Historical Forest Structure on the Uncompahgre Plateau: Informing restoration prescriptions for mountainside stewardship

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Summary:

The historical patterns of stand structure provide a starting point for designing forest management and restoration treatments for the future. A great deal has been learned about historical forest structures in ponderosa pine and mixed conifer forests across the Southwest, and a key lesson has been that no single story fits all conditions. Local variations in ecological factors (including disturbances such as fire) led to differences in forest composition and structure at scales from local hillsides to regions. A volunteer, collaborative project was undertaken to develop insights on historical stand structures on 25 Mesa on the Uncompahgre Plateau, with people contributing from the Uncompahgre Plateau Project, the USDA Forest Service, the Colorado State Forest Service, and the Colorado Forest Restoration Institute at Colorado State University. We looked for clues that included surviving large trees that were present in 1875 (at the end of the period before substantial impacts from European settlement), as well as logs and stumps that indicated former locations of trees. This reconnaissance-level survey does not provide highly precise reconstructions of stand conditions, but the approach is effective for gauging general patterns to guide restoration activities.

Forest composition and structure varied greatly across the landscape in the 1800s, within the ponderosa pine type as well as within the mixed conifer type. The historical ponderosa pine forests had much lower basal areas than almost any stands currently on the Plateau; small meadows (interspersed with clumps of pine) were very common and now are very rare. The mixed conifer forests also probably had lower basal area than the majority of the stands on the Plateau at present. We found no evidence, however, for major type-conversions from ponderosa pine to mixed conifer; most current mixed conifer stands were also mixed conifer stands in 1875.

Forest restoration treatments in the ponderosa pine type should emphasize lowering pine basal area substantially, with clumps of trees providing space for the historical small meadows. At the level of individual stands, the mixed conifer forests may not be outside historical ranges, but the lack of major mixed-severity and stand-replacing wildfires for more than a century has resulted in a near absence of young, post-fire forests; at least some of the current mixed-conifer forests probably have higher densities of shade-tolerant, small and medium size conifers than would have been typical in past centuries. We recommend that selective logging of some mixed conifer forests could be followed by mixed-severity fire (using the logging operation to create substantial fire breaks around logging units), providing valuable wood products and providing a safer opportunity for returning intense fires to the Plateau.

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Background

Change is fundamental to healthy forests. The seasonal cycle of tree growth begins before snows have melted from mountain landscapes, with roots growing to obtain water and nutrients to support the flush of springtime leaves that will provide the sugar to fuel the growth of summertime wood. Changes from one year to the next are typically subtle, often taking decades before we notice how much bigger the trees have grown, or how many small trees died as neighboring trees grew larger. Some years see very rapid changes, when huge numbers of trees die as a result of wind storms, insect or disease outbreaks, and fire. These slow and rapid changes are part of the development of all forests.

Some forest change is very predictable, at a broad scale. We know that young forests can support thousands of trees per acre, but that growth of the dominant trees will suppress the smaller trees, driving gradual thinning of the forest. A group of one thousand young Englemann spruce trees may have only ten surviving trees after 300 years have gone by. Other forest change is completely unpredictable. A rare downslope storm with 100 mile-an-hour winds coming from the east toppled centuries-old spruce-fir forests across thousands of acres in the Routt National Forest in 1997.

Many other types of change in forests fall between extremes of largely predictable and completely unpredictable. We can't predict when a wildfire will occur, but we do know how the fuel structure of a forest will influence fires in relation to various weather conditions. We know that the risk of a major outbreak of spruce bark beetles increases as spruce/fir forests develop old-growth conditions, even though not all old-growth spruce/fir forests will experience major beetle outbreaks.

Forest management and stewardship apply our understanding of these types of ecological changes to develop healthy forested landscapes that are resilient to change while contributing to the human communities that benefit from the forests' production of water, wood, forage, wildlife, recreation, and beauty.

Some of the forests of the Uncompahgre Plateau experienced new sorts of changes in the 19th and 20th centuries. Intensive livestock grazing developed in the late 1800s, particularly after the Utes were forced to leave the Plateau. Large predators were extirpated. Logging was heavy in some areas. These novel changes followed on the heels of an intense wildfire in 1879 that swept across much of the Plateau. Current conditions on the Plateau are a legacy of natural changes as well settlement-related changes, and management decisions about the future forests of the Plateau need to be informed by insights on historical forest conditions.

The Uncompahgre Plateau Project (http://www.upproject.org/) spearheaded an effort to develop forest restoration goals and objectives, with an aim toward enhancing the resiliency, diversity and productivity of the native ecosystem in the Uncompahgre Mesas area of the Uncompaghre Plateau, using best available science and collaboration. The Colorado Forest Restoration Institute (CFRI, http://www.cfri.colostate.edu/) developed this assessment of historical stand structure to provide the background for prescribing forest restoration treatments as part of a mountainside stewardship approach for the Plateau.

Approach

The forests of the Plateau would have shown a wide range of forest structure across the landscape and over time. During most periods, some forests would be recovering from the effects of moderate or severe fire in recent decades while other forests would be shaped by centuries of competitive interactions between trees and impacts of insects and diseases. Ideally we would like to document the variety of forest structures over the past 1000 years across the entire Plateau, but this information doesn't exist. A feasible goal was characterizing the typical forest structures in the late 1800s, realizing that the specific details of any single location and time would not represent all locations and other times. Our approach for the Uncompahgre Plateau was based on a great deal of experience around the Southwest in the detective work of reconstructing historical stand structure (see Allen et al. 2002, Friederici 2003 for general background). For example, Moore et al. (2004) used contemporary clues in 15 ponderosa pine stands to determine forest structure a century in the past. They measured the number and sizes of surviving trees, and used increment cores to determine the past sizes of the living trees. Not all trees survived the century, so stumps, snags, and logs were also measured for the reconstruction. Not all trees present a century ago would leave clues; small trees in particular may have died and decomposed, leaving no trace. Moore and colleagues examined this potential problem by comparing their reconstructions with actual stand maps (from 1909 to 1913), and they found that about 90% of the trees either survived or left measurable clues that would allow accurate reconstruction.

We chose 1875 as a target year for reconstructing forests on the Uncompahgre Plateau, because we felt that most trees present in 1875 would have left clues detectable in the present, and because this predated the widespread fire of 1879 and the major impacts of settlement. Some major limitations to this approach are highlighted in the text box on the next page.

A total of 26 plots were located on and near 25 Mesa, clustered in 9 locations (Figure 1). Eleven of the plots were placed in stands dominated by ponderosa pine with few other conifers (though some had large amounts of aspen that died within the past few decades), and fifteen were in mixed conifer. We avoided portions of the Mesa without ponderosa pine, including meadows, pure aspen stands, and spruce-fir stands. The plots were 0.5 to 1.0 acres in size (300' to 330' long by 66' to 132' wide). The locations and diameters of living trees were recorded for large trees that predated 1875. Some large trees were younger than 1875, and some small trees established before 1875; in these cases, judgment was made based on tree morphology, and in some cases on tree cores. The location and diameter of stumps, snags, and logs were also recorded, based on whether they appeared to be old enough to have been present in 1875. A guess was also made about how long each stump, snag or log had been dead. All diameters of living and dead trees was projected back to 1875, based on the general trend between diameter and tree age found on two dozen large trees that were cored (tree diameter was reduced by 0.1 inches for each year back to 1875; this is a crude approximation, but in the right ballpark).

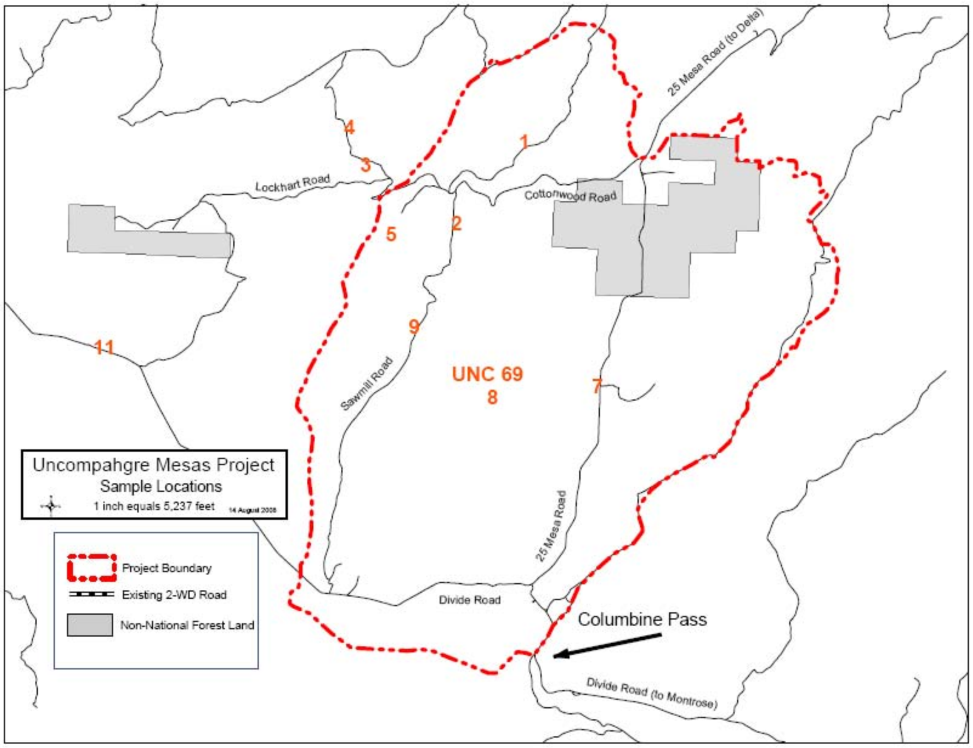


Figure 1. Map of the 25 Mesa unit, with locations of stands sampled to determine forest structure in 1875.

Limitations on Detecting and Using Historical Forest Structure

Our reconstruction of forest characteristics from the late 1800s should be generally useful for developing forest restoration prescriptions, but several fundamental limitations need to be stressed:

1. The condition of a stand at a single point in time is like a single frame from 2-hour movie; the snapshot may be accurate, but it does not trace the sweep of the plot through the movie. The forests of 1875 were not the same as in 1775 (during the Little Ice Age) or 1075. The UP forests in 1875 were shaped in part by previous fires (including widespread fires in 1842), and the fires of 1879 led to dramatic (natural) changes across the Plateau. In particular, we think aspen trees and stands likely expanded greatly after 1875, so an accurate reconstruction from 1905 would likely have far more aspen in the forests of the Plateau than one from 1875. The data from stand reconstruction are only useful if placed into a broader context.

2. We have no local assessment of how well clues about forest structure persist on the Plateau. For moderate-to-large ponderosa pine trees, we expect about 90% of the trees present in 1875 would still be alive or would be detectable as stumps, snags, or logs. We expect some other species would not be as reliable in leaving clues; small to moderate stems of subalpine fir and aspen may decompose well enough in a century that our field sampling missed them. This is such a large problem we did not attempt to estimate historical aspen quantitatively.

3. We sampled a total of 26 plots (one-half to one-acre in size) on 25 Mesa, clustered in 9 areas. This sampling intensity allows us to describe typical conditions for 1875 on 25 Mesa, but some areas of unusually high or low density forests were likely present but not encountered in our sampling.

Results for Ponderosa Pine Type

Ponderosa pine forests show great variation from Mexico to Canada, in density of trees, species composition, long-term dynamics, and fire regimes. Ponderosa forests on the Uncompahgre Plateau in 1875 also showed a range of structures and conditions, especially in relation to elevation. Lower, drier sites developed fairly open stands of ponderosa pine; in some cases the understory may have been dominated by Gambel oak shrubs, where other areas had meadow vegetation (Figure 2). Historical records do not describe how prevalent each type was in the 1800s, and any residual clues would require intensive research to unearth. The landscape patterns may have depended on local fire occurrence and intensity, on variations in soils, or other ecological factors.

Brown and Shepperd (2003) found evidence that fire occurred somewhere within the ponderosa pine and mixed conifer zones of the UP at least every 10-15 years. From existing data we cannot determine how large these fires were, nor how great their impacts were on the vegetation. Some of the fires apparently burned very large areas, because they were detected in widely separated locations. Large fire years included 1842 and 1879. However, many of the other fires detected on the UP probably burned relatively limited areas. It is unlikely that even the largest historical fires burned the entire ponderosa pine and mixed conifer zones. Observations of recent uncontrolled fires (e.g., in Yellowstone Park in 1988) have revealed that fires burn in a heterogeneous manner even under extreme fuel and weather conditions (Turner et al. 1994).

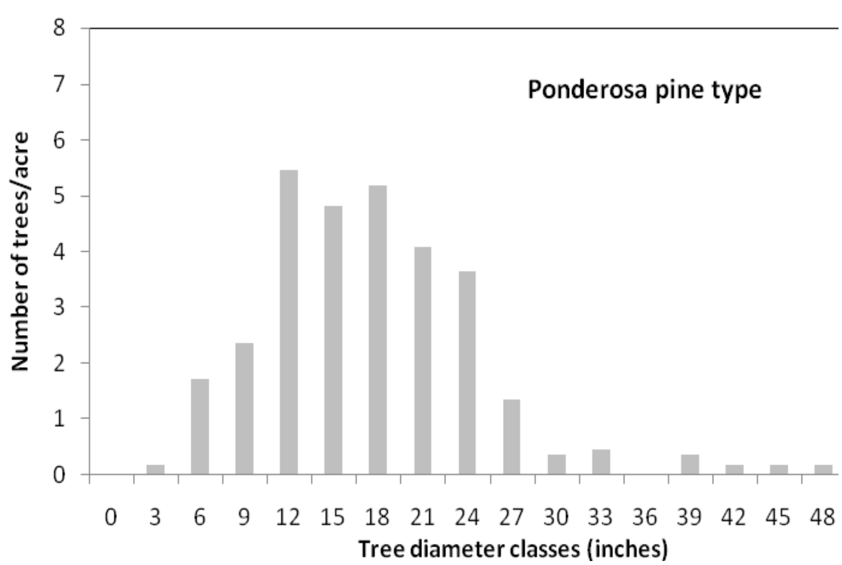
Figure 2. In 1875, most (all?) of the lower elevation ponderosa pine forests had low density of trees, clumped within a mosaic of meadows or Gambel oak. We don't know how dominant the meadow type or shrub type was; historical records are not very helpful, and any hidden clues still on the landscape would take intensive research to find.

Figure 3. In 1875, moister sites with ponderosa pine trees had substantial amounts of aspen. The aspen cover in most of these forests has declined, as evidenced by large numbers of decaying aspen logs. Some locations have increased densities of younger pine, Douglas-fir and spruce.

Above the drier ponderosa pine forests, aspen trees were a major component of the forests. Low densities of ponderosa pine trees occurred in clumps, with aspen filling much of the space between pines (Figure 3; see the table at the end of the report for plot totals). In the absence of fire for 125 years, many of the aspen trees died and large numbers of conifers (pine, Douglas-fir, and spruce) have created a midstory and understory in the forests.

Our survey of 11 ponderosa pine plots found an average of about 55 ft^2/acre basal (range of 20 to 90 ft^2/acre), with about 55 trees/acre (range of 30 to 90 trees/acre; Figs. 4, 5). Current ponderosa pine forests typically have two or three times this basal area and density. Across all plots, the average forest structure was characterized by a few large pines (including some greater than 3 feet in diameter), a relatively even distribution of medium-size trees (1-2 feet in diameter), and relatively few small trees.

Figure 4. Average diameter distribution of conifers in ponderosa pine stands in 1875.



A major finding from our field surveys is that ponderosa pine forests on the Uncompahgre Plateau typically had higher densities and basal areas than ponderosa pine forests in northern Arizona and New Mexico. For example, Moore et al. (2004) reported an average basal area of 35 ft^2/acre in 1910 for 15 forests, with a range of 13 to 62 ft^2/acre. Only one of the eleven ponderosa pine plots on 25 Mesa had a reconstructed basal area as low as the average of the stands from Arizona and New Mexico, and four out of eleven had higher basal areas than the single highest stand in Moore et al.'s (2004) study. Higher historical stocking on the Uncompahgre Plateau is not surprising, given moister conditions and less frequent surface fire; our findings reinforce the importance of tailoring local restoration prescriptions to match local situations (see Friederici 2003).

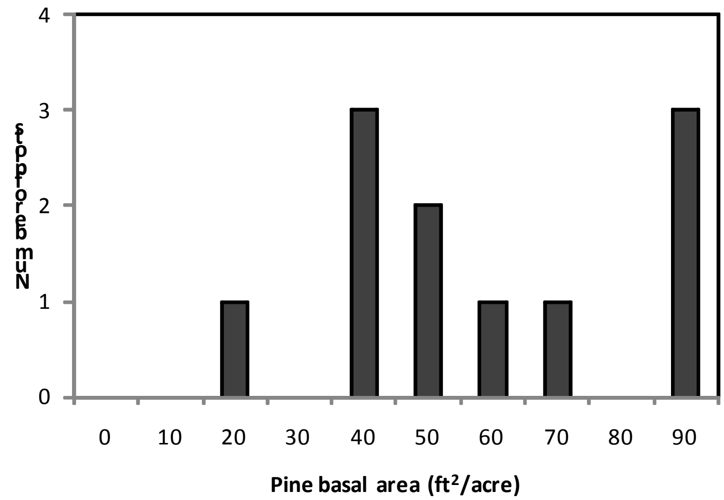


Figure 5. 1875 Distribution of basal area of the ponderosa pine plots.

The actual density of the ponderosa pine forests on 25 Mesa might have been somewhat higher in 1875 than our reconstructions would indicate. Some smaller trees may have died and decomposed leaving little clue. This is particularly a problem for aspen trees (see Kaye et al. and Kashian et al. for examples of historical aspen reconstructions in the Front Range), given the widespread presence of aspen stems in many ponderosa-pine type stands. The widespread presence of aspen clones in the middle and upper elevations of the ponderosa pine type means that the forests in 1875 could have had hundreds of aspen trees that died (after the 1879 fire, or more gradually) and decomposed. Again, more small trees may have been present in 1875, leaving no trace to be detected 125 years later.

The spatial arrangement of trees was generally clumped (based on Ripley's K function) with trees aggregated at distances of less than about 75 feet. The spatial pattern at larger distances was either random, or uniform. A uniform distribution means that clumps would be spread out uniformly through the stand, but the spacing of the trees themselves would tend to be clumped (see the patterns in Figure 10 at the back of this report). We note that no plot showed a uniform distribution of trees; a silvicultural prescription to maximize wood growth would space trees uniformly, a pattern without historical precedence. All stands had a clumped or random structure, with meadows, oak patches, or aspen occupying patches of 0.1 to 0.25 acres. The landscapes may have had larger open areas; we anchored our plots in locations with at least some large ponderosa pine trees, so larger meadows in 1875 would not have been included in our survey.

Results for Mixed Conifer Type

Most of the mixed conifer type on the Uncompahgre Plateau includes at least some large, old ponderosa pine trees (or stumps). We were particularly interested in knowing whether these stands would have been mixtures of species in 1875, or if the presence of large numbers of other trees (many in younger age classes) indicates a type conversion as a result of absence of fire. The results showed the plots were largely mixed conifer in 1875 (Figures 6, 7), with ponderosa pine comprising only about 40% of the total stand basal area (range of 3% to 83%). Total basal area averaged about 70 ft^2/acre (range of 25 to 130 ft^2/acre), with 60 trees/acre (range of 30 to 110 trees/acre).

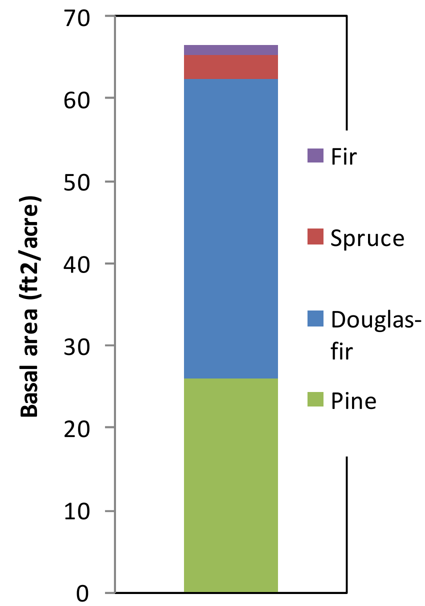


Figure 6. Average basal area by species for the mixed-conifer plots in 1875.

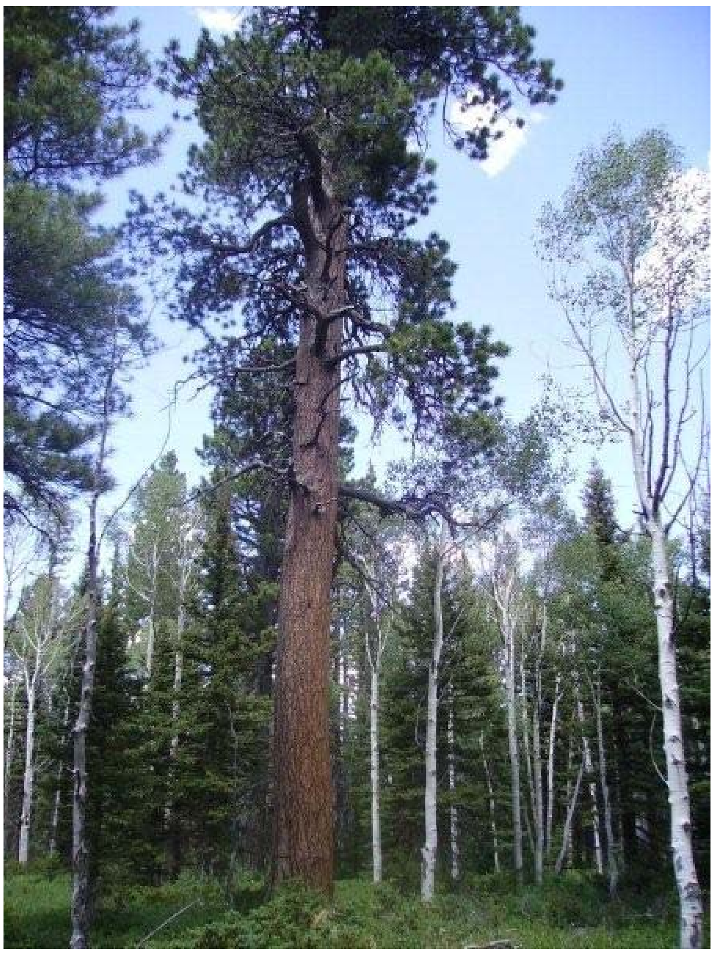


Figure 7. Dry mixed conifer forests in 1875 were typically dominated by Douglas-fir, ponderosa pine (pictured here), and varying amounts of spruce, subalpine fir, and aspen. High variation in species composition, tree density and tree sizes in 1875 are largely consistent with high variation across the landscape now; although low basal area stands, and major aspen stands, may be less common.

The distribution of tree sizes in 1875 showed a classic inverse-J pattern, for trees >6" diameter (Figure 8). The low number of small trees could represent a decline in establishment of trees in the two decades prior to 1875, but more likely our sampling did not account for small trees that died and decomposed in the past century.

About half of the mixed conifer stands had less than 50 ft^2 of basal area in 1875, not counting for a likely minor contribution of small trees, and perhaps major contribution of aspen trees (Figure 7). The spatial arrangement of trees was also clumped, as in the ponderosa pine type. At distances of less than about 75 ft., trees tended to be clumped. At greater distances, tree arrangement was random or uniform (indicating a uniform distance between clumps of trees of about 150 feet).

Risks in the absence of restoration

The forests of the Uncompahgre Plateau will continue to change, even without restoration treatments. Some changes may be slow, such as the gradual (but perhaps accelerating) death of aspens as conifer basal area increases. Others may be rapid, such as sudden aspen decline, and mixed-severity or stand-replacing wildfires like those of 1879. Some changes would reflect similar long-term dynamics in the past (such as shifts in the boundaries between lower elevation ponderosa pine and oak shrublands), but others might be unprecedented (such as a lack of pine regeneration after stand replacing fires if no large trees survive to provide seeds).

Some key risks should be highlighted. One of the largest is a risk of conversion of ponderosa pine forests to oakbrush, especially following a fire. A mixed-severity fire would likely created patches of oakbrush without trees, and a stand-replacing fire would create large, treeless fields of oak brush. A similar risk of type conversion applies at moderate elevations, where the presence of extensive aspen clones might lead to a post-fire landscape dominated by aspen rather than pine.

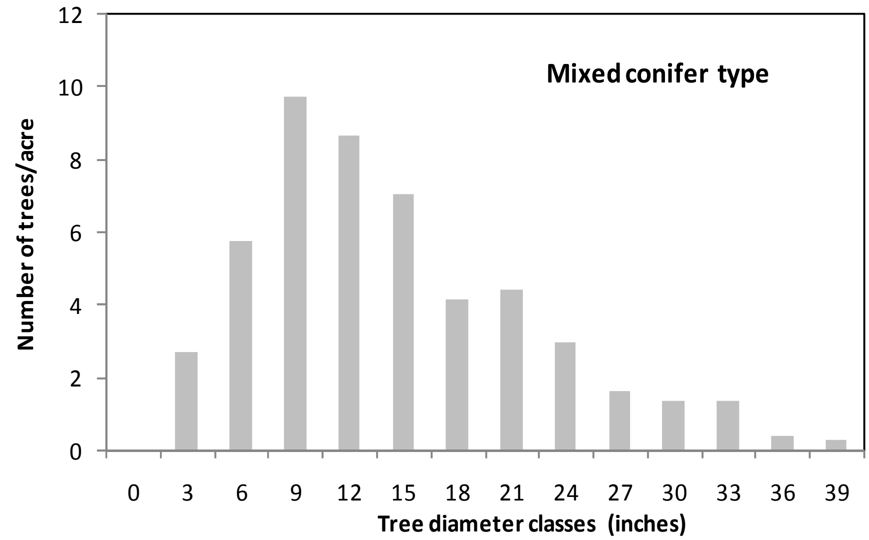


Figure 8. The average diameter distribution in mixed conifer plots showed a classic inverse-J pattern, for trees larger than 6” in diameter. Smaller diameter classes are probably underrepresented in our sampling, as small trees that were present in 1875 may have died and decomposed leaving little trace.

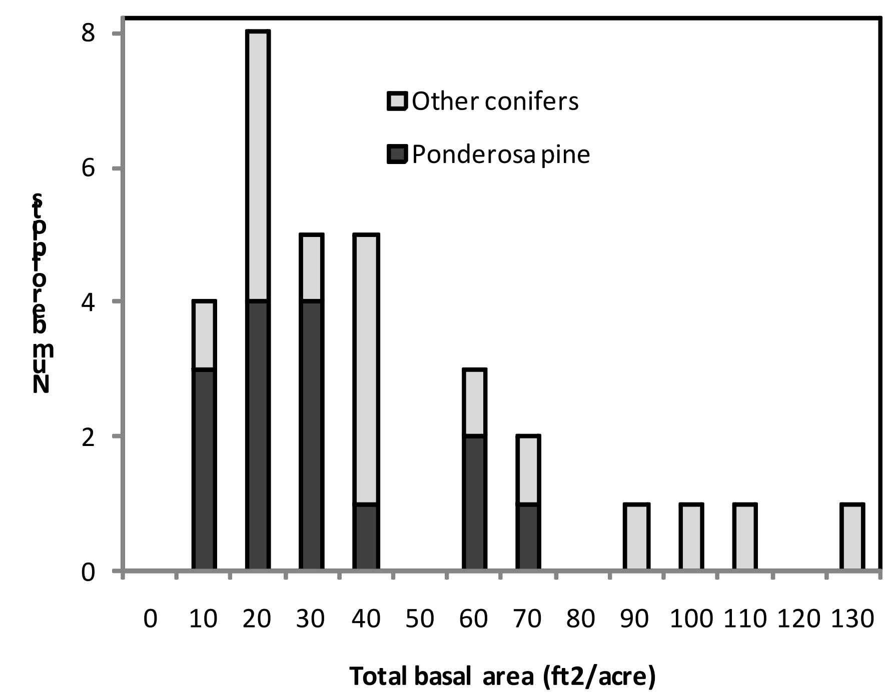


Figure 9. Most mixed conifer forests had less than 70 ft2/acre basal area in 1875, and ponderosa pine comprised from 0 to about 80% of the basal

A more subtle risk faced by the current forests is the gradual (but accelerated) death of the remaining old ponderosa pine trees. The ability of large, old trees to withstand drought, bark bettles, and other stresses is lowered by high densities of surrounding, younger trees. A large (and unknown) proportion of the remaining 200+ year-old ponderosa pine trees are likely to die in the next few decades in the absence of major restoration treatments. Many of these ancient trees would survive for another century or more if forest structure is returned to historical conditions.

A third risk is the decline of aspen trees mixed with dense pine forests. Many stands show the remains of large numbers of aspen trees that have been outlived by old conifers and more-recently established conifers. Restoration treatments that lower conifer density would benefit aspens (where clones are present). The response of aspen may depend substantially on the frequency of recurrent fire and on fire intensity. Fire recurrence near the shorter end of the historical trends (5-10 years) would probably result in notably less aspen than longer intervals (15+ years). Even large aspen trees are relatively susceptible to stand-replacing fires, but we have little insight on the ability of sapling-size aspens to survive relatively low-intensity surface fires. Investigations will be needed on aspen response to fire-return interval.

In the mixed-conifer forests, the presence of a diversity of tree species almost guarantees moderate or high rates of change in forest composition and structure. Mortality may be accelerated by high densities of shade-tolerant trees, and susceptibility of large trees to diseases and insects may be high. Tree mortality often causes concern among foresters and the public, but both gradual and rapid rates of tree death are normal aspects of forest development.

So what are the risks of not applying restoration treatments in mixed conifer forests? Our stand reconstruction surveys did not provide evidence that current forest conditions are outside the range that would have been common in the 1800s. Current stand basal areas are 50% or more beyond those from the reconstruction; part of this may be real, with greater tree density and size than in the past. However, we could not reconstruct historic aspen basal area, and some of the apparent increase in basal area of conifers may be a natural result of deceasing aspen basal area during normal forest succession. The current range of basal area across the landscape probably overlaps that from the 1800s, though low-basal area stands may be less common now. In the absence of normal frequencies of mixed-severity fires, the current landscapes may be less heterogeneous than in 1875, so the risk of higher severity fire across larger areas may now be higher.

Mixed conifer forests may be considered to be extremely resilient. If western spruce budworms kill many of the Douglas-fir trees (alone or in combination with Douglas-fir beetles), surviving spruce or aspen trees ensure the continuation of the forest. A mixed-severity or canopy fire would promote rapid development of aspen stands. This high ecological resilience does not imply that any and all changes to mixed conifer forests would be equally desirable. A wide range of management options would be feasible for mixed conifer forests, each with varying influences on future forest changes (and risks).

Key points for restoration on the Plateau

- Mission: To enhance the resiliency, diversity and productivity of the native ecosystem in the Uncompahgre Mesas area of the Uncompaghre Plateau, CO using best available science and collaboration.
- Restore ecosystem structure, composition and function. The protection and restoration of ecosystem structure, composition and function encourages viable populations of all native species in natural patterns of abundance and distribution.
- Using passive and active management techniques, vegetation communities should be moved toward conditions that are more consistent with their historical ranges of variability.
- The establishment and maintenance of more natural patterns of vegetation diversity and abundance are integral to ecological restoration.
- Restore ecological processes. Natural processes, including fire, insect outbreaks, and droughts, are irreplaceable shapers of the forest… A key priority should be to restore stands to a more natural condition and to reduce the risk of unnatural crown fires both within stands and across landscapes.
- Preserve old or large trees while maintaining structural diversity and resilience… the largest and oldest trees (or in some cases the trees with old-growth morphology regardless of size) should be protected when feasible from cutting and crown fires, focusing treatments on excess numbers of small young trees where this condition is inconsistent with HRV conditions.
- Treatments should focus on achievement of spatial forest diversity by managing for variable densities.
- Reestablish meadows and open parks.
- Manage herbivory. Grass, forbs, and shrub understories are essential to plant and animal diversity and soil stability. Robust understories are also necessary to restore natural fire regimes and to limit excessive tree seedling establishment. Where possible, defer livestock grazing after treatment until the herbaceous layer has established its potential structure, composition, and function. The partnership will seek to work with the Colorado Division of Wildlife to manage big game populations to levels that will contribute to successful restoration treatments.

Suggestions for restoration

The goals and objectives for forest restoration on the Uncompahgre Plateau provide several key points for the context of recommendations for restoration treatments (see box).

Ponderosa pine forest type. Very little (if any) of the Plateau's forest of ponderosa pine retain the structure that was most common in 1875. Our stand reconstructions indicated that much of the landscape would have had forests with 20 to 90 ft^2/acre in a clumped distribution, interspersed with small (0.1 to 0.5 acre) meadows. Larger meadows were probably more common as well, though our field work was not aimed to determine changes in meadows. Most of the Plateau's ponderosa pine forests have basal areas beyond the upper limit that was common in the 1800s; and the landscape is almost completely lacking the type of ponderosa pine forest that would have been most common in 1875. We expect that the majority of the ponderosa pine stands on the Plateau will not receive restoration treatments, so we recommend restoration prescriptions aim to restore the forest conditions that are most rare on the Plateau.

Harvesting and restoration treatments (for example, see Lynch et al. 2000 and Romme et al. 2003 for recommendations from the San Juan National Forest) should aim to produce relatively low basal area forests (perhaps 20-50 ft^2/acre), dominated by large trees (along with a similar number (but low basal area) of saplings and medium size trees, somewhat clustered (with clump diameters of 20 to 100 feet) with small meadows between clumps. The size of units to be treated should be as large as feasible, as historic disturbances that shaped forests would have occurred at scales of hundreds to thousands of acres. However, entire units need not be treated uniformly; variation in density, size of meadows, and other features can be applied across a unit. In particular, intentional variations in treatment intensity within units will enhance learning opportunities from the monitoring program. No single forest structure would have been found across the landscape in 1875 (or any other period), so the goals should focus on restoring stand structure that set the forests into the normal context for ecological processes and patterns over space and time.

The focus of the prescription should be on creating the desired forest condition, rather than a prescription defining which trees may or may not be removed. Prescriptions should include retention of most or all of the largest trees in treated stands, and removal of most (but not all) the small diameter trees. However, no arbitrary cap on maximum harvest tree size (such as 18" and larger) should be used; size-cap based prescriptions would *prevent* restoration goals in some stands.

Several issues about the subsequent development of the restored forests will need attention. Retaining the value of the restoration treatments will depend on the re-establishment of a normal fire regime (or alternatives such as frequent mechanical treatments). No single fire return interval would be appropriate. An initial fire within a few years of the harvesting treatment would be useful; subsequent surface fires varying from 5- to 20-year intervals might be ideal.

The response of Gambel oak to the restoration treatments will need to be monitored, and this monitoring would be most informative if applied to plots that received varying levels of overstory removal and fire intervals.

Mixed conifer forest type. The value and opportunities for forest restoration are different in the mixed conifer portions of the Plateau. Unlike the ponderosa pine type, where very few (if any) acres remain within the historical range of variation, most acres of mixed-conifer forests may be within historical ranges. This major difference results from the inherently broader range of historic variation of mixed conifer forests, and perhaps partially from a longer fire-return interval resulting fewer "missed fires" in the past century.

Even though individual acres may not be outside historical conditions, the patterns at the scale of the Mesa or Plateau may be quite unusual. Very few acres have burned on the Plateau in the past Century, so young, post-fire conditions are rare. Would this have occurred in the past? We know that some fires tended to burn across much of the Plateau (such as the fires of 1842 and 1879), so some uniformity in forest age across large portions may not be unusual.

This wide range of typical forest conditions means that restoration prescriptions can be even more varied than in ponderosa pine forests. Recent post-fire forests are rare, and silviculture aimed at restoring mixed-severity fires would serve restoration goals. In particular, selective harvesting of high-value trees could provide the opportunity for using large equipment (already on site) to developing ambitious fire breaks around harvest units that would allow a prescribed fire of high intensity.

The diversity of species would also allow prescriptions to foster some species over others. For example, if the future is expected to be hotter and drier, ponderosa pine or aspen might be favored over blue spruce. We caution that not only is future climate unknown, the changes may not be uniform; a warmer climate could also be associated with a wetter conditions. More importantly we cannot predict how the complex ecological interactions between tree species, their pests and pathogens, and with other tree species. A goal of increasing diversity across the landscape (through increased harvesting and burning to create currently rare, post-fire forests) would have very low risk, whereas aiming to favor one particular species in a diverse forest would be risky (and perhaps unwise).

In mixed conifer forests, restoration goals may not constrain forest management choices that would be based on other resource objectives. Increased harvesting would create more young forests on the landscape; a combination of harvesting with mixed-severity fire might be particularly useful for broad ecosystem management goals.

Monitoring

No forest restoration program would be complete without describing forest characteristics before treatment, and following the forest changes after treatment. A monitoring program needs to be designed in advance, including clear plans for establishing control areas (receiving minimal treatment), and various treatment alternatives (such as broadcast fire with varying levels of prior harvest). CFRI would be anxious to work with the UP Project and the Ouray District to develop and implement pre- and post-treatment monitoring, incorporating lessons learned from the Ponderosa Pine Partnership (Romme et al. 2003)) and from the forest restoration institutes in Arizona and New Mexico.

Table 1. 1875 forest structure on 25 Mesa.

Plot	All species		Ponderosa pine		Douglas-fir		Spruce		Subalpine fir		Aspen	
	Stems/ acre	Basal area (ft2/ acre)	Stems/ acre	Basal area (ft2/ acre)	Stems/ acre	Basal area (ft2/ acre)	Stems/ acre	Basal area (ft2/ acre)	Stems/ acre	Basal area (ft2/ acre)	Stems/ acre	Basal area (ft2/ acre)
1a	32	40	32	40								
1b	46	51	46	51								
2a	19	36	19	36								
2b	19	47	19	47								
2c	36	41	14	18	12	17	10	6				
3a	44	87	44	87								
3b	22	70	20	70			2	2				
3c	14	32	14	32								
4	34	87	34	87								
5a	57	84	57	84								
5b	35	41	35	41								
7a	41	78	17	28	17	9			2		5	12
7b	99	96	10	7	70	85			19	7		
7c	51	85	17	17	34	65			2	3		
7d	70	52	24	15	44	36	2	1				
8a	109	79	64	66	30	14	15					
8b	30	58	8	24	8	30	14	4				
9a	66	128	18	35	48	93	0	0				
9b	53	60	15	25	18	23	11	12				
9c	68	80	48	52	12	21	8	7				
9d	44	69	18	51	26	19	0	0				
UNC6 9a	37	24	26	14	4	7	7	2				
UNC6 9b	86	33	40	17	7	1	35	12	2	2		
11a	77	107	4	3	65	99	4	6	0	0	4	2
11b	18	37	12	27	6	10						
11c	18	45	4	7	14	37						

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Figure 10. Spatial arrangement of trees in ponderosa pine type plots, estimated for 1875.

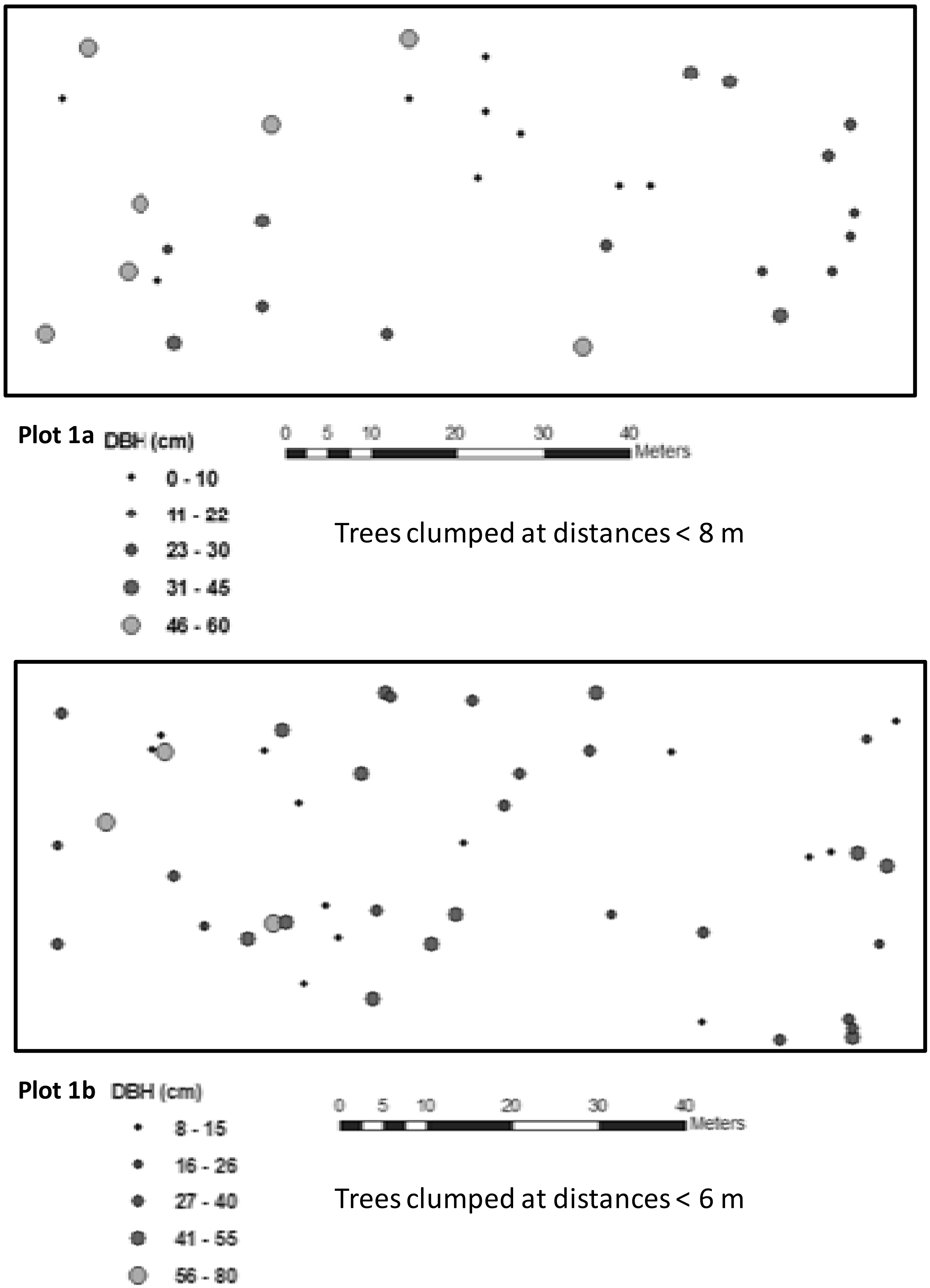
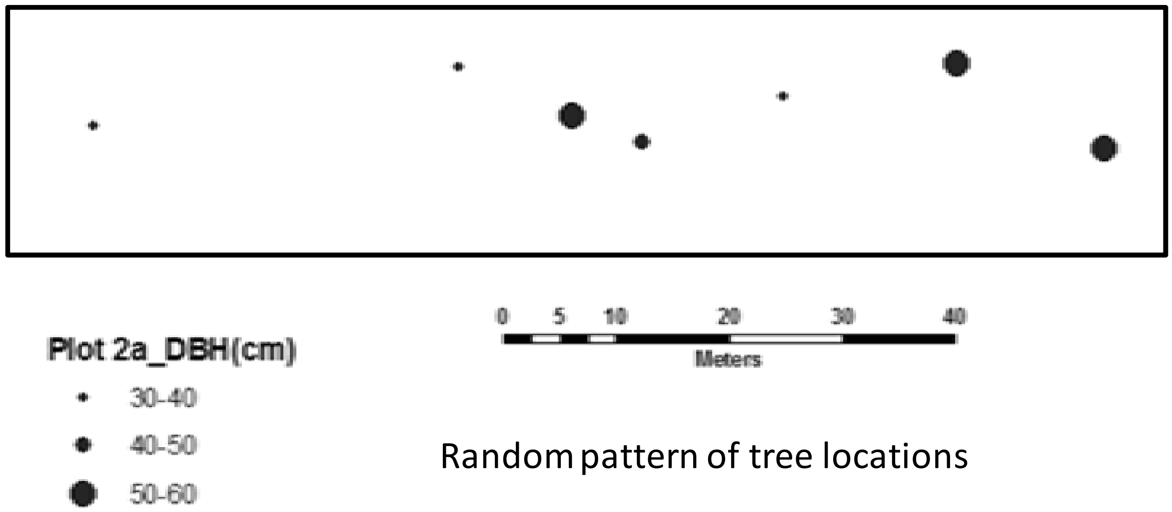
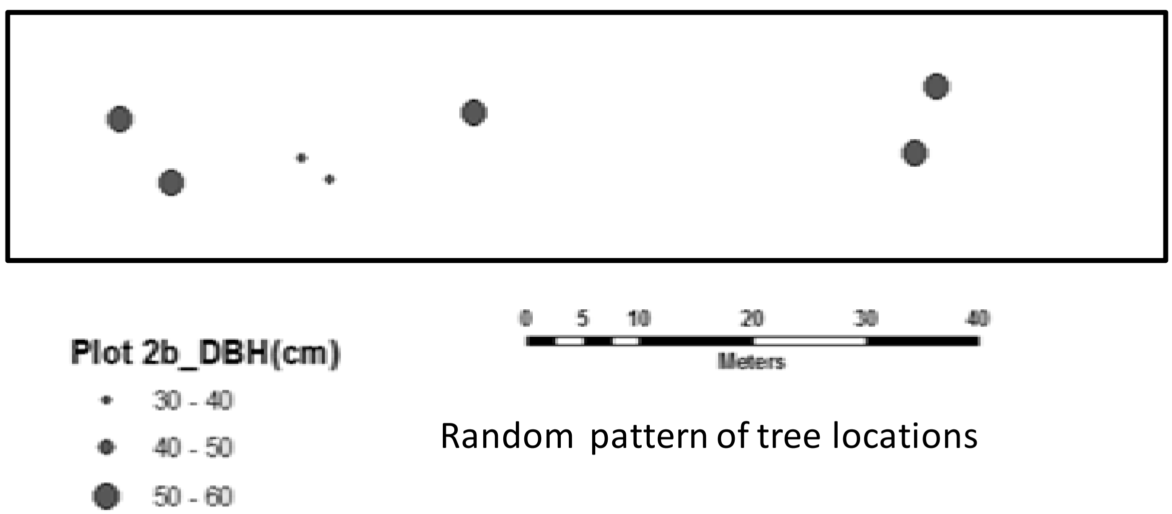


Figure 10 (cont.). Spatial arrangement of trees in ponderosa pine type plots, estimated for 1875.





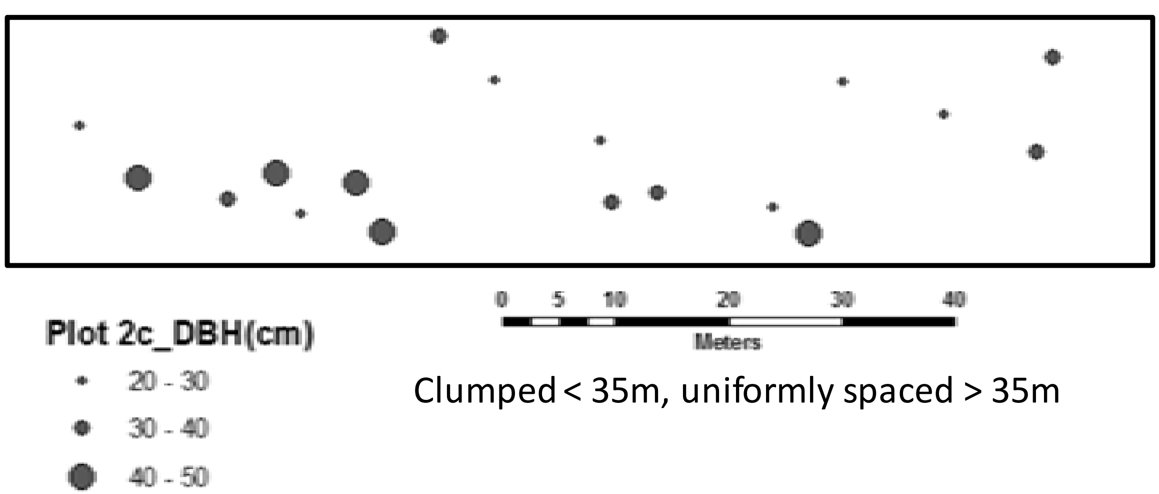
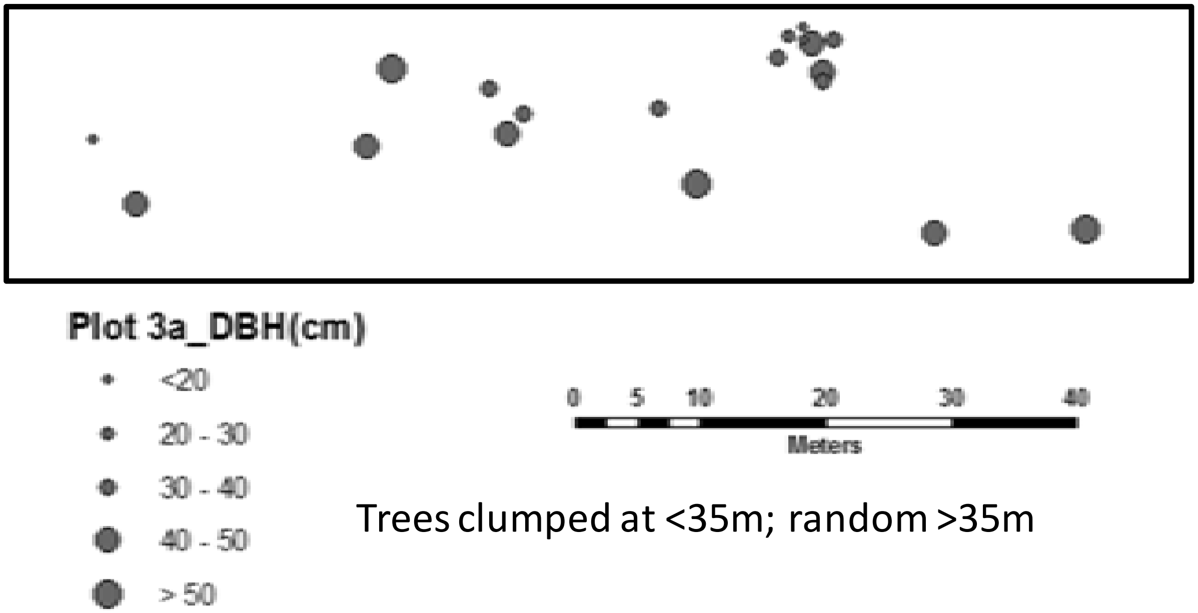


Figure 10 (cont.). Spatial arrangement of trees in ponderosa pine type plots, estimated for 1875.



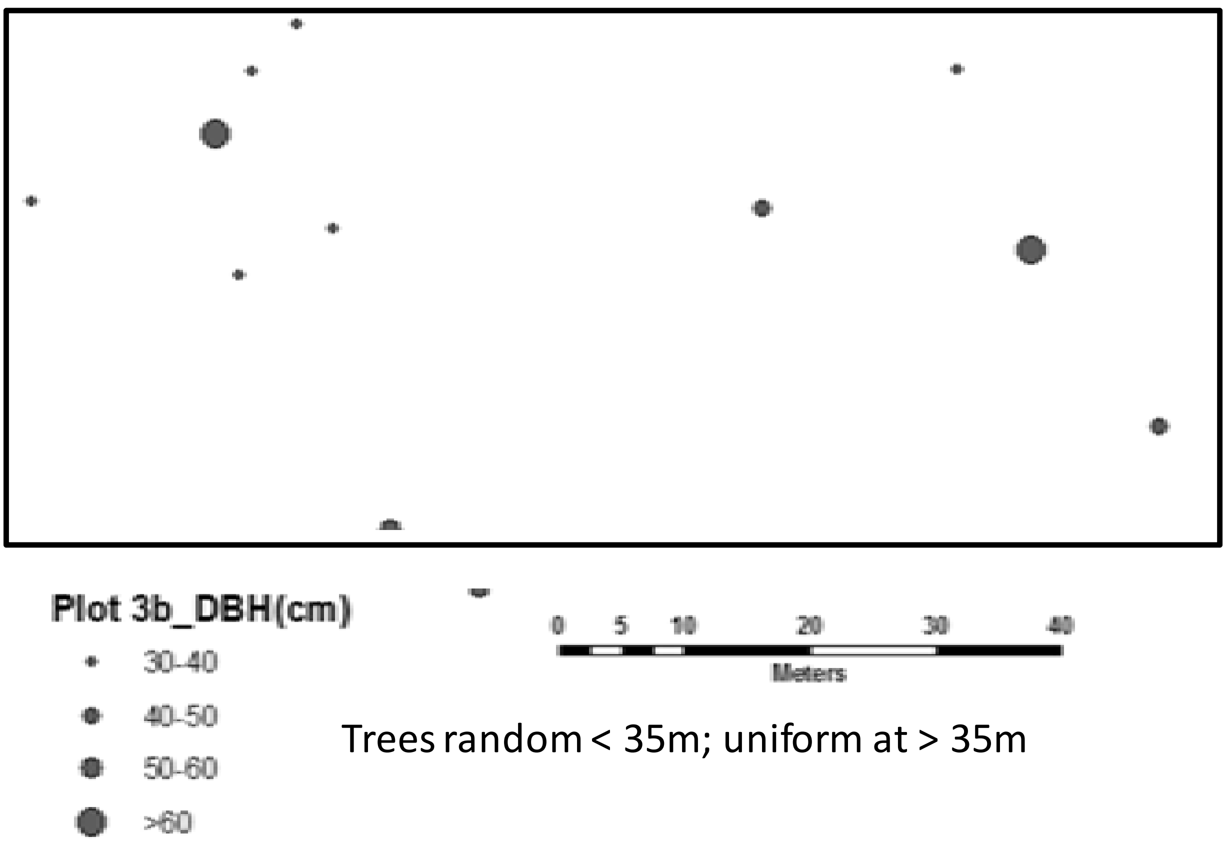
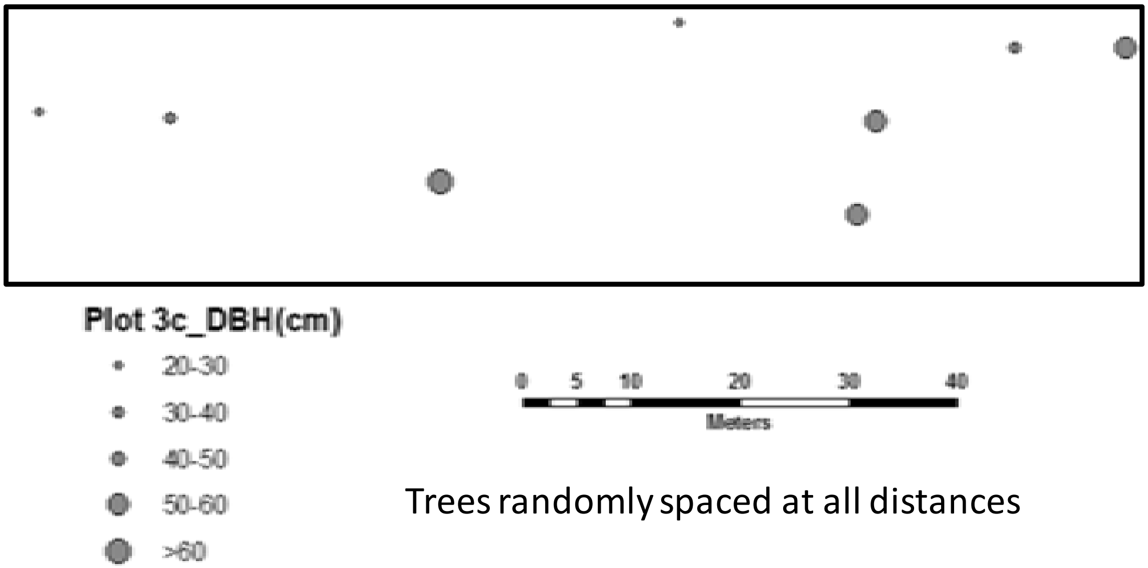
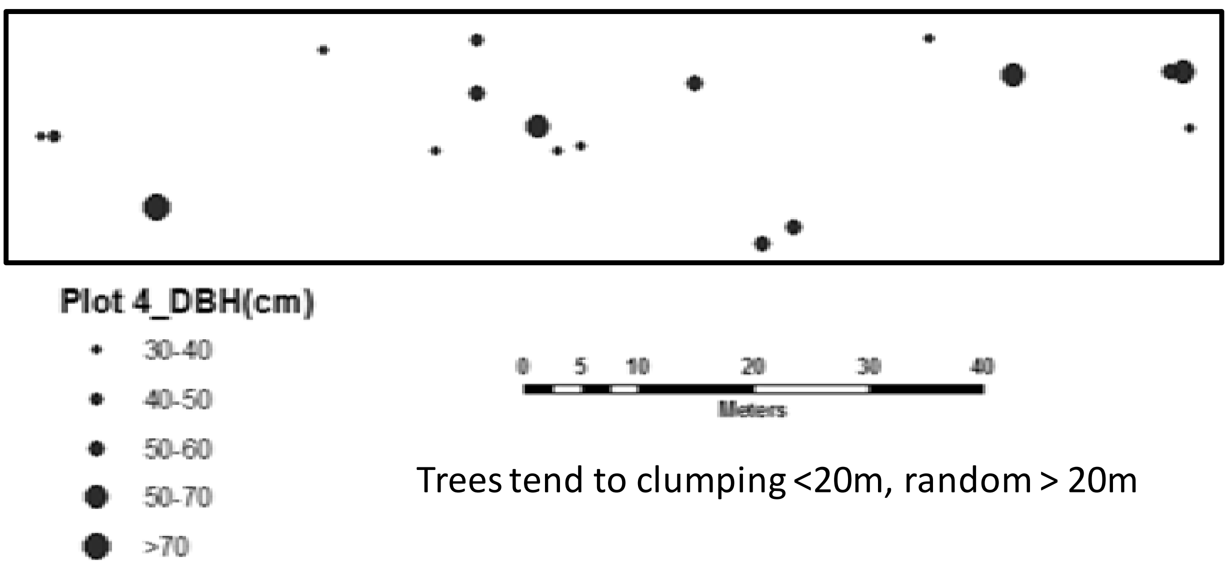


Figure 10 (cont.). Spatial arrangement of trees in ponderosa pine type plots, estimated for 1875.

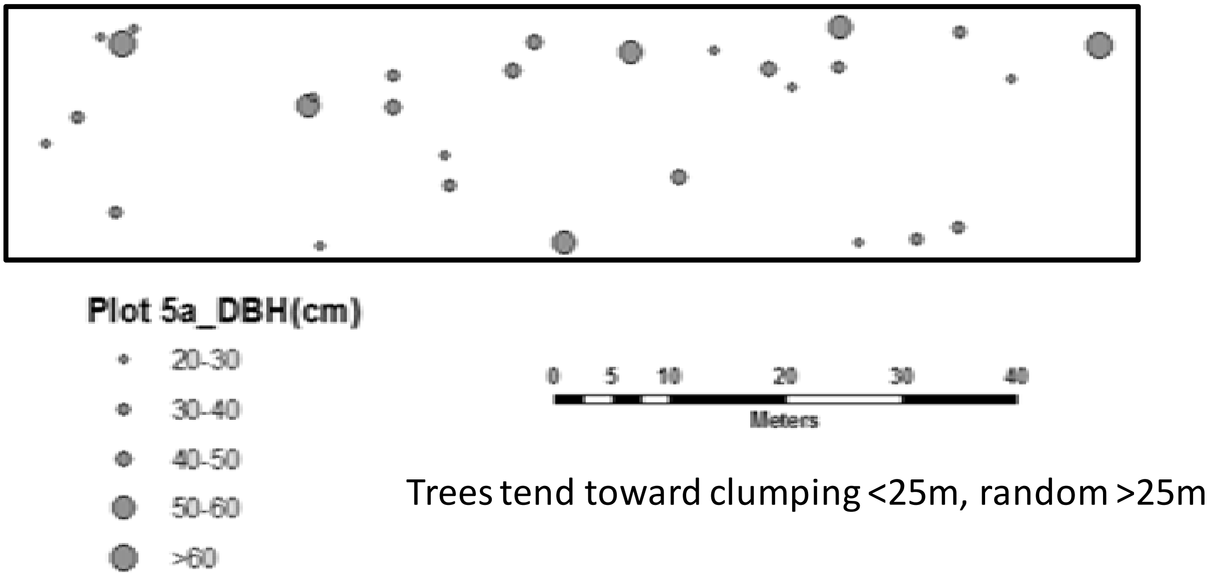


Trees randomly spaced at all distances



Trees tend to clumping <20m, random > 20m

Figure 10 (cont.). Spatial arrangement of trees in ponderosa pine type plots, estimated for 1875.



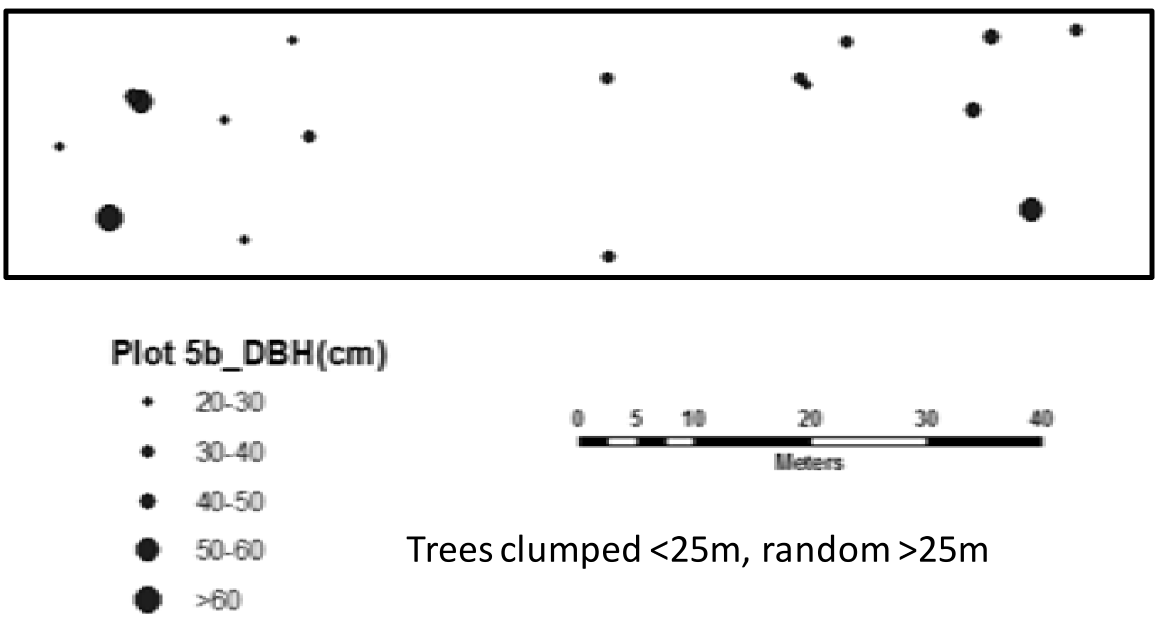


Figure 11. Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875.

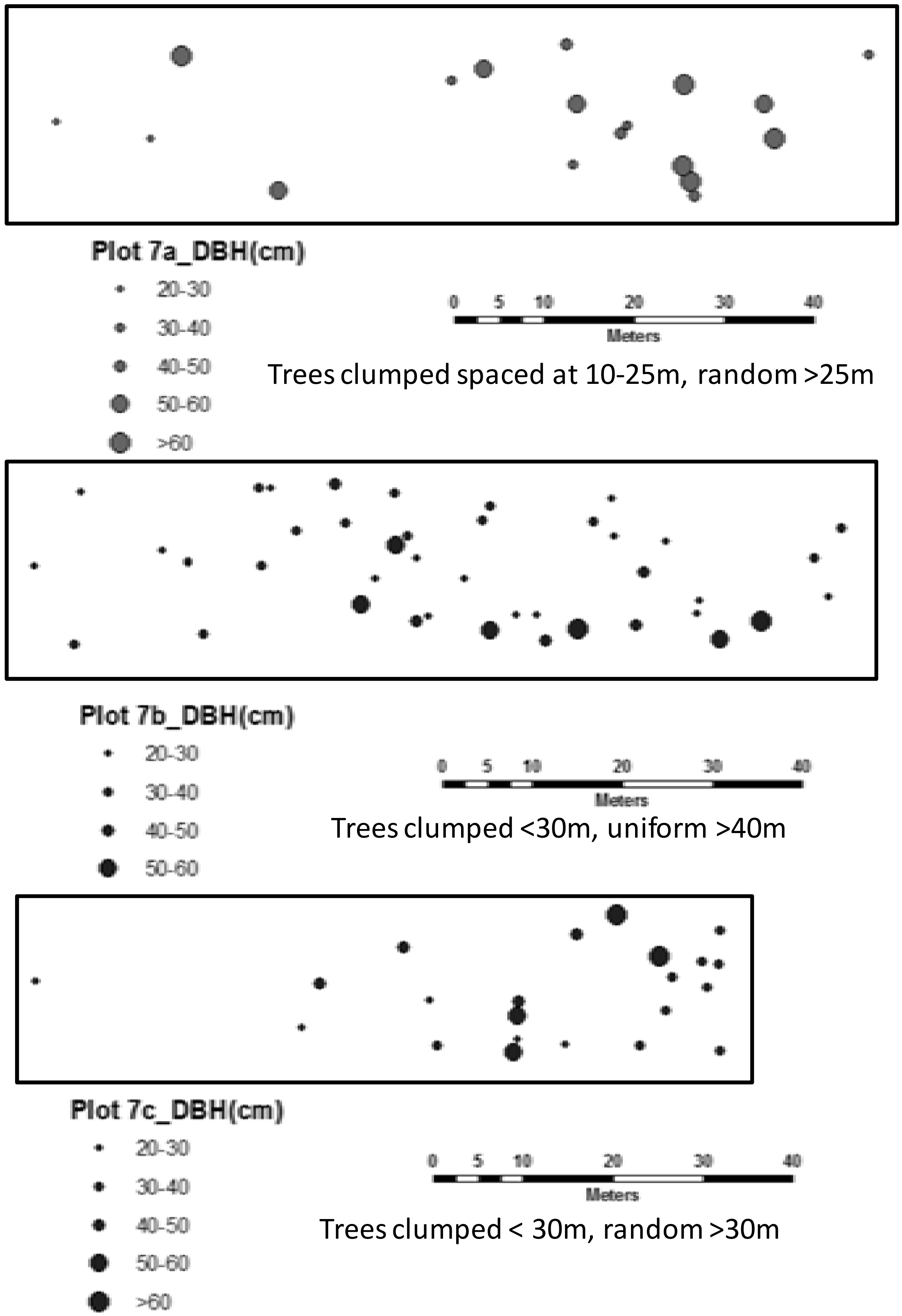
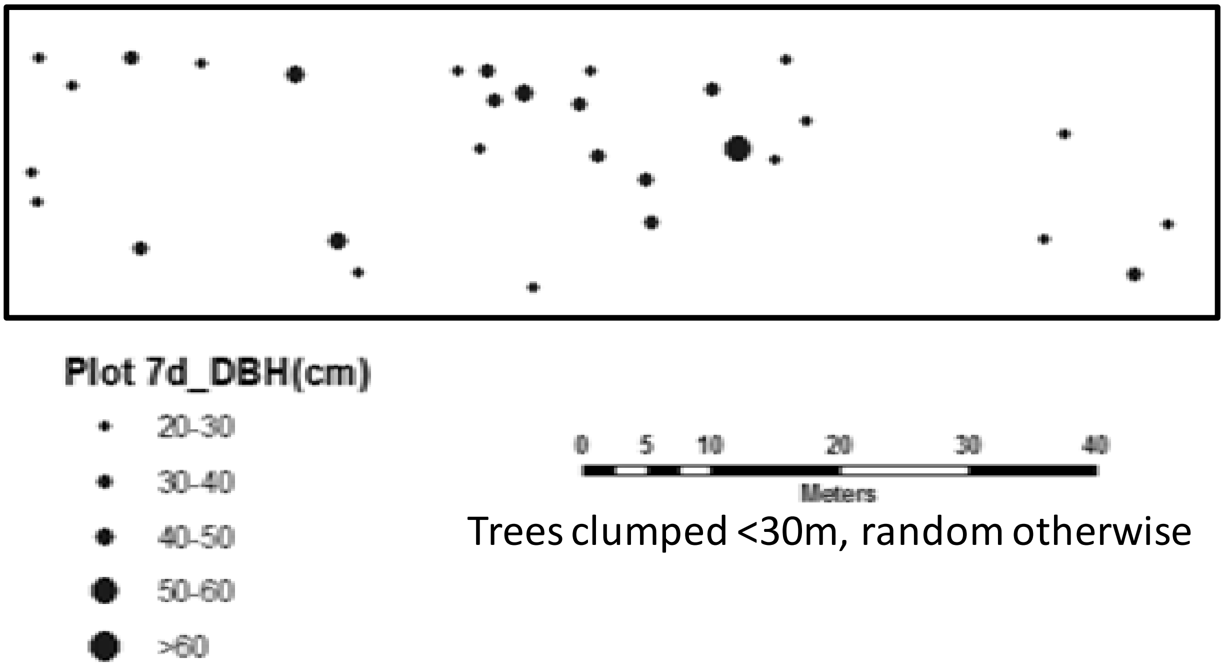


Figure 11 (cont.). Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875.



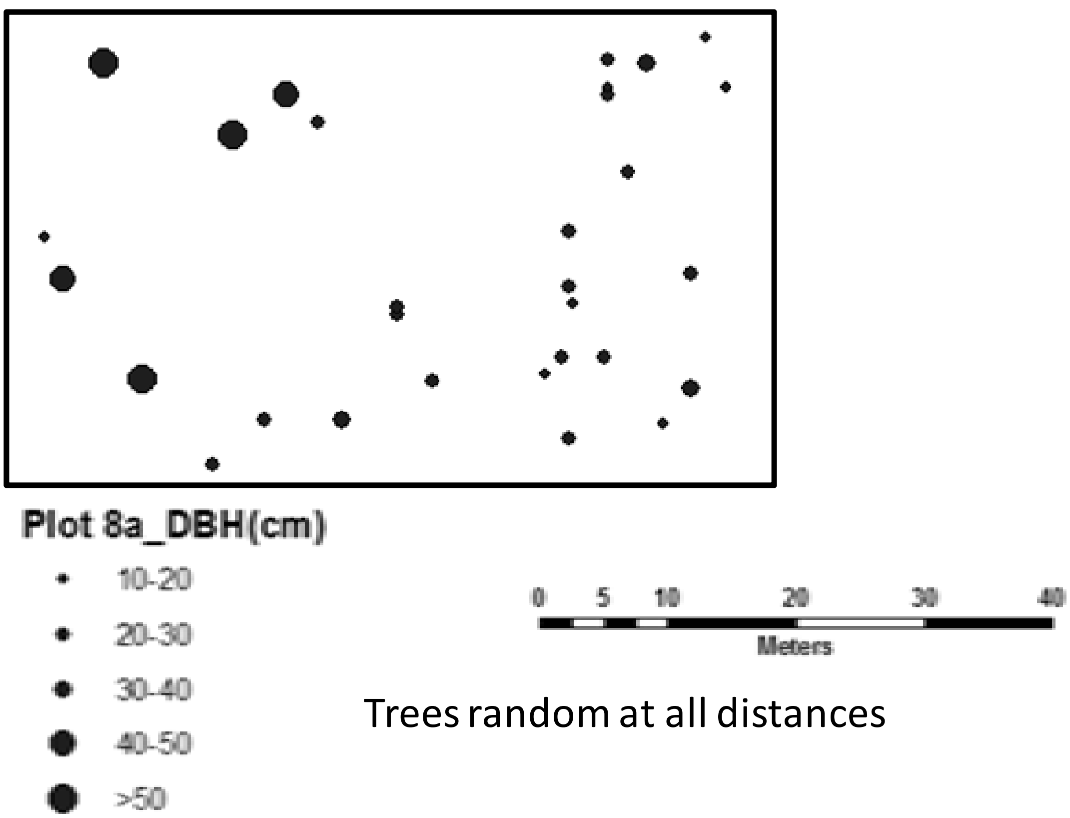
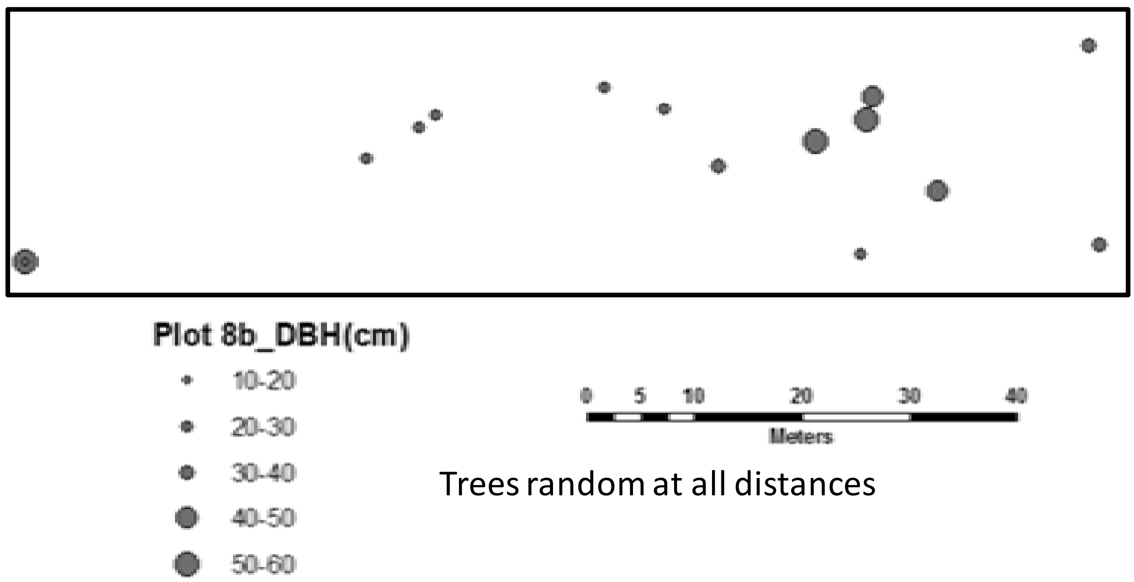
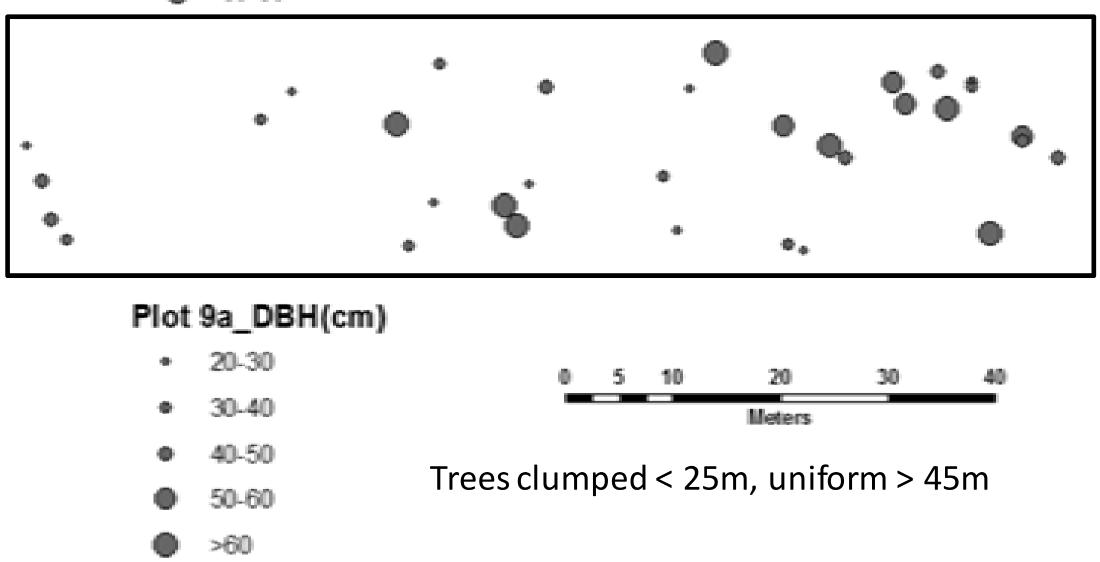


Figure 11 (cont.). Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875.





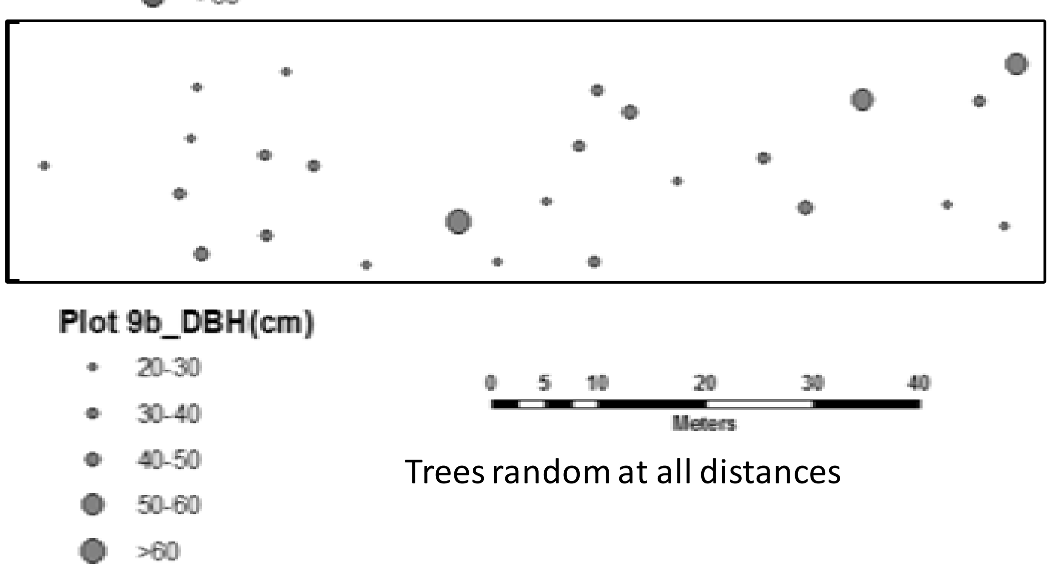
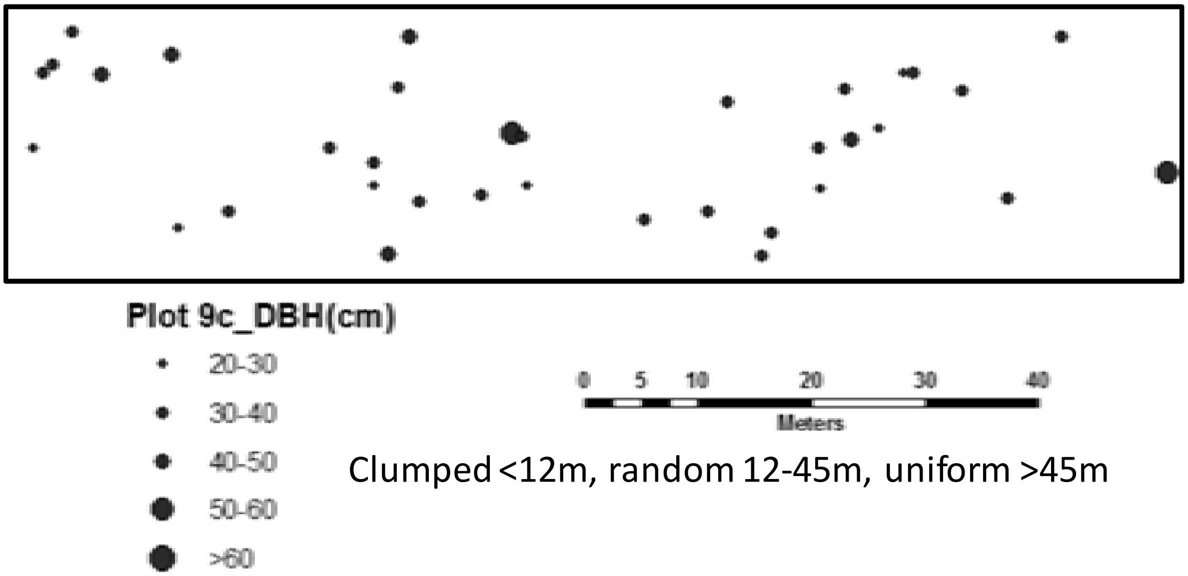


Figure 11 (cont.). Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875.



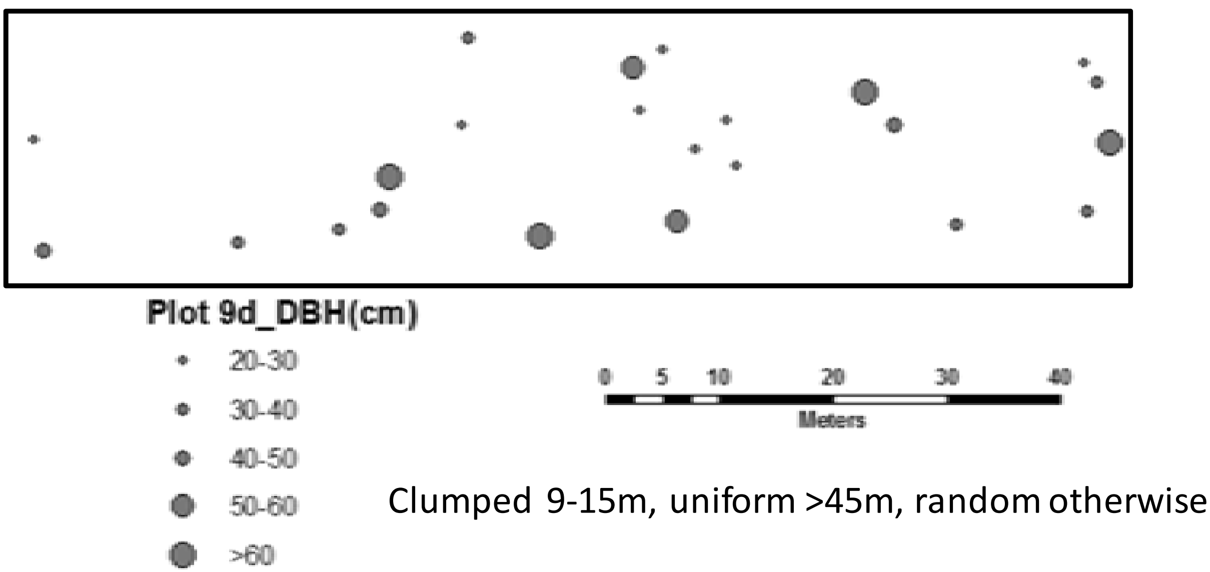
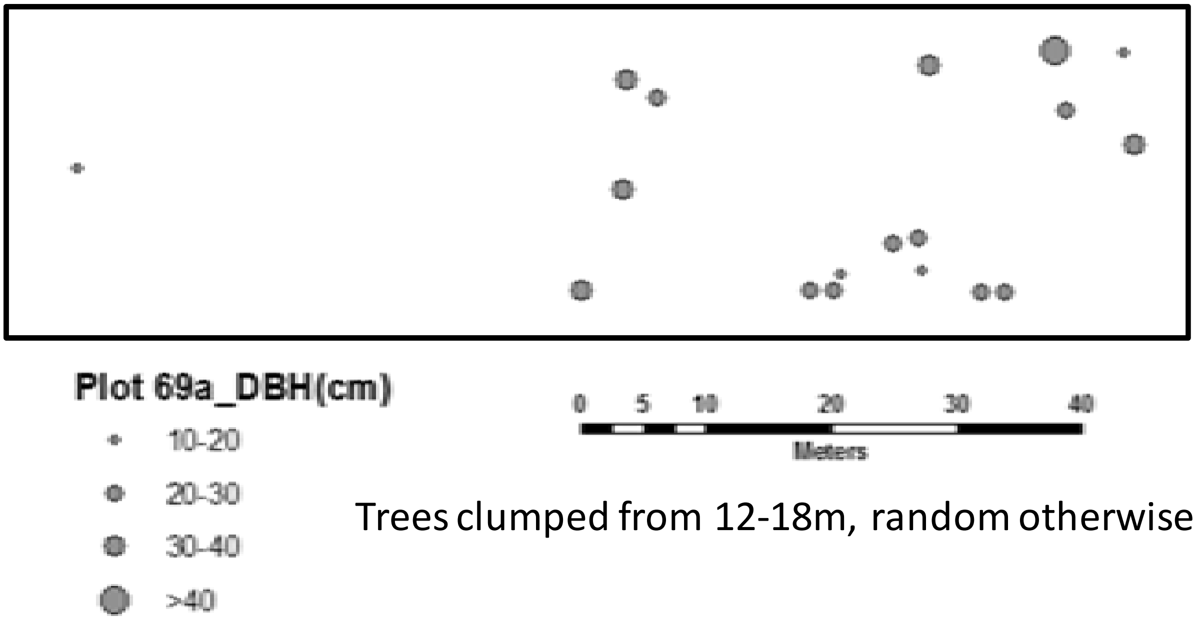


Figure 11 (cont.). Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875..



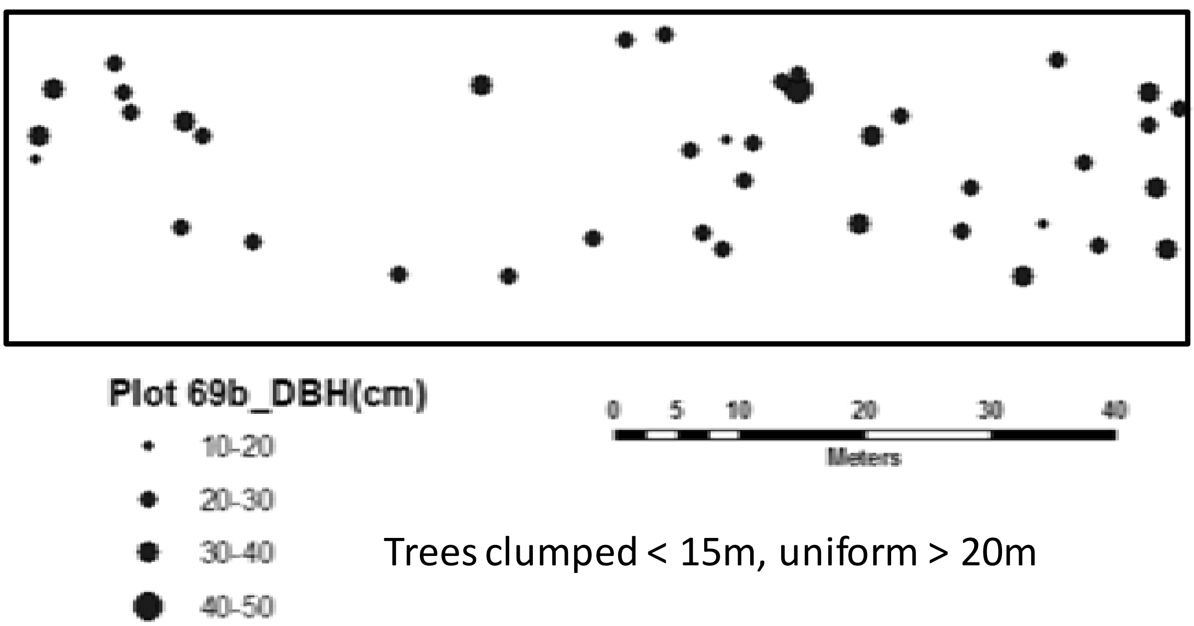


Figure 11 (cont.). Spatial arrangement of trees in mixed-conifer type plots, estimated for 1875.