Thinning with Prescribed Fire and Timber Harvesting Mechanization for Forest Restoration: A Review of Past and Present Research

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ABSTRACT

Fire suppression and previous logging practices in forested regions of the Blue Mountains in northeastern Oregon have set the stage for catastrophic wildfire, epidemic insect attack, and disease. This paper investigates the current knowledge on stand manipulation from timber harvesting from past research projects in the region and discusses present research. Prescribed fire in conjunction with a cut-to-length harvesting system are currently being investigated in an integrated research project. The research outcome will provide managers with the decision making tools to make sound economical and environmental decisions, and aid in forest restoration.

KEYWORDS

Cable yarder, single-grip harvester, prescribed fire, fuels reduction, forest health, GPS, stand structure

INTRODUCTION

In the Blue Mountains of eastern Oregon, the dry conifer forests and much of the inland west are at risk to catastrophic wildfire. Over 80 years of fire suppression and the selective harvest of ponderosa pine (*Pinus ponderosa*) have resulted in levels of fuels that have set the stage for wildfires (McIver et al. 1997).

Fire has been an important disturbance process for millennia in the wildlands of the Blue Mountains. Records from early explorers and on many older trees suggest that fire burned at frequent intervals (fire return intervals of 5-10 years on some sites) in many of the Blue Mountain forests and grasslands (Agee 1996). Since about 1900, the forest structure and composition have changed. Most of the change is directly related to fire exclusion (McIver et al. 1997). Also, the practice of selectively logging ponderosa pine left stands with increased densities of lodgepole pine (*Pinus contorta*) and favored Douglas-fir (*Pseudotsuga menziessi*) and grand fir (*Abies grandis*). As a result, the dense stands of these species increased the incident of pine beetles and defoliating moths (Barret 1983). Conifer tree pathogens and climatic events such as the severe drought conditions over the past several years are also contributing factors (Mutch 1993).

High stocking levels, reduced tree vigor, insect attack, and disease have left many of these stands with high fuel levels and wildfire potentials. With a combination of standing dead and downed trees, high levels of litter fall, and suppressed regeneration, the stage has been set for catastrophic wildfires.

In an effort to improve stand health and reduce wildfire risk, several studies have been completed or they are underway in the Blue Mountain region. A pilot study (Deerhorn project) investigated the use of a standing skyline and single-grip harvester (SGH) to reduce stocking levels and remove standing dead and downed trees (Brown 1995, Kellogg and Brown 1995). A second study (Limber Jim project) compared the use of a SGH and standing skyline to a SGH and forwarder in a cut-to-length (CTL) operation (Drew et al. 1998, McIver 1998, Doyal 1997). Both studies focused on the reduction of fuels by mechanical methods and the utilization rates of the standing dead and downed wood versus sawlogs. However, the objectives were expanded in the Limber Jim project to include environmental effects of the harvesting treatments.

Currently an integrated study is being conducted (Hungry Bob project) that will provide scientific information to land managers on the systematic interactions that shape the operational feasibility, economics, and environmental effects of alternative fuel reduction methods (McIver et al. 1997). The Hungry Bob project will build on the body of knowledge from the previous studies and include a prescribed fire component in the treatment.

The purpose of this paper is to discuss the existing knowledge that the Deerhorn and Limber Jim project produced, as well as discuss the current study underway (Hungry Bob). Specifically, economics, feasibility, and fuel reduction will be covered.

CURRENT KNOWLEDGE

Deerhorn Project (From Brown 1995)

The Deerhorn project, conducted in the summer of 1994, was a pilot project designed to answer the following questions:

1. Can fuel loads be acceptably reduced with a SGH combined with a small skyline yarder?
2. Is it economically feasible to harvest fiber material and small sawlogs with such a system?
3. What degree of soil disturbance and compaction can be expected with a harvester/yarder combination?
4. What effect does the system have on small mammal and log dwelling ant populations?

The study site consisted of a 50-acre harvest unit, located southwest of Pendleton, Oregon. The terrain was relatively flat with slopes under 10%. An average diameter at breast height (DBH) of 9 inches and in some areas as much as 1000 stems per acre covered the varying stand structure. In the 1970's, the mountain pine beetle (*Dendroctonus ponderosae*) attacked the timber stand, which left most of the lodgepole pine dead and eventually on the forest floor. The silvicultural prescription for the stand included the following points: reduce the fuel loading, increase stand vigor by eliminating diseased trees and thin the green trees to 80-90 trees per acre (tpa), retain 50 pieces of woody debris per acre, and provide some late forest structure in a landscape dominated by pine.

The harvesting equipment included a Koller K501 yarder (trailer mounted) combined with an Eagle Eaglet carriage. The Carriage was a radio-controlled slack pulling carriage on a standing skyline, slackline system with intermediate supports and tailtrees. With a 4-person crew, the owning and operating cost of the yarder was calculated to be $132.79/SMH (scheduled machine hour). The SGH was a Link Belt 'C' Series II tracked carrier (LS 2800), a Pierce modified feller-buncher boom, and a Waratah 20-inch single-grip hydraulic tree felling and processing head. Hourly owning and operating cost (with operator) was calculated to be $89.41/SMH. Loading cost was $67.64/SMH using a John Deere 690 ELC grapple loader. All harvesting layout occurred prior to logging. Potential skyline corridors, tailtrees, and intermediate supports were located and flagged using a corridor centerline spacing of 150 to 250 feet. The harvester operator removed standing, unmarked trees as well as processed the down material on the forest floor. Moving parallel to the skyline corridors, the harvester processed strips approximately 50 feet in width.

The following summarizes the type of products that were harvested and the production rates from the Dearborn timber sale. Logging productivity rates for both the harvester and yarder are summarized in Table 1. Utilization rates for the harvester and yarder were 80% and 57% respectively.

Timber removed from the site consisted of the following:

- 42% live
- 14% standing dead
- 44% dead and down

The percent species composition removed from the stand was (determined by board foot volume):

- 23% Douglas-fir
- 31% grand fir
- 33% lodge pole
- 1% ponderosa pine
- 12% western larch (*Larix occidentalis*)

The gross volume removed and scaled at the mills was:

- 29% sawlogs
- 60% pulpwood
- 11% cull and deduction

Table 1. Production rates for SGH and yarder on the Deerhorn project.

	SGH		Yarder	
	Prod/ SMH	Prod/ PMH	Prod/ SMH	Prod/ PMH
Logs	151.5	188.5	78.5	139.0
Ft^3	589.4	733.3	305.4	540.7
Bdft	2918	3631	1512	2677
Tons	13.5	16.8	7.0	12.4

Total revenue was determined using the present market prices at the time of the study. Sawlogs and pulpwood generated a revenue of $515/MBF and $36/ton respectively at the mill. The calculated logging costs for the different pieces of equipment are shown in Table 2.

Table 2. Logging costs for Deerhorn project

	$/ Cunit	$/ Mbf	$/ ton	$/ m^3
Layout	1.45	2.93	0.64	0.51
Harvester	15.92	32.11	6.97	5.62
Yarder	40.53	81.78	17.74	14.31
Loader	18.15	36.61	7.94	6.41
Trucking	20.19	42.19	9.15	7.39
TOTAL	96.97	195.6	42.44	34.24

Total revenue was calculated to be $103,258 and total owning, operating, and labor cost was found to be $78,808 (with no profit or risk allowance) which produced a net profit of $24,250. Thus the study concluded that it was economically feasible to combine a SGH and a small cable yarder on flat ground in a fuel reduction treatment (in this case study). A key factor was the component of higher value sawlogs (29% in this study).

Fuel loading prior to harvest averaged 47.8 tons per acre, with 40% of the fuel occurring in the 3-9 inch diameter class. There was an overall 20% reduction of fuels due to the harvesting. The 3-9 inch and 9-20 inch diameter class were reduced by a total of 20%, while all other diameter class increased. Fine fuels in the 0-3 inch were increased due to the activities of the harvester and the processing of trees into short log lengths in the stand, however, these fuels should decompose in a relatively short time frame following harvest. Large fuels greater than 20 inches were left in the stand to enhance wildlife habitat.

Limber Jim Project (From Drew et al. 1998)

The main objective of the Limber Jim study, conducted in the summer of 1996, was to compare the use of a SGH and small cable yarder with a CTL harvester/forwarder system. As a fuel reduction project, the overall management objectives were to reduce crown fire potential, meet soil protection standards, and pay for the operations with harvesting revenues. The following items were measured in the study:

1. Fuel loading before and after harvest
2. Soil disturbance and compaction impacts of harvesting on soils
3. Logging production rates, harvesting costs, and revenues

The study was located on the Wallowa-Whitman national Forest, near the La Grande municipal watershed in northeast Oregon. The study design included seven distinct research units from a pool of 18 units. The research units ranged from 6.5 to 23 acres in size, and percent slopes ranged from near 0% to 20% slope. The average DBH was 7 inches with approximately 250-300 tpa removed. Chip material removed was 54 and 42 green tons/acre for the skyline and CTL system respectively. In addition, there were 4 and 6 green tons/acre of saw logs removed (skyline and CTL respectively). Stands were either mixed conifer with grand fir, western larch, and Douglas-fir or primarily lodgepole pine. The mountain pine beetle and the western spruce budworm had severely damaged the stands (similar to the conditions found the Deerhorn project). The attacks on these stands left many standing dead and downed trees. Fuel loadings were some of the highest in the area, with up to 80 tons/acre. The silvicultural prescriptions varied somewhat from unit to unit, however, all standing dead and downed trees in the 4 to 15 inch DBH were removed. Tree marking was either to leave or to cut depending on the volumes of green tree removal. A target residual tpa was not required, and left to a unit by unit decision.

The harvesting equipment included two SGH. Both were 1991 Hitachi 200LC excavators fitted with 1992 Keto 500 harvesting heads. The owning and operating cost of each harvester was $114.00/SMH. The cable yarder was a 1997 Diamond D210 3-drum swing yarder (track mount) combined with an Eagle Eaglet carriage. The yarder used a standing skyline, slackline system with tail trees and intermediate supports, when needed. With a 5-person crew, the owning and operating cost of the yarder was calculated to be $230.00/SMH. The cable yarding operation also used a John Deere 690 knuckleboom loader for sorting and stacking logs($73.00/SMH). The forwarder in the CTL system was a 1996 Valmet 646 (12-ton capacity), with an owning and operating cost of $80.00/SMH. A Morbark 27-inch disk chipper, was onsite for processing pulp for both systems. Limited to eight truckloads of chips per day, the owning and operating cost was $93.00/SMH.

Timber removed from the study units was:

- 19% live
- 26% standing dead
- 55% dead and down

The percent saw log versus pulpwood harvest for the project was:

Skyline system
- 12% sawlogs
- 88% pulpwood

CTL system
- 6% sawlogs
- 94% pulpwood

Table 3 shows the logging productivity and costs for the different pieces of equipment in the skyline and CTL systems. The different productions that were observed from the skyline and CTL systems were 13.5 tons/SMH and 10.3 tons/SMH, respectively. Revenue from timber harvesting are shown in Table 4.

Total revenue was determined from the present market price at the time of the study. Sawlogs generated $425/MBF, which converted to $86.00/green ton. Delivered values for chips was $97.50/DBU (bone dry unit), equivalent to $59.00/green ton.

Table 3. Logging productivity and costs for skyline and CTL systems on the Limber Jim project.

	Skyline		CTL	
	Tons/ SMH	$/ton	Tons/ SMH	$/ton
Layout		1.38		
Harvester	5.9	19.32	8.9	12.86
Yarder or Forwarder	10.3	29.54	13.5	5.93
Chipper	19.8	4.13	19.8	4.4
Loader		0[1]	30.0	0.15
Trucking		18.15		18.15
Stump-to-Mill		72.51		41.49

[1]Included with yarding cost

Table 4. Gross revenue per green ton and per acre.

	Skyline		CTL	
	$/ton	$/acre	$/ton	$/acre
Chips	59	2512	59	3181
Sawlogs	86	500	86	302
System Total	63	3012	61	3483

Subtracting the stump to mill costs, the forwarder system produced net revenues of $19.50/ton ($1112/acre), and the skyline system lost $9.5/ton ($-479/acre).

Harvester costs were higher for the skyline system due to the increase in corridor spacing. With skyline corridors spaced approximately 120 feet between centerlines compared to 60 feet for the forwarder, the harvester had to spend more time positioning and bunching logs for the cable yarder. Costs for the skyline system was also higher than those found in the Deerhorn project. Factors such as a decrease in saw log percentage, increased fuel loading, and higher equipment owning and operating costs, resulted in an increase in harvesting cost.

Fuels loading prior to harvest averaged 55.6 tons/acre. There was a 52% reduction in fuels due to harvesting. Fuel was reduced in all fuel classes except the 0-3 inch diameter class, where tonnage increased by an average of 11%. Fuel reduction was the greatest in the 3-6 inch size class (47% of pretreatment), followed by the 6-9 inch size class (29% of pretreatment). Statistically the skyline and CTL system produced similar fuel reduction patterns.

Of the seven study units, 6 had overall soil disturbance levels under 10% of the total area. Soil disturbance in this study was defined as areas were soils were either compacted or displaced. The CTL system averaged 6% and the skyline system averaged 7% total soil disturbance for the harvested areas. There was no statistically significant difference in soil disturbance between the two systems at the 95% significance level.

RESEARCH UNDERWAY

Currently, an integrated research team is investigating three distinct management scenarios (prescribed fire, thinning, thinning and fire). A brief explanation of each scenario is:

1. Prescribed fire will be used in units without any pretreatment of fuels and standing timber.
2. Thinning will involve CTL systems harvesting the standing dead, downed wood and some green tree removal.
3. Thinning and fire will combined both a CTL system and later be treated with prescribed fire.

These scenarios will be compared with regard to the following management factors (McIver et al. 1997):

1. Attainment of desired future stand conditions
2. Operational economics
3. Value of timber and morel mushrooms produced
4. Effects on residual stand and soil resources

The Hungry Bob research project area is located in the Wallowa-Whitman National Forest, 20 miles north of Enterprise, Oregon. The research project is contained within the 30,000-acre "Wapiti Ecosystem Management Project".

A complete randomized block design with replication and controlled units was located to measure both economic and environmental response to the treatments. The integrated design of study topics will produce a decision matrix that will help forest managers to identify threshold levels in both economic and environmental components, that indicate when minimum acceptable levels of output are achieved (McIver et al. 1997).

The main objectives of the study are (McIver et al. 1997):

1. Assess the extent to which treatments reduce fuels.

2. Determine operational production rates and economics, and identify the principal factors that explain them.
3. Determine the value of timber products and morels obtained.
4. Identify how different stand conditions (e.g. live to dead tree ratio) and fuel loading effects the economics of operations and the value of resources (timber and morels) removed.
5. Assess how treatments directly influence residual tree damage/mortality, morel production, morel species composition, and the soil/litter foodweb.
6. Determine how treatment impacts on soils and residual trees influence morel and the soil/litter foodweb.
7. Develop a matrix that identifies economic and environmental tradeoffs that occur among treatments.

Though an integrated study, the main focus in this paper is to discuss the operational intricacies of the work in progress. Linkages to the future integration are also briefly illustrated.

Experiment Design and Operations

On slopes ranging from 0-25%, the preharvest basal area ranged from 100-144 ft^2. Unit size varied from 27-162 acres, with a total area of 980 acres. With a mix of ponderosas pine, lodgepole pine, Douglas-fir, and western larch, the stands had similar standing structure as well as fuel loading.

A total of 16 experimental units were selected, and approximately 20, 50 meter, permanent, fixed radius sampling plots were located on transects at 100 meter intervals in homogenous stands with similar vegetation type (for each unit). The units were then randomly assigned to a treatment (control, prescribed fire, thinning, thinning and fire).

Preharvest data was collected from each fixed radius plot. Stand structure, fuel loadings, stand damage, morel production, and soil compaction were measured using appropriate protocol to later be revisited and compared with postharvest conditions. In addition, the position of the plot centers have were located using a global positioning system (GPS, Trimble XR Pro), for later analysis in a geographical information system (GIS) environment. Attributes and data collected from the fixed plots will be analyzed on a quantitative level by unit and treatment as well as on the landscape level, utilizing GIS technology.

Both the thinning, and thinning and fire treatment units were harvested in the summer of 1998. A CTL system was used to harvest all units using two pair of harvester/forwarders. Harvesters were rubber-tired mounted with a hydraulic single grip processing head. Forwarders were six wheeled, 10 and 12 ton capacity machines. All material removed was delivered to mills in short log lengths for further processing into pulp or sawlogs.

An economic analysis is currently being conducted on the harvesting data collected by shift level and detailed time studies. Variables of particular interest that are under investigation are: the percent composition of green tree, standing dead, and downed dead timber removed, and their effects on production and harvesting costs. In addition, GPS units were attached to the forwarders and their position was tracked throughout the harvesting units. From the GPS data, individual points were recorded on 5-second intervals, along with a times signature. This data will investigated as a potential way for measuring harvesting productivity, soil disturbance, and its use in landscape management.

While data analysis is in the early stages, the expected outcome is that (McIver et al. 1997):

1. Harvesting costs will be highest for the thin and burn treatment, followed by thin and then fire.
2. Timber value obtained from thinning will offset the total cost of fuels reduction methods.
3. A higher portion of live tree removal will improve operation economics.
4. From a landowners perspective, the planning and implementation cost (including offsetting value obtained from timber removal), will be lowest for the thinning alternative.

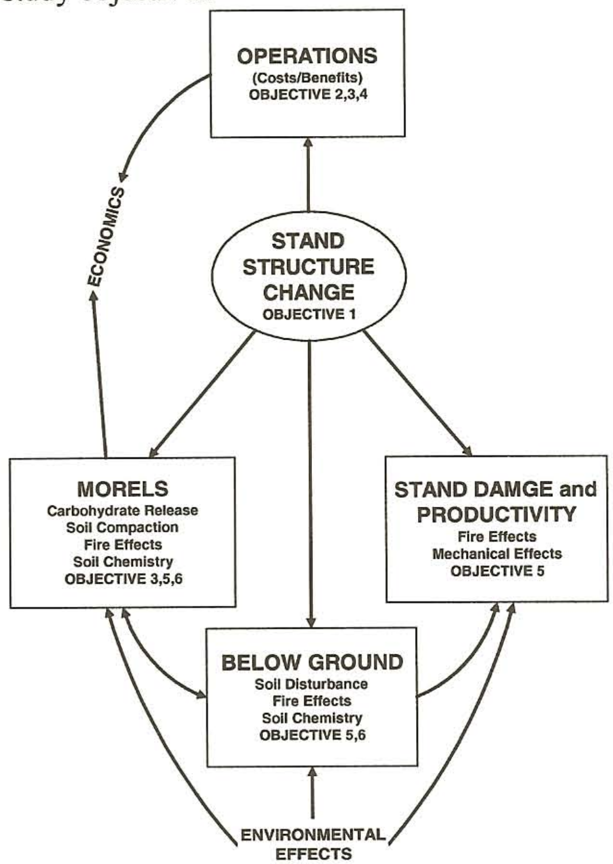
The year following harvest (fall 1999), prescribed burning of the understory will be conducted on the prescribed fire, and thinning and fire treatments. Again, a detailed and shift level time study will be conducted on the treatment operations and with the use of GPS units, the movement of personel conducting the prescribed burn will be monitored. This data will be investigated as a method for predicting and computing economic costs and behavior for prescribed burning on a unit (area) and landscape basis.

Response Linkages for Integration

The hungry Bob research project is designed to expand on the knowledge that was obtained from the Deerhorn and Limber Jim research projects and incorporates the use of prescribed burning. The study design involves collecting data on a set of potentially interacting variables. An integrated study is essential to gather the appropriate and useful information to aid management decision involving forest resource tradeoffs. Undertaking such a task is more complex in nature and involves many scientists from a variety of disciplines.

In order to link the different study objectives together, and form a true integrated study a proposed model was created to illustrate the potential interactions and linkages among the study components. This model of response linkages (Figure 1) is provided to aid in understanding the different objectives and how they are related (McIver et al. 1997).

Figure 1. Response linkages for integrating study objectives.

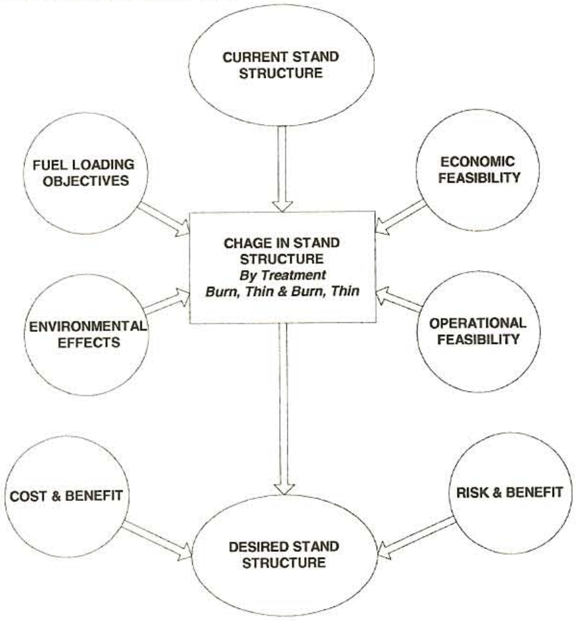


The areas of research and study objectives are listed within figure 2. Objective seven is the result of the first six objectives and is illustrated in Figure 2.

Decision Matrix

Of the seven objects previously listed, the seventh will provide a decision making tool to assist forest managers. By integrating the economic and environmental effects into a decision matrix, components of the study will be linked to management decisions. A preliminary list of the variables that will be considered are: operational feasibility, economic feasibility, environmental effects, current stand structure, desired stand structure, change in stand structure (by treatment), fuel loading objectives, risk and benefit, and cost and benefit. A flow chart illustrating the basic components of the decision matrix is shown in Figure 2.

Figure 2. Flow chart of basic components in the decision matrix.



The following points explain the nodes in the decision matrix flow chart:

- Current stand structure and changes in stand structure will be determined and compared from the fixed radius plots located in each unit and for each treatment.
- The fuel loading assessment in the pre and post treatment conditions will quantify fuel loading objectives. A threshold level can be used to identify if stands post treatment conditions are meet.
- Environmental effects are the combination of the above and below ground effects on soil disturbance, smoke management, stand damage, soil chemistry, etc.
- Economic feasibility will be determined from production studies of both harvesting and prescribed burning, as well as the morel mushroom production.
- Operational feasibility will relate different variables from the productions studies to predict changes in cost and harvest system performance to physical variables (e.g. yarding distance, percent slopes, ratio of green tree to dead wood removal, etc.).
- Cost and benefit is an outside factor that might influence the decision to manage a stand if an economic benefit is not the main objective.
- Risk and benefit encompasses the potential issues of introducing prescribed fire into an environment that has been managed under a fire exclusion regime.
- The management objects of the study define the desired stand structure.

CONCLUSION

Fire was a common occurrence in the Blue Mountains of northeastern Oregon. Years of fire suppression and prior harvesting practices have set the stage for catastrophic wildfire, epidemic insect attack, and disease. Current stand structure and composition has changed from the historic past. With knowledge from past studies and the current work in progress, management of these stands can be economically feasible and environmentally sound.

The Hungry Bob research project is striving to provide the required knowledge to properly manage these stands. The outcome of a replicated randomized block design will allow us to compare stand structure and other environmental components with the economic outcome of harvesting and provide us with needed integrated knowledge to manage these stands. It will also give mangers the ability to look at tradeoffs from three different silvicultural treatments (prescribed fire, thinning, thinning and fire) to aid management decision.

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