. Using this point as the first plot center, measure a radius of 26.3 feet. Use powdered chalk or other marking method to delineate the boundaries of the plot.

Determining number of plots

For properties of one the five acres use Table 1 to determine the number of evenly spaced plots to measure. For larger properties of 6 to 100 acres add one additional plot per acre [i.e. 6 acres = 11 or 16 plots, 10 acres = 15 or 20 plots, 20 acres = 25 or 30 plots (uniform or non-uniform). Thirty plots will be sufficient for 25 to 100 acres.

TOM DEGOMEZ

Figure 1a. Basal area of ~30 square feet per acre.

TOM DEGOMEZ

Figure 1b. Basal area of ~60 square feet per acre.

TOM DEGOMEZ

Figure 1c. Basal area of ~90 square feet per acre.

TOM DEGOMEZ

Figure 1d. Basal area of ~120 square feet per acre.

TOM DEGOMEZ

Figure 1e. Basal area of ~150 square feet per acre.

Figures 1a-e. Photos from top to bottom represent basal areas of approximately 30, 60, 90, 120, and 150 square feet per acre, from an even-aged stand in Flagstaff, Arizona.

Table 1. Stands of uniform basal area and non-uniform basal area. Begin measuring the plots and if the variation in the plots becomes greater than 10% use the number of plots for non-uniform stands.

	Uniform stands	Non-uniform stands
Number of Acres	Number of plots	
1	6	11
2	7	12
3	8	13
4	9	14
5	10	15

Table 2. Tree circumference in inches as it relates to diameter at breast height (DBH) and basal area (BA). (Use this form to tally all the trees in each diameter from each 1/20th acre plot. Also use as a master tally sheet for all plots on a property. To calculate total basal area for a diameter class: multiply the number of trees in each diameter class times the corresponding basal area per tree.)

Circumference in inches at breast height (4.5' above the ground)	Diameter classes (inches in diameter at breast height -DBH)	Basal area (BA) per tree	Number of trees in each diameter class	Basal area for each diameter class
12.6	4	0.09		
15.7	5	0.14		
18.9	6	0.20		
22.0	7	0.27		
25.2	8	0.35		
28.3	9	0.44		
31.5	10	0.55		
34.6	11	0.66		
37.8	12	0.79		
40.9	13	0.92		
44.1	14	1.07		
47.2	15	1.23		
50.3	16	1.40		
53.4	17	1.58		
56.5	18	1.77		
59.7	19	1.97		
62.8	20	2.18		
65.9	21	2.41		
69.0	22	2.64		
72.1	23	2.89		
73.3	24	3.14		
76.4	25	3.41		
79.5	26	3.69		
82.6	27	3.98		
85.7	28	4.28		
88.8	29	4.59		
92.0	30	4.91		
95.1	31	5.24		
		Totals for 1/20 acre plot		

20 x number of trees in a 1/20 acre plot =_____ number of trees per acre

20 x total basal area in 1/20 acre plot = basal area per acre _____

Table 3. Recommended basal area (square feet per acre) for ponderosa pine stands in Arizona when matching elevation to precipitation.

		Elevation				
		5,500'	6,000'	6,500'	7,000'	7,500'
Precipitation	16"	35	40	45	50	55
	18"	40	45	50	55	60
	20"	45	50	55	60	65
	22"	50	55	60	65	70
	24"	55	60	65	70	75

Table 4. Suggested number of trees per diameter class per acre at various basal areas for uneven age/size stands (using a q of 1.24 [Bailey and Covington]). (To use this table: Determine from Table 3 which basal area best fits your stand. Then, go down the column to determine how many trees should remain in the stand in each diameter class after thinning).

Tree diameter	Number of trees in each diameter for various basal areas per acre.								
	35	40	45	50	55	60	65	70	75
4 -7	7.3	8.4	9.4	10.5	11.5	12.6	13.6	14.6	15.7
8 - 11	5.9	6.8	7.6	8.5	9.3	10.1	11.0	11.8	12.7
12 - 15	3.9	4.4	5.0	5.5	6.0	6.6	7.1	7.7	8.2
16 - 19	3.1	3.6	4.0	4.4	4.9	5.3	5.8	6.2	6.7
20 - 23	2.6	3.0	3.3	3.7	4.1	4.4	4.8	5.2	5.5
24 - 27	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5
28 - 31	1.7	1.9	2.2	2.4	2.6	2.9	3.1	3.4	3.6
Number of tree per acre	26.6	30.5	34.2	38.0	41.7	45.5	49.3	53.1	56.9

Determining stand density

Count all the trees within the 1/20th acre circle, then multiply times 20. This will give you an estimate of the number of trees per acre. Use your map to help layout a grid-work of plots in a manner that is uniformly spaced and represents variation in stand composition across the property.

Determining basal area

Table 2 will help determine the basal area of each tree in each plot. The table can be copied and used in the field as a tally sheet. Make one copy of Table 2 for each sample plot. Use a dot tally or similar system to keep track of the number of trees in each diameter class. Use a flexible measuring tape (inches) to determine the circumference of each tree at 4.5 feet above the ground. Then multiply the number of trees in each diameter class times the basal area per tree (found in Table 2). Totaling all the trees and basal areas will give the total number of trees and total basal area for each plot sampled. If a 1/20th acre plot was used, multiply the total number of trees and basal area by 20 to give values per acre. (Note that inches become square feet in the conversion.) Prepare a master table that combines all the data from the sub-plots; this information will help when deciding which trees to remove.

Table 3 can assist in choosing the target basal area for thinning the property. This table assumes relatively flat land and good soil. Reduce the basal area if the stand is south facing, there is a steep slope and/or the soil is rocky. Likewise, if the stand is north facing, or flat with deep soils the basal area could be higher. Note: Changing the basal area due to individual site conditions more than 10 square feet/acre from what is recommended in Table 3 is not suggested without consulting a certified forester. Remember that the stand will grow 1-2 square feet/acre/year following thinning, so you can gauge when you might need a second thinning.

Once the basal area is determined for the stand, refer back to the "master" Table 2 with the overall stand data to determine whether the stand has more or less basal area than is recommended for your location. If you have a lower basal area than recommended, no action is needed. However, if the basal area for the stand is more than the optimal amount listed in Table 3 it is recommended the stand be thinned.

Marking trees for thinning

Even- vs. uneven-aged stands

Even-aged stand thinning tends to leave the oldest and largest trees in a regular spacing throughout the

stand. Even-aged stands are much easier to mark and the methodology is comparatively simple. We will discuss two methods here. This type of thinning will be less "natural looking" than uneven-aged stands because the "leave" trees will be the largest and more uniform in size and can be fairly evenly spaced (e.g. more like an orchard or plantation). Even-aged stands typically are harvested or naturally die uniformly near some maximum age, and therefore must be uniformly regenerated and grown again. Uneven-aged stands will be harder to mark but will look more natural because they have a wide range of tree sizes and variable spacing. Uneven-aged stands may also resist stand replacing mortality from bark beetles due to their preference for trees of 4 inch DBH or greater. Table 4 will aid in determining which trees to cut in an uneven aged plan. Uneven-aged stands offer perpetual forest cover with constant low levels of regeneration and mortality.

Even-aged/size stands

Method 1: *Thinning from below* — The general theory with this type of thinning is to remove only the smallest trees. If the basal area is 110 square feet/acre and it should be 60 then 50 square feet of basal area needs to be removed from the smallest trees. Use your "master" Table 1 to determine if the cut will take out all trees smaller than 6", 8", or whatever the case may be. This technique is particularly effective at minimizing ladder fuels and maximizing growth of remaining trees.

Method 2: *Diameter plus 7* — This method is designed to favor the largest trees by removing neighboring trees near the largest one in an area. This mark is done by finding one of the biggest or most desirable trees within eyesight. Measure its diameter at breast height and add 7 to it. This number is the radius of a circle in feet using the selected tree as the center point. Thus, if the tree has a diameter of 10" then any other tree within 17 feet would be marked and subsequently removed. The drawback to this method is if your stand has large trees in groups, then all but one of the trees in the group would be removed. In this instance, you may add all the trees diameters in the group together and then add 7. (Note: After marking the first 1/20th acre plot you may need to raise or lower the addition factor to meet your projected basal area. If the proposed mark doesn't take enough trees use a factor larger than 7, and if it takes too many make it smaller.)

Both thinning from below and diameter plus 7 have the added advantage of removing ladder fuels from the stand. Ladder fuels provide a route for fire to move up into the tree crowns of the stand.

Uneven-aged/size stands

Prior to Euro-American settlement in the Southwest, trees in the typical ponderosa pine forest were open and of uneven ages (Cooper 1960; Covington and Moore 1994b). This was due to frequent low-intensity surface fires that burned expanses of grass and prevented large numbers of seedlings from becoming established during good periods for seedling growth and development. Occasionally, a seedling would escape these fires, but this would happen just often enough to replace old trees that died in the stand (e.g. from lightening or old age). If you are interested in having a stand that is less uniform in tree size and age with a wide variety of size classes, then you will want to mark the stand so that you have a representative number of trees in a range of diameter classes. Table 4 gives the number of trees to keep in each diameter class to attain an uneven-aged stand but each diameter class can vary by 30% with little effect on the stand structure. Again, use the data in the "master" Table 2 to determine how many trees of each diameter class to remove relative to the target number of trees in Table 4. If there are no trees in a diameter class then substitute the not basal are from another similar class.

An uneven-aged stand structure will have more small trees than large trees. Over time however, some trees will grow into the next diameter class less those that die or are removed. In time, new trees will regenerate in the stand providing for a perpetual uneven-aged stand. Uneven-aged stands can be more prone to crown fire since the younger/shorter trees can act as a fire ladder. Fire danger can be reduced in uneven-aged stands by maintaining good tree spacing and open areas within the stand. If the stand is even-aged to begin with, it may take several thinnings over decades to convert it to the uneven-aged standard represented in Table 4.

General recommendations

When marking trees for removal, start the process in one or more of the 20th acre plots that were used to determine the basal area of the stand. After the plot is marked and before cutting, re-evaluate the basal area and compare the new basal area with your target. This will indicate how closely your marking is coming to the target basal area. Visualize what the harvest will look like when completed.

Caution! It is rare that you would ever remove a tree larger than 20" in diameter from your stand, even though it may be necessary on paper to reach the desired basal area. It is generally recommended that large trees be retained at the cost of surrounding smaller trees to reach your desired basal area. However, there may be areas and/or times where large tree removal is necessary to meet stand objectives and improve overall forest health.

Slash management

Depending on time of year, thinning may cause increases in bark beetle populations due to the beetle's ability to utilize fresh, moist thinning residue (slash). Slash produced in the fall will have a longer time to dry out prior to the peak beetle flights in late spring through mid summer of the following year. Small diameter slash (limbs and tops less than 3 inches in diameter) can be used by adult bark beetles, but they won't successfully reproduce in it. Larger diameter slash should be chipped, converted to firewood or piled for winter burning. When piling slash, put the smallest diameter material in the middle of the pile with the largest on the outside to promote drying of the large material.

TOM DEGOMEZ

Figure 2. Low hanging dwarf mistletoe broom.

Standing trees adjacent to slash accumulations have a greater chance of getting attacked by the offspring of bark beetles utilizing fresh slash. If the slash is hauled off the property to a landfill or if it is chipped within 30 days, then it will not cause a problem. When chipping on site, don't pile the chips next to live trees as the chips may also attract bark beetles. Keep chip piles in the open sun and as far from live trees as possible. If slash removal or chipping is not an option, it may be best to wait until fall to begin thinning.

For more information on slash management refer to University of Arizona Extension publications:

DeGomez, T., and B. Loomis. 2005 revised 2011. Firewood and Bark Beetles in the Southwest. University of Arizona, College of Agriculture & Life Sci. Bull., AZ1310. Tucson, AZ.

DeGomez, T., C.J. Fettig, J.D. McMillin, J.A. Anhold, and C. Hayes. 2008, revised 2014. Managing Slash to Minimize Colonization of Residual Leave Trees by *Ips* and Other Bark Beetles Species Following Thinning in Southwestern Ponderosa Pine. University of Arizona, College of Agriculture & Life Sciences Bulletin, AZ1449. Tucson, Arizona.

Further reducing ladder fuels by pruning

Prune lower branches to improve fire safety. Lower branches (live or dead) close to the ground can act as a fire ladder to the crown of the tree. Dwarf mistletoe brooms (Fig. 2) are more flammable than normal branches given their resinous nature and density of foliage. They are particularly hazardous when brooms are in the lower part of the tree. Dead branches can be pruned flush with the bark on tree; live branch pruning should be done so as to leave the branch collar exposed, this ensures proper healing of the wound.

Additional Help

Felling (cutting) trees can be dangerous even for those with extensive experience. Do not attempt to fall trees without proper training and equipment. Help is available if you need assistance with marking or cutting. For a listing of certified professionals consult the yellow pages, call your local University of Arizona County Extension office (http://extension.arizona.edu), or log on to www.safnet.org/certifiedforester/findcertifiedforester.cfm to find a certified forester or www.isa-arbor.com/faca/findArborist.aspx to find a certified arborist.

Glossary and Terms

- Basal area (BA) – The total cross-sectional area of the tree in square feet measured at breast height.
- Crown fire – A wildfire that spreads quickly from tree crown to tree crown consuming the crowns, and surface fuels along its front.
- Diameter at breast height (DBH) – The diameter of a tree outside the bark at 4.5 feet above the average ground level.
- Ladder fuel – Flammable material, dead or alive, at a lower level in the stand than the average tree crown height.
- Slash – Undesirable residues from harvesting, consisting mainly of limbs, leaves, bark, and undesirable species of any size or condition.
- Stocking rate – The quantity of tress in a stand compared with the ideal number for best growth and management.
- Surface fire – A fire that spreads along the ground and below the crowns of the trees.

References

Bailey, J.D. and W.W. Covington. 2002. Evaluating ponderosa pine regeneration rates following ecological restoration treatments in northern Arizona, USA. Forest Ecology and Management 155:271-278.

Brown, T.C., and T.C. Daniel. 1986. Predicting scenic beauty of timber stands. Forest Sci 32:471-487.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forest since white settlement. Ecological Monographs 30(2):129-64.

Covington, W.W., P.Z. Fule, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the southwest. Journal of Forestry, 95(4):23-29.

Covington, W.W. and M.M. Moore. 1994a. Changes in multiresource conditions in ponderosa pine forests since Euro-American settlement. Journal of Forestry 92(1):39-47.

Covington, W.W. and M.M. Moore. 1994b. Post-settlement changes in natural fire regimes and forest structure: ecological restoration of old-growth ponderosa pine forests. Journal of Sustainable Forestry 2(2):158-81.

Kolb, T.E., M.R. Wagner, and W.W. Covington. 1994. Concepts of forest health. Journal of Forestry 92(7):10-15.

Moore, M.M. and D.A. Deiter. 1992. Stand density index as a predictor of forage production in northern Arizona pine forests. J. Range Mgt. 45:267-271.

Ronco, F., Jr., and C.B. Edminster. 1985. Growth of ponderosa pine thinned to different stocking levels in northern Arizona. Rocky Mtn. Forest and Range Experiment Station, USDA Forest Service, RM-469:10.

COLLEGE OF AGRICULTURE & LIFE SCIENCES
Cooperative Extension

The University of Arizona
College of Agriculture and Life Sciences
Tucson, Arizona 85721

Tom DeGomez
Regional Specialist and Area Agent, Agriculture and Natural Resources, University of Arizona

Contact:
Tom DeGomez
degomez@cals.arizona.edu

This information has been reviewed by University faculty.
extension.arizona.edu/pubs/az1397-2014.pdf

Originally published: 2006

Other titles from Arizona Cooperative Extension can be found at:
extension.arizona.edu/pubs