Preliminary Thinning Guidelines Using Stand Density Index for the Maintenance of Uneven-aged Pinyon-Juniper Ecosystems

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ABSTRACT – *Pinyon-juniper ecosystems cover expansive landscapes in the western United States. As landscapes are developed, management of these systems is becoming increasingly important for various reasons, including wildland interface fire/fuels, visuals, wildlife habitat, wood products, and pine nuts. Where once most management of these ecosystems focused on removal of trees to favor rangeland species, land managers today are giving greater consideration to the management of sustainable ecosystems. This paper presents a silvicultural tool that utilizes science-based ecology for the sustainable management of pinyon-juniper ecosystems. This paper demonstrates how Stand Density Index may be used to guide post-thinning stand structure. The post-thinning residual stand density can be varied to achieve various management objectives. Uneven-aged management is recommended as a better approximation of the natural development process of pinyon-juniper stands.*

INTRODUCTION

Various valid guidelines have been used for thinning pinyon-juniper stands including single-tree selection, thin-from-below, and diameter limit prescriptions. Perhaps the most common has been the specification of a diameter limit, above which trees are to be left uncut. While diameter limit prescriptions can yield acceptable results, done without sufficient pre-treatment stand exam data, diameter limit prescriptions can yield undesirable results (such as converting a mixed stand into one dominated by a single species or retaining only the older portion of a population that, to be considered healthy and sustainable, should contain young, mid-aged, and old).

The following are preliminary thinning guidelines for forest health based upon research, standard principles of forest ecology, and the ecology of pinyon juniper ecosystems.

STAND DENSITY INDEX

Stand Density Index (SDI) is an index of competitive interaction. The maximum SDI varies for each tree species and is measured at a given reference diameter. At 25% of maximum SDI, trees begin competing with each other (and begin to out-compete understory species).[1] At 35% of maximum SDI, trees fully occupy the site. At higher densities competition between trees either results in reduced growth and vigor on individual trees or may result in competitive stress and tree mortality (perhaps due in part to secondary agents such as insects that are attracted to stressed trees).

[1] Long 1985.

The maximum SDI's for pinyon and juniper are still being studied,[2] and current literature should be consulted to determine if the numbers presented here should be modified prior to implementing a thinning strategy. SDI's have been developed for Rocky Mountain juniper (*Juniperus scopulorum*) and twoneedle pinyon pine (*Pinus edulis*), but not to date for Utah juniper (*Juniperus osteosperma*) or singleleaf pinyon pine (*Pinus monophylla*). Research by Schuler and Smith suggests that the maximum SDI for mixed pinyon-juniper stands is higher than for single-species stands of either species. Speculation is that this may be (in part) a factor of differing rooting depths of the two species. For the purposes of this paper, maximum SDI's of 415 for mixed stands was selected. It is recommended that when faced with a choice of maximum SDI's, the user select the lower SDI as the more conservative approach.[3]

SDI can be used as a guideline to develop desired residual stand structure goals. Residual SDI targets may be varied to help achieve various resources objectives. Higher residual SDI's will retain more dense trees, and lower SDI's may be appropriate for projects where more open conditions are desired, such as hazardous fuels reduction projects.

It is my recommendation that thinning leave no more than 25% of maximum SDI after treatment. This will maintain the site in tree cover (providing aerial cover and root mass to protect soils), but still open the canopy sufficiently to allow understory species to increase or become established in the canopy gaps between trees. It will also allow for a reasonable interval of time before retreatment will become necessary to maintain desired densities. The length of time between treatments will vary by site, and might best be estimated using a stand growth simulator program such as the Forest Vegetation Simulator. A residual stand density index of 5% of maximum SDI will leave very open, savanna like conditions. For management goals that are to retain a "woodland" component, it is suggested that residual stand density targets be between 5% and 25% of maximum SDI. When initiating a thinning program, it may be desirable to try several different residual densities, and to monitor the initial treatments over a several year period to determine which residual density seems the best fit for a given site and set of management objectives.

THINNING GUIDES

The desired after treatment species mix will be determined by what is available on the pre-treatment site and by management objectives. Managers will want to keep in mind that juniper tend to regenerate faster than pinyon, and where high proportions of juniper-to-pinyon are retained, this may lead to the need to retreat units earlier to maintain the proper size class mix.

The example below (Table 1) uses the uneven-aged system. If multiple size classes are to be maintained, the total stand SDI should be apportioned among size classes. Relatively

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[2] Sources for information on SDI for pinyon and juniper include: Schuler and Smith, 1988; Shaw, 2004; and the USDA-Forest Service Forest Vegetation Simulator (FVS). The current version of FVS lists the maximum SDI's for pure pinyon or pure juniper as 360 and the maximum for mixed stands as 415.
[3] Personal communication, Dr. James N. Long, Utah State University.

simple mathematical equations may be used to compute the number of residual trees and spacing for any given SDI and size class by manipulating the basic SDI formula: SDI = N $(D/10)^{1.6}$, where N = number of trees and D = diameter root collar. The desired number of residual trees then becomes: N = SDI / $(D/10)^{1.6}$. The spacing is a function of the number of size classes and the number of trees per acre by size class:
square root of [(43560/# of size classes) / N].

TABLE 1 – Target After-Treatment Stand (at 25% of max SDI)[a]

Size Class[b]	**SDI**	**TPA**	**BA**[c]	**Spacing**[d]
Regen (<3”)	26	178	8.8	8
Small (3-6”)	26	59	11.6	14
Mid (6-9”)	26	31	13.6	19
Large (>9”)	26	15	16.2	27
Total	*104*		*50.2*	--

[a] Numbers calculated on larger trees in each size class: 3”, 6”, 9”, and 14” DRC, respectively.
[b] Diameter class breaks will be specific to a given site, and it is desirable to use stand examination data to help set these breaks.
[c] Basal area is depicted here for comparative purposes only.
[d] It should be noted that the “spacing” column represents space between trees of the same size class. To obtain approximate spacing between trees of different size classes, divide the figure for each size class by two then add these figures together.

For practical contract application, size classes may be rather broad, with perhaps no more than 3 to 4 classes (or implementation may get too complex to be practical). It may be desirable to simplify the desired residual tree table and to disregard the regeneration size class as impractical to treat (see Table 2). Spacing guides are more important to follow than are the target number of trees per acre as not every acre will contain the correct mix of trees to obtain the ideal.

TABLE 2 – Contract: Target After-Treatment Stand (at 15% of max SDI)

Diameter Root Collar	**TPA**	**Spacing (clearing radius)**
<8”	30	22’ (11’ radius)
8-16”	10	38’ (19’ radius)
>16”	7	46’ (23’ radius)

[a] Numbers calculated on larger trees in each size class: 8”, 16”, and 20” DRC, respectively.

Some will find illustrations easier to understand than tables, thus graphics similar to Figure 1 may be an appropriate addition to a contract. Photographs of previous treatments that successfully achieved management goals may also be an aid to contractors.

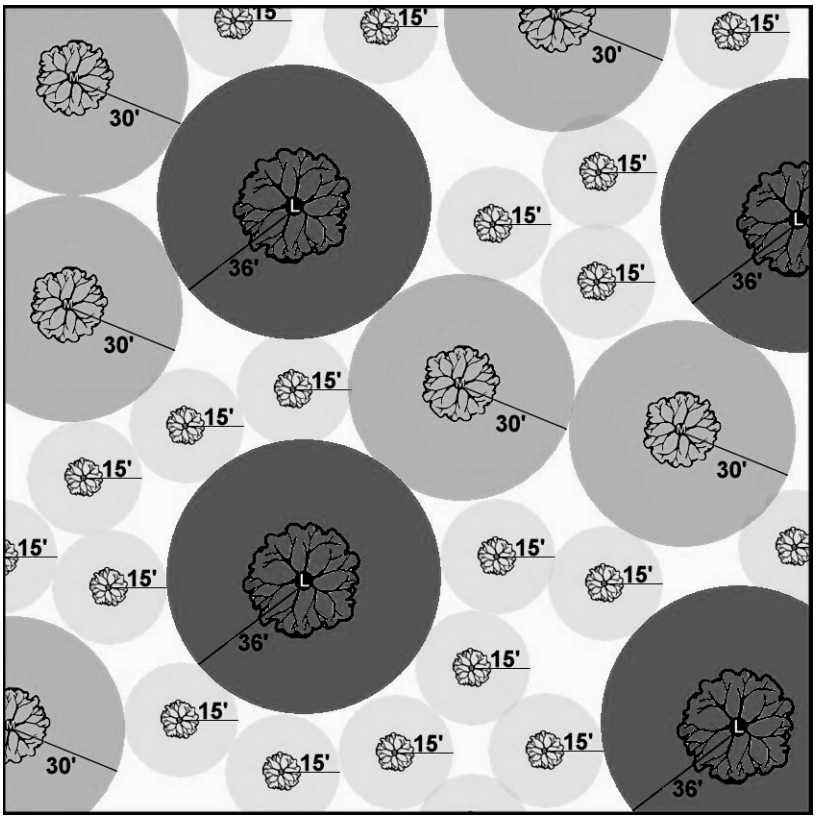

Figure 1 – Shaded circles represent the clearing around three size classes of leave trees.

In additional to spacing guidance, tree selection guidelines similar to the below should be provided.

Trees to be left after thinning should have the following characteristics:

- Pinyon pine are favored over juniper, however, healthy juniper may be retained where there are no suitable pinyon pine.
- Full-crowned trees are preferred over trees with sparse crowns.
- Trees with healthy crowns and free of disease and damage/deformity are preferred over sparse-crowned, diseased, damaged, or deformed trees.

To begin, select a good quality leave tree. Based upon its diameter class, clear other trees around this tree equal to the radial spacing value in the Table 2. From the edge of the cleared area, find another quality leave tree that is approximately its radial diameter-spacing from the cleared area and repeat step one around this tree, again clearing the radial spacing guide around this tree based on its size. Vary the size of leave trees when possible based upon the target number of trees to be left and the quality of the on-site trees from which to select. When thinning is complete, the desired condition will be variably spaced trees (based upon the size of the remaining trees) and variably sized trees with only a few large trees, a few more medium sized trees, and most trees in the smallest diameter class.

ADDITIONAL CONSIDERATIONS

Should pinyon *Ips* beetles be a consideration, it may be appropriate to manage for more open canopied stands. Based on research by Negron and Wilson[4], residual SDI's greater than 5.6% of maximum (where pinyon pine dominates) may leave stands that remain susceptible to attack by the beetle, particularly when high levels of beetle activity are present in the general area. Negron and Wilson studied unmanaged, post-epidemic residual stands and recorded post-epidemic densities at approximately 5.6% of maximum SDI. *Ips* beetles prefer trees with somewhat reduced crown ratios. Pinyon leave trees should be those with the higher percentage of crown-to-height ratio. *Ips* beetles prefer larger diameter pinyon trees, thus it may be desirable to remove most older/larger pinyon trees that show signs of declining vigor. Stand susceptibility to *Ips* may also influenced by stand composition, and those stands with a higher percentage of pinyon-to-juniper tend to be more susceptible to *Ips*-caused mortality. Thus it is thought to be desirable to maintain a good mix of species.

Timing of implementation and treatment of pinyon slash can be critical factors when *Ips* beetles are present in the general area. Green pinyon slash can serve as an attractant to beetles. Beetles can colonize slash during the spring and summer months and maturing beetles can emerge from this slash seeking new hosts, which will tend to be the nearest available suitable pinyon trees. Even chipped pinyon debris can attract beetles during the beetles' flight periods (*Ips* cannot colonize chips but may attack nearby pinyon trees). If chips or slash are to be left on the site, then treatment is best done in late fall, allowing the winter months for material to dry and become less attractive to beetles. Even then efforts should be made to increase drying rates on any remaining larger green pinyon material. Scattering pieces in sunny locations and damaging the bark to expose the phloem will help dry the phloem layer so it is no longer provides good habitat for bark beetles. If green pinyon material greater than 3" in diameter can be removed from the site within four to six weeks of cutting, then operations may be done at any time without risking increasing the incidence of *Ips* beetles. If neither can be practically accomplished, then mitigation for increased beetle activity may be either to leave more juniper and fewer pinyon or to leave more trees than the target residual stand, realizing that many of these trees may be subsequently killed by *Ips* beetles. If retention of pinyon trees on the site is of prime concern and *Ips* populations are high in the drainage where the treatment is to take place, it may be best to delay thinning pinyon stands until *Ips* populations subside.

Debris from cut trees may be scattered in created openings to enhance soil protection and provide for microsite protection for establishing vegetation. However, use of green pinyon pine material >3" in diameter should be limited, as noted above.

It may be desirable to vary the spacing (density) within stands through a project area to achieve a mosaic of within-stand conditions, i.e. thin one area to 5% of maximum SDI and another to 25%. This technique is being used to reduce fuels along power line

[4] Negron and Wilson. 2003.

corridors in southern Utah: residual stand densities become progressively lower as one nears the power line.

For wildlife habitat, groups of trees with interlocking crowns may be left interspersed with thinned trees. All trees in the group should have at least one side of the tree free from competition. Use either the largest tree in the group or the largest diameter class for the project as the spacing guide between the group and adjacent trees.

Effectiveness monitoring of the treatment areas will need to be done for a period of years following treatment to help refine future thinning prescriptions. A minimum of five years is suggested. Items to be monitored should be consistent with the project objectives and may include the response of understory species and the comparative incidence of post-treatment *Ips* beetle in treated and untreated areas. Pine nut production and tree vigor, as compared to nearby untreated areas, may also be monitored. These items should be monitored as they relate to residual stand densities and species composition.

APPENDIX
THINNING TABLES

The following tables may be used to determine the proper spacing between trees of various size classes for selected stand density indices. Guides are applicable to even-aged stands using average or quadratic mead diameter of the stand or they may be applied to uneven-aged stands, using the average or upper diameter limit in each size class. For a contract, numbers should be rounded.

TABLES A1 - A4 SPACING GUIDES FOR PURE PINYON OR PURE JUNIPER STANDS.

(Maximum SDI for pure stands of either species is 360.)

Table A1. 35% of maximum SDI = Site fully occupied by trees leaving limited resources for understory species. Trees are competing with each other.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
126	6	285	56.0	12.4	6.2
126	8	180	62.9	15.6	7.8
126	10	126	68.7	18.6	9.3
126	12	94	73.9	21.5	10.8
126	14	74	78.6	24.3	12.2
126	16	59	82.9	27.1	13.5
126	18	49	86.9	29.8	14.9
126	20	42	90.7	32.4	16.2
126	22	36	94.2	34.9	17.5

Table A2. 25% of maximum SDI = Trees on site begin to compete with each other, space is available for understory species to maintain themselves.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
90	6	204	40.0	14.6	7.3
90	8	129	44.9	18.4	9.2
90	10	90	49.1	22.0	11.0
90	12	67	52.8	25.5	12.7
90	14	53	56.2	28.8	14.4
90	16	42	59.2	32.0	16.0
90	18	35	62.1	35.2	17.6
90	20	30	64.8	38.3	19.2
90	22	25	67.3	41.3	20.7

Table A3. 15% of maximum SDI = Trees do not generally compete with each other. A substantial amount of site resources is available for understory species.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
54	6	122	24.0	18.9	9.4
54	8	77	26.9	23.8	11.9
54	10	54	29.5	28.4	14.2
54	12	40	31.7	32.9	16.4
54	14	32	33.7	37.2	18.6
54	16	25	35.5	41.4	20.7
54	18	21	37.3	45.5	22.7
54	20	18	38.9	49.5	24.7
54	22	15	40.4	53.4	26.7

Table A4. 5% of maximum SDI = Savanna conditions where non-tree species dominate the site.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
18	6	41	8.0	32.7	16.3
18	8	26	9.0	41.2	20.6
18	10	18	9.8	49.2	24.6
18	12	13	10.6	56.9	28.5
18	14	11	11.2	64.4	32.2
18	16	8	11.8	71.6	35.8
18	18	7	12.4	78.7	39.4
18	20	6	13.0	85.7	42.8
18	22	5	13.5	92.4	46.2

TABLES B1 – B4 SPACING GUIDES FOR MIXED PINYON-JUNIPER STANDS.
(Maximum SDI for mixed stands is 415.)

Table B1. 35% of maximum SDI = Site fully occupied by trees leaving limited resources for understory species. Trees are competing with each other.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
145	6	328	64.5	11.5	5.8
145	8	207	72.3	14.5	7.2
145	10	145	79.1	17.3	8.7
145	12	108	85.1	20.1	10.0
145	14	85	90.5	22.7	11.3
145	16	68	95.4	25.2	12.6
145	18	57	100.0	27.7	13.9
145	20	48	104.4	30.2	15.1
145	22	41	108.4	32.6	16.3

Table B2. 25% of maximum SDI = Trees on site begin to compete with each other, space is available for understory species to maintain themselves.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
104	6	236	46.2	13.6	6.8
104	8	149	51.9	17.1	8.6
104	10	104	56.7	20.5	10.2
104	12	78	61.0	23.7	11.8
104	14	61	64.9	26.8	13.4
104	16	49	68.5	29.8	14.9
104	18	41	71.8	32.8	16.4
104	20	34	74.8	35.6	17.8
104	22	29	77.8	38.5	19.2

Table B3. 15% of maximum SDI = Trees do not generally compete with each other. A substantial amount of site resources is available for understory species.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
62	6	140	27.6	17.6	8.8
62	8	89	30.9	22.2	11.1
62	10	62	33.8	26.5	13.3
62	12	46	36.4	30.7	15.3
62	14	36	38.7	34.7	17.3
62	16	29	40.8	38.6	19.3
62	18	24	42.8	42.4	21.2
62	20	20	44.6	46.2	23.1
62	22	18	46.4	49.8	24.9

Table B4. 5% of maximum SDI = Savanna conditions where non-tree species dominate the site.

SDI	D	TPA	BA	Spacing Between Trees of Same Size	Clearing Radius
21	6	48	9.3	30.3	15.1
21	8	30	10.5	38.1	19.0
21	10	21	11.5	45.5	22.8
21	12	16	12.3	52.7	26.3
21	14	12	13.1	59.6	29.8
21	16	10	13.8	66.3	33.2
21	18	8	14.5	72.9	36.4
21	20	7	15.1	79.3	39.6
21	22	6	15.7	85.6	42.8

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