Harvesting Western Juniper (*Juniperus occidentalis*) in Eastern Oregon - A Case Study

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This paper summarizes the results of a recent study of harvesting operations in a stand of western juniper near Klamath Falls in eastern Oregon (See attached Vicinity Map). Harvesting juniper stands is fairly appealing to many ranchers in eastern Oregon, due to the large areas of range land that have, over time, become dominated by juniper. Juniper stands also reduce the amount of water available to grasses and other forage plants.

Conversion of land invaded by juniper stands is not an easy task. The timber has traditionally been considered a weed species with little or no commercial value as a wood product. When attempting to convert their lands, ranchers are often forced to simply cut down the trees, pile them, and burn the piles. The cost of these operations are prohibitive, ranging from $35 to $75 per acre, and few ranchers are in a position to finance large scale clearing operations to improve their grazing lands.

At present, there are approximately four million acres of western juniper woodlands (where juniper has a 10 percent or greater canopy) in eastern Oregon, northeastern California, and southwestern Idaho. Total volume is estimated to be well over 700 million cubic feet on these lands. About 58 percent of the total acreage Is on public lands and the remainder is privately owned. Over 61 percent of all juniper woodland is located in eastern Oregon.

The area dominated by western juniper represents a three to ten-fold increase since the late nineteenth century. Reasons for this expansion are complex, but generally involve the absence of fire, increases in domestic livestock grazing, and short-term changes in local climatic conditions. The expansion and increasing density of western juniper woodlands is of great concern to private landowners, government land management agencies, and scientists. Many juniper-dominated sites show clear evidence of watershed degradation, loss of site productivity, decreases in forage production, loss of wildlife habitat, and reductions in biodiversity levels.

Western juniper is currently the least utilized wood fiber source in eastern Oregon. Juniper is not considered a viable commercial species by most forest products companies for a number of reasons. Juniper trees have numerous and large limbs, large flared butts, and can contain extensive pockets of butt rot. Other major barriers to more intensive commercial use include the distance to major fiber markets, lack of an industry-specific infrastructure for the commodity, and lack of market acceptance. However, the most significant problems associated with using western juniper as a commercial timber species are those encountered during harvest operations.

Conventional harvesting systems commonly used in Eastern Oregon -- typically consisting of a feller-buncher, skidder, and sometimes a stroke delimber -- are not suitable for handling the butt flare and large, flexible limbs common to western juniper. These properties affect harvesting system productivity in the following manners:

- 1. **Increased time required for manual falling operations** - Fallers are often required to spend considerable amounts of time delimbing the standing tree and clearing limbs from around the bole prior to falling to allow them access to the bole, a practice that requires between two and six minutes depending on the limbiness of the tree. Stem form and limb structure also make the tree butt bounce up after falling, creating a hazard for the faller and adding time to the falling operation.
- 2. **Delays in delimbing** - Considerable time can be lost when manually delimbing the felled tree with chainsaws. Fallers reported average delimbing times that exceed five minutes per tree. This is a significantly longer time than anticipated with other, less branchy species.
- 3. **Reduced skidder loads** - It is difficult, if not impossible, to bunch unlimbed juniper trees prior to skidding, unless the operator is willing to take only one or two stems to the landing per cycle. Aside from

the fact that the trees are manually felled - which limits the potential for bunching an adequate load - the size and quantity of limbs limit the size of the bunches to no more than one or two trees, far less than required for a full load when using a grapple skidder.

Study Objectives

The previously noted problems that can occur when harvesting juniper suggest that there is a limited window of opportunity for this species. A major concern is the actual productivity of a conventional harvesting system and the costs associated with that harvesting operation when working in juniper. Thus, the primary objective of this study is to determine the average productivity by phase for a conventional harvesting system while harvesting juniper. In addition, mechanical delimbing of juniper will be analyzed to determine what changes in productivity might occur through the adoption of this technique into the harvest system.

Methods

The stand harvested during this study was measured and marked prior to harvest. Three stocking densities were noted during the pre-harvest inventory. These included low density stands with between 25 to 50 stems per acre, medium density stands with 50 to 100 stems per acre, and high density stands with 100 to 160 stems per acre. Marking varied depending on initial stocking densities, with 5 to 15 stems removed per acre in the low density stands, 15 to 25 stems removed per acre in the medium density stands, and 50 to 100 stems per acre removed in the high density stands. The average diameter of the harvested stems was 13.6 inches at breast height. The mean weight of the merchantable portion of each harvested stem was 721 pounds or 0.361 tons per stem. The site was relatively flat to rolling terrain with few obstacles present that would affect primary transport operations.

The harvest system used during the study consisted of two to three chainsaw operators, a grapple skidder, a mechanical delimber, and a hydraulic knuckleboom loader (or shovel). The crew had been working for at least five years in harvesting operations, with about six to nine months of experience harvesting juniper stands. The pre-limbing crew (See note below for details on pre-limbing process) had limited experience. The operations involved in the harvest of these stands included the following:

Pre-limbing: Standing trees were manually "pre-limbed" by a chainsaw operator to a height of about six to eight feet. This allowed the faller to later access the base of the tree for the falling phase. This operation is not typically required when harvesting other species, but was necessary in nearly every case during this study. Branches were removed from around the base of the tree by the chainsaw operator to provide an escape route for the faller.

Falling: The falling phase was carried out independent of the pre-limbing operation. Falling was done in a conventional manner using chainsaws. Wedges were used in many cases because of the short (mean height of 30 to 40 feet), limby nature of the tree, which made the severed stems "sit down" on the stump.

Manual Delimbing: Trees were delimbed and topped after falling was completed. All manual delimbing was done "at the stump", where the tree had been felled. Trees were never completely delimbed during the manual operation, because of the problems with accessing the bottom side of the tree. Some work was then required at the landing to finish the delimbing process.

Mechanical Delimbing: Mechanical delimbing with a low cost pedestal mount delimber was studied as an option to manual delimbing to determine if this approach would improve system productivity and lower costs. Two mechanical delimbers were evaluated during the study, a Dansco and a CTR. Both operated on the principle of drawing the stem through a set of hydraulically actuated knives with a knuckleboom loader. A number of factors were critical to the success of this operation:

1. Operator experience - The operator had little or no experience with this phase prior to the study. As the study progressed, delimbing cycle times improved dramatically.

2. Loader performance - If the loader had been a bit more powerful, delimbing would have been somewhat faster, although no major problems were encountered relative to the loader.

3. Knife angle and length - Some problems were encountered due to the placement angle of the delimbing knives, where the knife blade would "dig in" to the bole while delimbing. Also, the knife blades on one delimber were not large enough to completely shear off some larger limbs. The typical limb diameter at the bole averaged between three and six inches, with some limbs ranging to nine inches in diameter at the bole.

4. Presence of a self-centering head - The operator indicated that the presence of a self-centering head greatly improved delimbing times.

5. Size and weight of the delimber - The taller, heavier delimber observed in this study did not tip over, and provided a better pull through motion for the loader.

6. Pre-limbing height - Pre-limbing heights of at least eight feet were required to adequately handle the stem during mechanized delimbing.

7. Presence of slash - It was critical that slash be removed from the front of the delimber after only one or two cycles. If this was not done, positioning of the stem in the delimber was more difficult and resulted in longer delimbing cycle times.

Skidding: The system uses a grapple skidder, which may be the only option available for skidding juniper. Skid cycles were timed for both limbed and unlimbed stems. In addition, the number of stems skidded per cycle was obtained to estimate differences in load for these two options.

The skidder's return cycle was used to distribute slash throughout the harvest unit to improve groundcover growth and survival. The site was seeded with forage grasses prior to harvest and the slash added organic material to the marginal soils, decreased soil temperature, and improved soil water retention. The slash was also considered a deterrent to grazing of the newly established grasses by domestic and wild animals.

Loading: Loading was not timed during this study, as most of the material was decked. However, loading cycles can probably be estimated from other studies where loading cycles were observed since there is little difference in loading times by species for specific log sizes.

All trees were manually pre-limbed and felled. Some were then manually delimbed prior to skidding to provide comparative data. The remaining trees were skidded without being delimbed (whole-tree skidding), mechanically delimbed at a central landing, and then decked or stored for later delivery to a local mill. Slash was then re-distributed throughout the harvest unit using the grapple skidder.

After the data for each cycle was collected, the information was entered into a spreadsheet for analysis. The objective of the analysis was to determine the average time required to complete each phase of the processing operation.

Data was collected using conventional time and motion study techniques. Cycles were defined for each phase of the harvest operation and then timed using a stop watch. Recorded times were then entered into a spreadsheet for basic statistical analysis. After the average time to complete each phase was estimated from the data, a complete cycle time estimate was developed. Cycle times were then paired with production estimates obtained from mill records to obtain an estimate of the average production per cycle in tons per productive minute.

All phases of this system typically handled only one stem per cycle. Only during the skidding phase was more than one stem handled during a single cycle. To estimate the cycle time per stem, the following equation was used to modify the average cycle time for skidding:

SpS = S/N (eq. 1)

Where:
SpS = Mean Skid time per stem
S = Mean Skid time (observed)
N = Mean number of stems per cycle (observed)

A total cycle for the harvesting operation could include either manual or mechanical delimbing, but not both phases. So, the total cycle time estimate for the operation consisted of:

TC (min) = PL + F + SpS + MD (eq. 2)

or:

TC (min) = PL + F + S + DM (eq. 3)

Where:
TC = Total Cycle Time
PL = Pre-Limb Time
F = Fell Time
MD = Mechanical Delimb Time
DM = Manual Delimb Time

Total scheduled hour production was estimated using the relationship illustrated in equation 4. By determining the total number of cycles per scheduled hour and combining that value with the estimated average weight per stem, an estimate of the average hourly production can be obtained.

Prod = (60 min per SchedHr/TC) * Wt (eq. 4)

Where:
Prod = Production per Scheduled Hour (tons/hr)
Wt = Mechantable weight per stem (tons)
TC = Total system cycle time per stem (scheduled minutes)

As no estimates of the overall utilization of the system were made, an assumption was made regarding utilization. The system was assumed to work approximately 75 percent of the total scheduled time during the day. In addition, the system was assumed to be harvesting trees with an average yield equal to that estimated in the study. Predictions outside the range observed in the study were avoided. However, it should be pointed out that these estimates of production will typically hold for only small changes in stem size, so that any significant change in stem size would make production estimates difficult using the data provided through this study.

Results

Descriptive statistics are provided in Table 1 for all of the harvesting phases observed during the study. Using equations (2) and (3), two different estimates of the total harvest cycle time per tree can be obtained, depending on whether manual or mechanical delimbing was included:

For mechanical delimbing:

TC = PL + F + S + MD

and;

TC = 2.53 + 2.02 + 2.27 + 2.91
TC = 9.73 productive minutes per cycle

For manual delimbing:

TC = PL + F + S + DM

and;

TC = 2.53 + 2.02 + 2.27 + 3.13
TC = 9.95 productive minutes per cycle

Assuming an average 75 percent utilization rate for the system, the total cycle tome for the system using a mechanical delimbing phase can be estimated as:

TC (sched) = (9.73)/0.75
TC (sched) = 12.97 scheduled minutes

and

Prod = 60 min/12.97
Prod = 4.64 cycles per scheduled hr

Where:
Prod = Total number of cycles per scheduled hour

Table 1: Descriptive statistics for harvest phases during harvest operations in a partial harvest of western juniper.

Harvest Phase	Mean Cycle Time	Std. Deviation	N
Pre-Limbing	2.53	1.90	64
Manual Felling	2.02	1.14	21
Manual Delimbing[1]	3.03	2.02	9
Skidding[2]	5.20	2.37	14
per stem...	2.27		
Mechanical Delimbing[1]	2.91	1.77	59

[1] Manual delimbing occurred prior to skidding and precluded any need for mechanical delimbing operations. Mechanical delimbing occurred at the landing after skidding operations and no manual delimbing was required when this operation was included in the system.

[2] Skidding cycles averaged 2.3 stems per cycle. Average cycle time was adjusted to provide the average cycle time per stem, as indicated above.

For manual delimbing, the same approach is used, and the total cycle is estimated as:

TC = (9.95)/0.75
TC = 13.27 scheduled minutes

and

Prod = 60 min/13.27
Prod = 4.52 cycles per scheduled hr

Where:
Prod = Total number of cycles per scheduled hour

The production rate for this system defines the volume or weight of wood harvested per scheduled hour of production. Using the mean weight per harvested stem of 0.361 tons and equation 4, the production rate for a system using mechanical delimbing is estimated to be:

Prod = (4.64*0.361)
Prod = 1.67 tons per scheduled hour

Thus, the estimated production for this system using mechanical delimbing on an hourly basis is 1.67 tons per hour. If the value of a green ton (freshly harvested) of juniper is estimated to equal $40 per ton, the gross return from this system is estimated to be:

Gross = 1.67 tons * $40 per ton
Gross = $67 per hour of production

For the manual delimbing option, the production rate is very similar, estimated at 1.63 tons per scheduled hour. Combined with the estimated harvested stem weight for the stand, the gross revenue that could be expected for juniper bringing $40 per ton would be $65 per scheduled hour.

If the cost of the equipment, insurance, parts, repairs, fuel, and labor exceed this revenue on an hourly basis, the operation is unprofitable. If these costs are less on an hourly basis, then the system can operate profitably when harvesting

a stand similar to that studied here. The productivity associated with mechanical delimbing did not differ significantly from that for manual delimbing. However, it should be noted that the mechanical process required only the loader operator, who was located in a protected cab during delimbing. In contrast, the manual delimbing process required an individual on the ground to operate the chainsaw. The manual delimbing was also considered a very dangerous and fatiguing operation, particularly given the average limb size and number of limbs that had to be removed. Generally, the contractor greatly preferred the mechanical system, as it seemed more productive, and created a safer work environment for the crew.

This analysis assumed no costs associated with stumpage. While this is uncommon in most harvest operations, the situation with juniper is somewhat different. Many landowners in eastern Oregon and elsewhere want to have their juniper woodlands thinned, and know that they cannot do it themselves. Some are willing to exchange the harvested timber for having the stand thinned to their specifications. In this study, for example, no stumpage fee was charged to the contractor, and the landowner appeared pleased with the initial results.

On the other hand, many landowners will need to be convinced that their particular patch of juniper is virtually worthless. Based on the experience of the few who have commercially harvested juniper, there are only a few situations where stumpage can be paid for western juniper. For example, stumpage ranging to a high of $5 per green ton has been paid to landowners in the following situations:

- 1. Where there is easy access to a local mill willing to take the material.
- 2. Good quality logs in a dense stand (> 100 stems per acre)
- 3. Presence of a strong biomass or "dirty" chip market

Generally, landowners should not expect to receive any stumpage for their juniper stumpage. If the market for this material becomes more viable and mills begin to accept western juniper as a needed raw material, the situation might change.

Conclusions:

This study examined partial harvest operations in a western juniper stand in eastern Oregon. Total cycle time estimates for this operation were developed for both manual and mechanical delimbing operations. While there was little difference in the productive times recorded for these two options, the contractor preferred the mechanical option, both for safety and production reasons.

Generally, production for this system was low, with an observed average productivity of less than two tons per scheduled hour. This low rate of production is countered by the negligible cost associated with the stumpage, suggesting that a conventional harvesting operation could be effective in harvesting juniper from rangeland sites. Obviously, factors such as initial stocking, harvested stem size, log quality, and removal densities will also have a significant effect on the profitability of these operations. Land owners interested in harvesting juniper woodlands need to work closely with local logging contractors and mills to determine whether commercial harvest is an option for thinning their woodlands. In many cases, due to the factors mentioned previously, commercial harvest will not be an option, even if the landowner is willing to give the timber to the contractor.