An Analysis of Opportunity Costs with Wet-Weather Timber Hauling

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ABSTRACT

Hauling logs during wet weather on low-volume roads can be a significant source of chronic turbidity and fine sediments that may be detrimental to aquatic organisms including salmonids in streams. As a result, regulations governing wet-weather hauling in the western timber-producing states and British Columbia have become increasingly restrictive. A potential result of the changes in regulations is limited access to an increasing proportion of commercial forestland during the winter months. The cost of restricted hauling and harvesting is potentially a resource that could be made available to improve aggregate road surfaces to minimize hauling restrictions during wet weather. The objective of this research was to investigate the opportunity costs associated with regulatory restrictions for hauling timber on a forest road during wet weather. The regulatory restrictions set forth in the *California Forest Practice Rules of 2004* were applied to the MacDonald-Dunn Research Forest at Oregon State University. Historic rainfall data were applied randomly over twenty 20-year simulation periods and harvesting and hauling activities were restricted accordingly. The estimated costs and revenue for a 20-year simulation period without wet-weather restrictions were compared to three management scenarios for harvesting and hauling with wet-weather restrictions to determine the opportunity costs associated with wet-weather restrictions. Dependent on the management scenario, wet-weather restrictions decreased total net revenue for the McDonald-Dunn Research Forest from 1.7 to 18 percent. From this analysis, opportunity costs (and total net revenue decreases) were smallest with the management alternative that involved the overtime use of equipment during periods when hauling and harvesting activities were not restricted.

Keywords: *opportunity costs, low-volume roads, wet-weather hauling*

Introduction

Forest roads used to haul timber are most often surfaced with unbound aggregate. These low-volume roads produce fine sediments especially during wet-weather use (Bilby et al. 1989, Reid and Dunne 1984). Studies have shown that forest roads can be hydrologically connected via surface flow to streams and that road runoff can enter the stream (Toman 2004, Wemple 1994). The potential for increased fine sediments and turbidity in fish-bearing streams has led to increased regulation in recent years in the western United States regarding timber harvesting and hauling activities during wet weather. The *California Forest Practice Rules of 2004* (CA Dept. of Forestry and Fire Protection 2004) require that landowners submit winter period operating plans that address erosion and road use issues for timber operations during the winter period (October 15 through May 1). Also, hauling on forest roads during the winter period cannot occur when saturated soil conditions exist on the road, although no definition or standard of determination of when saturation exists is included in the rules (Chapter 4, Subchapters 4, 5, and 6, Article 12: 923.1, 943.1, 963.1 (j)). Forest landowners in California have taken these regulations seriously, and some have further restricted timber hauling during any period of precipitation. Regulations in California and other western states may become even more restrictive as technical panels review current regulations and suggest changes.

The current changes in California's state regulations and potential changes in other western states mean that an increasing proportion of commercial forestland is taken out of production. In addition, the costs of conducting intensive forest management activities, especially timber harvesting, are increased and the management flexibility of forestland managers and owners is decreased during the winter harvesting period. Thus, forestland managers, especially private industrial land managers, are increasingly put at a competitive disadvantage in domestic and international markets for solid wood as domestic costs grow.

A viable option for forest managers who wish to take advantage of winter log markets is to improve road surfaces and reduce the environmental problems that accompany wet-weather hauling. The objective of this analysis was to investigate the opportunity costs, or money available to improve the

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roads, associated with regulatory restrictions for timber hauling on a forest road during wet weather.

Methods

In this analysis, the opportunity costs were taken as the difference between the cost for an all year operation and the cost for operations based on seasonal, wet-weather hauling restrictions. Three elements were necessary:

1. a land base over which to apply the analysis,
2. a harvest plan of sufficient detail that the sequential harvesting could be analyzed unit by unit, and
3. weather information of a form that allowed simulation of seasonal haul restrictions.

These elements were available for the McDonald-Dunn Research Forest located northwest of Corvallis, Oregon.

The McDonald-Dunn Research Forest is owned and managed by the College of Forestry at Oregon State University. The forest consists of roughly 4,550 hectares and is predominately managed for Douglas-fir (*Pseudotsuga menziesii*) in even-aged, two-storied, uneven-aged, and old-growth stands. A database is available for the forest that includes forest stand information by harvest unit. The McDonald-Dunn Research Forest is managed using a plan designed and periodically revised by the College of Forestry to provide "a management framework of policy and direction for forest staff" (Fletcher et al. 2005).

The forest management plan for the McDonald-Dunn Research Forest was recently reviewed and revised to evaluate possible silvicultural systems and harvesting systems, estimate production volume for each harvest unit, and determine harvesting scenarios for a future 10-year period. One such harvesting scenario is shown in **Figure 1**. Suggested 10-year scenarios from the forest management plan for the McDonald-Dunn Research Forest for the next two 10-year periods were chosen for this analysis and will be hereafter referred to as the 20-year harvest plan. The forest management plan for the McDonald-Dunn Research Forest and the existing forest database supplied this analysis with the silvicultural system (thin or clear cut), harvesting system (ground-based or cable harvest system), estimated production volume, hillslope gradient, stand density, stand type, stand age, and average tree diameter at breast height (DBH) for each harvest unit as well as the harvesting sequence.

Total daily precipitation for the area is available dating from 1889 to the present from the Hyslop Field Research Laboratory located approximately 4 miles northeast of Corvallis. The data from the Hyslop Lab are available as precipitation to the nearest 0.25 mm (0.01 in.) for each day. Annual blocks of daily precipitation data for the winter period from 1889 to 2003 were randomly applied to each year of the 20-year harvest plan.

The *California Forest Practice Rules of 2004* regulations on hauling and harvesting during the winter period were applied to the McDonald-Dunn Research Forest and the 20-year harvest plan. As previously mentioned, these regulations require that hauling shall not occur when saturated soil conditions exist on the road. They also require that tractor yarding and the use of tractors be done only when the soils are not saturated (Chapter 4, Subchapters 4, 5, and 6, Article 4: 914.7, 934.7, 954.7 Timber Operations, Winter Period [All Districts] (c)(1)). This includes ground-based harvesting equipment and equipment that operates on the road surface such as loaders. As the rules do not define soil saturation or the precipitation levels that create this condition, a threshold precipitation value was required to represent saturated soil conditions for this analysis.

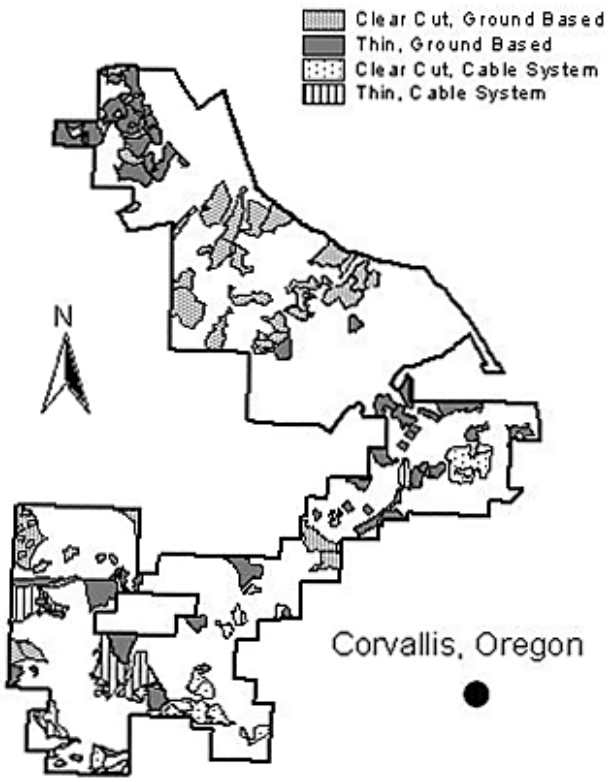

Figure 1. *~ A map showing the McDonald-Dunn Research Forest and one possible harvesting scenario for a future 10-year period.*

Operation managers apply the regulations of the *California Forest Practice Rules* on saturated soil conditions by monitoring precipitation. Personal communication with forest operation managers in California about harvesting and hauling during wet weather in past years established that, while most managers did not gauge precipitation with equipment, there existed some precipitation continuum with a threshold cumulative precipitation value at which harvesting and hauling activities were suspended. Comparison of harvesting and hauling days in past years with precipitation records determined that a daily precipitation value of 5 mm (0.20 in.) agreed with operating practices to suspend timber harvesting and hauling activities for that day. Although the exact days that timber harvesting and hauling activities were suspended

in this analysis may not have been the same days that were suspended in reality, the total annual number of suspended days were consistent with operating practices.

With the regulations in the *California Forest Practice Rules of 2004*, managers have some alternatives for their harvesting and hauling activities dependent upon their management objectives and equipment flexibility. The regulations decrease the number of days available during a year for harvesting and hauling timber when compared to a full year of operations without restrictions. Managers have the option of decreasing the annual timber production proportionally by the number of days that harvesting and hauling is suspended or having timber production remain the same and increasing the machinery and operators or increasing the hours worked during non-suspended days. If managers chose to reduce timber production they have the additional option of moving the harvesting and hauling equipment to a different location that is not restricted (such as in contract use) or keeping the equipment inactive at location during suspended days.

For this analysis the estimated costs and revenue for the 20-year harvest plan without wet-weather restrictions were compared to three management scenarios for harvesting and hauling with wet-weather restrictions to determine the opportunity costs associated with wet-weather restrictions. The full year of harvesting and hauling without restrictions operated with 2,000 scheduled machine hours (SMH) for all harvesting equipment and 2,500 SMH for haul trucks (Brinker et al. 2002). Machine hours were scheduled for a Monday through Friday work week that did not include U.S. holidays. The analysis assumed that all harvesting operations were conducted on an independent contracting basis. Operator wages were calculated as hourly pay including benefits. Log prices were kept constant over the harvest year. The volume of annual timber production was determined from the 20-year harvest plan for the McDonald-Dunn Research Forest.

Three management scenarios with wet-weather restrictions were evaluated:

1. Timber harvesting and hauling in the McDonald-Dunn Research Forest were suspended on days that precipitation exceeded 5 mm. Harvesting and hauling equipment were kept idle at location on these days. Consequently, SMH for all harvesting and hauling equipment were reduced based on the number of work days with precipitation that exceeded 5 mm and hence, annual timber production was reduced.
2. Timber harvesting and hauling in the McDonald-Dunn Research Forest were suspended on days that precipitation exceeded 5 mm. Production goals were met during hours when there were no wet-weather restrictions by the overtime use of existing equipment and labor or by bringing in additional equipment and labor.
3. Timber harvesting and hauling in the McDonald-Dunn Research Forest were suspended on days that precipitation exceeded 5 mm. All mobile equipment was used off-site on suspended days (no change in SMH); however, production within the McDonald-Dunn Research Forest was decreased.

Hourly costs of timber harvest activities were estimated for each scheduled unit based on production studies from the literature that were relevant to the characteristics of each harvest unit (Zhang et al. 2003). Hourly costs for timber hauling from the harvest units to a lumber mill located in Eugene, Oregon were based on new vehicle costs and were estimated using standard costing procedures. Hauling costs depended on routes taken and road standards. Hauling routes taken and number of trips per day were optimized using Network2000® (Chung and Sessions 2000). Annual timber harvesting and hauling costs were discounted at an inflation free rate of 7 percent for future costs, and all costs were calculated in present net worth. Discounted costs for timber harvesting and hauling were subtracted from timber revenue to calculate net revenue for the forest in present net worth.

Results

Optimal Harvest Plan

The 20-year harvest plan for the McDonald-Dunn Research Forest included thinning and clear-cut operations with ground-based and cable harvest systems determined by the average gradient of the hillslope in the harvest units. An average hillslope gradient of 35 percent in a harvest unit was used as the cut-off value between ground-based and cable harvest systems. The 20-year harvest plan had an annual timber production of approximately 27,500 m^3 (4.1 million board feet [MMBF]). Of the total timber production from the forest for the 20-year harvest plan, 23 percent was harvested using a cable system and 77 percent harvested with a ground-based system.

The McDonald-Dunn Research Forest consists of predominately Douglas-fir (*Pseudotsuga menziesii*) with a small grand fir *(Abies grandis*) component. The units in the 20-year harvest plan were managed for short-rotation and long-rotation, even-aged, Douglas-fir dominated plantations. For this study, only the harvest of Douglas-fir was considered. The average DBH of Douglas-fir was 30 cm (12 in.) within the thinning units and 51 cm (20 in.) within the clear-cut units. The average stand density was 667 trees per hectare (270 trees per acre) in the thinning units and 334 trees per hectare (135 trees per acre) within the clear-cut units.

Without reductions in timber production due to wet-weather restrictions the total production of the forest for the 20-year harvest plan was 550,990 m^3 (82.6 MMBF) with an average of 27,550 m^3 harvested each year. Of the 550,990 m^3 produced, 81 percent was harvested as clear cuts using both ground-based and cable harvesting systems and 19 percent was harvested as thinning using both harvesting systems (**Table 1**).

Harvesting and hauling costs and timber revenue were calculated for the McDonald-Dunn Research Forest for a full year of operation without reductions due to wet-weather restrictions. Productivity costs ranged from \$13.36 to \$17.36 per m^3 for ground-based systems and \$26.22 to \$48.34 per m^3 for cable systems. The hauling costs were estimated to be \$54.86 per SMH. Discounted harvesting and hauling costs totaled \$7.9 million with \$6.2 million related to the harvesting operation (78%) and \$1.7 million related to hauling (22%). Labor costs were approximately 40 percent of the total harvesting and hauling costs and the remaining 60 percent were equipment costs. Total net revenue for the 20-year harvest plan for the McDonald-Dunn Research Forest was \$35.5 million in present net worth.

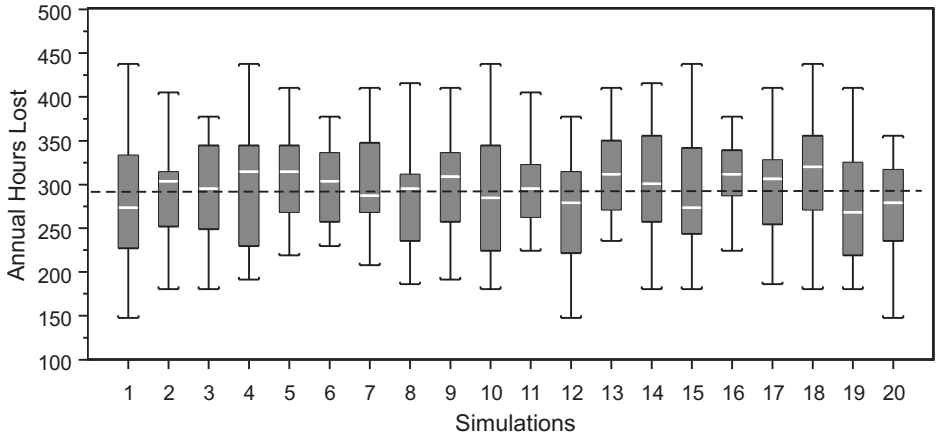

Figure 2. *~ A whisker and box plot with the median (horizontal marker), first, and third quartiles (boxes), and range of hours lost each year in the 20-year harvest plan over 20 simulations with daily rainfall restrictions at 5 mm. The historic average (1889–2003) of annual hours lost is shown with the dashed line.*

Wet-Weather Restrictions

The three management scenarios halted all timber harvesting and hauling in the forest on days when rainfall exceeded 5 mm. Over the 115-year record of precipitation from 1889 to 2003, halting timber harvesting activities when a daily rainfall reached or exceeded 5 mm resulted in an average annual reduction of 36.6 work days (27% of eligible work days during the winter period of October 15 to May 1), or 293 work hours based on an 8-hour work day. Historical annual precipitation data was randomly applied to the 20-year harvest plan in 20 simulations. Over the 20 simulations, the average annual reduction of work hours was 294 hours with a standard deviation (SD) of 63 hours totaling an average of 5,878 hours lost over the 20-year period. **Figure 2** shows the median, quartiles, and range of the annual reduction in work hours for each 20-year simulation with wet-weather restrictions as well as the historical average (dashed line).

Costs of Wet-Weather Restrictions

The first management scenario considered a situation where harvesting and hauling equipment were not used on days when rainfall exceeded 5 mm and therefore there was no timber production on these days. The annual SMH for timber harvesting and hauling equipment were reduced by the hours lost to wet-weather restrictions. Although this decreased the annual operating costs, ownership costs remained the same and thus total machine costs per SMH were increased. Increases in timber harvesting and hauling costs per cubic meter over 20 simulations of the 20-year harvest plan ranged from 1.3 percent (simulation 12, year 8) to 7.1 percent (simulation 4, year 11) and averaged 3.5 percent. Approximately 73 percent of the increased harvesting and hauling costs were associated with the harvesting operations and 27 percent of the increased costs were associated with hauling timber from the harvest unit to the lumber mill. A histogram of increased costs per cubic meter over the 20 simulations is shown in **Figure 3**.

Table 1. *~ Timber production for the 20-year harvest plan for the McDonald-Dunn Research Forest by year, silvicultural system, and harvest system.*

	Timber volume (m^3)[a]				
	Clear cut		Thinning		
Year	Cable	Ground	Cable	Ground	Total
1	9600	11520	6960	0	28080
2	0	24400	2747	0	27147
3	22027	0	0	5067	27093
4	0	21413	4427	2187	28027
5	0	30933	0	0	30933
6	15040	6960	4560	1520	28080
7	0	21920	5013	2587	29520
8	0	21040	6747	0	27787
9	13573	8907	0	4347	26827
10	6960	13520	0	6800	27280
11	0	20240	0	7680	27920
12	0	19707	0	7547	27253
13	0	23520	0	3387	26907
14	0	27040	0	0	27040
15	3067	17440	0	6320	26827
16	0	25307	0	2160	27467
17	0	27040	0	0	27040
18	0	17120	0	10587	27707
19	20747	0	3947	1707	26400
20	0	17653	0	8000	25653
Total	91013	357013	34400	69893	550987
Percent of total	17%	65%	6%	13%	

[a] 1 m^3 = 150 board feet

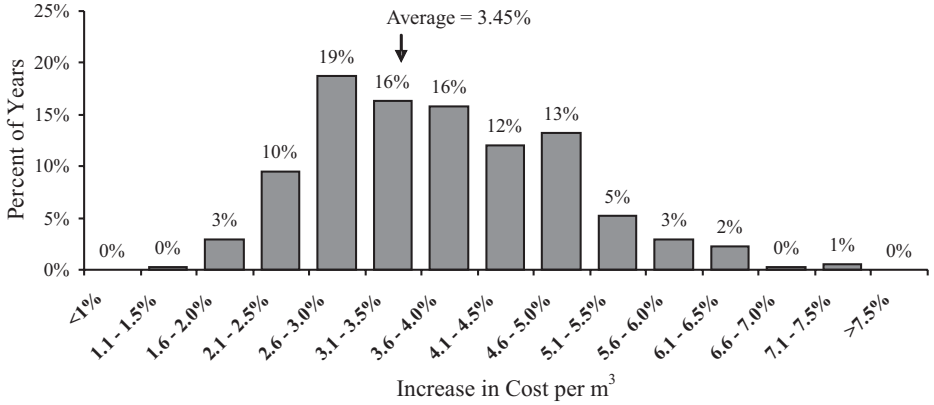

Figure 3. ~ *The annual increase in timber harvesting and hauling costs per cubic meter over 20 simulations of the 20-year harvest plan (400 total years).*

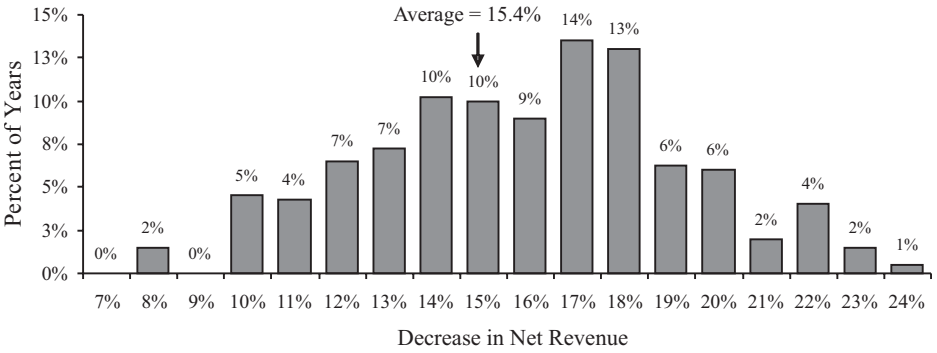

Figure 4. ~ *The annual decrease in net revenue over 20 simulations of the 20-year harvest plan (400 total years).*

The hours lost annually to wet-weather restrictions were also used to reduce the annual timber production. Over 20 simulations of the 20-year harvest plan, total timber production ranged from 465,330 m^3 (84% of the total harvest, simulation 13) to 478,000 m^3 (87% of the total harvest, simulation 12) and averaged 470,000 m^3 (85% of the total harvest without wet-weather restrictions).

An increase in machine costs and a decrease in timber production produced an annual decrease in net revenue in comparison to the 20-year harvest plan without any wet-weather restrictions. Over 20 simulations of the 20-year harvest plan, this annual decrease in net revenue varied greatly. One year (simulation 20, year 16) had a 7.6 percent decrease in net revenue and another year (simulation 1, year 3) had a decrease of nearly a quarter of the annual net revenue (23.8%). The decrease in annual net revenue averaged 15.4 percent over 20 simulations of the 20-year harvest plan (**Fig. 4**). The total net revenue for the McDonald-Dunn forest over the 20-year harvest plan with this scenario ranged from $29.7 to $30.6 million in present net worth and averaged $30.0 million.

The second management scenario also halted harvesting and hauling with wet-weather restrictions. In this scenario, however, production goals were met during hours when there were no wet-weather restrictions. This was accomplished by using the available equipment and labor beyond the 8-hour work day (overtime). Only labor costs were affected because production and thus SMH for the equipment remained the same. Labor costs for work beyond the 8-hour work day were assumed to increase 50 percent (time and a half). Wet-weather halted harvesting and hauling, on average, 294 work hours a year over 20 simulations of the 20-year harvest plan. This is approximately 15 percent of the SMH for the harvesting equipment. Labor represented 40 percent of the total harvesting and hauling costs. Increasing 15 percent of the labor costs by 50 percent resulted in an average increase in total discounted harvesting and hauling costs of 3 percent over the 20-year harvest plan. In this scenario, total harvesting and hauling costs for the 20-year harvest plan for the McDonald-Dunn Research Forest totaled approximately $8.1 million.

Another approach to this second management scenario is to meet production goals during hours in which there were no wet-weather restrictions by bringing in additional equipment and labor. Additional move-in costs and contract administration costs are associated with this approach; however, the authors assume that these additional costs will be of a similar magnitude to the overtime approach.

Harvesting and hauling were again halted with wet-weather restrictions in the third management scenario. In this scenario the mobile harvesting and hauling equipment and labor were moved and used at a different location. An example of this situation is the contract use of equipment. Production from the McDonald-Dunn Research Forest decreased with wet-weather restrictions (similar to the first scenario), but harvesting and hauling costs remained the same. Over 20 simulations of the 20-year harvest plan, total timber production was between 465,330 m^3 and 478,000 m^3. Discounted harvesting and hauling costs totaled $7.9 million which resulted in a total net revenue of $28.7 to $29.7 million. With wet-weather restrictions, there was a decrease of $5.8 to $6.8 million in net revenue from the McDonald-Dunn Research Forest over the 20-year harvest plan with this scenario. **Table 2** describes production, cost, and revenue results for the 20-year harvest plan for the McDonald-Dunn Research Forest without wet-weather restrictions

Table 2. ~ *The timber production, discounted costs, and revenue in present net worth for the 20-year harvest plan for the McDonald-Dunn Research Forest without wet-weather restrictions and for the three management scenarios that include reductions due to wet-weather restrictions (averaged over 20 simulations).*

	Without wet-weather restrictions	Scenario		
		1	2	3
Timber production (thousand m^3)	551.0	470.0	551.0	470.0
Harvesting and hauling costs (million $)	7.9 ($14.34/$m^3$)	7.0 ($14.84/$m^3$)	8.1 ($14.77/$m^3$)	7.9 ($16.81/$m^3$)
Timber revenue (million $)	43.4 ($78.75/$m^3$)	37.0 ($78.75/$m^3$)	43.4 ($78.75/$m^3$)	37.0 ($78.75/$m^3$)
Total net revenue (million $)	35.5 ($64.41/$m^3$)	30.0 ($63.91/$m^3$)	35.3 ($63.98/$m^3$)	29.1 ($61.94/$m^3$)
Decrease in net revenue with wet-weather restrictions (million $)	--	5.5 ($11.58/$m^3$)	0.2 ($0.43/$m^3$)	6.4 ($13.56/$m^3$)

and for the three management scenarios that include reductions due to wet-weather restrictions.

Table 3 compares the differences between the average total net revenue for the 20-year harvest plan for the three scenarios in relation to production and harvesting and hauling costs and the total net revenue for the 20-year harvest plan for the McDonald-Dunn Research Forest. The $0.2 to $6.8 million decrease in total net revenue between the full-year operation and the three management scenarios that include restrictions for wet-weather hauling could be considered opportunity costs and used to upgrade the road surfaces to minimize sediment production and to allow for timber harvesting and hauling to occur during wet-weather.

Discussion and Conclusions

Main Findings

With all management scenarios presented in this analysis, wet-weather restrictions decreased total net revenue for the McDonald-Dunn Research Forest. The magnitude of the decrease was dependent on the management objectives and equipment flexibility. The first management scenario did not have the flexibility to move equipment around during suspended days or have more equipment brought in on non-suspended days. This scenario may be representative of small landowners. The opportunity costs associated with this type of management scenario were great, averaging 15.4 percent of the annual net revenue.

Management of the McDonald-Dunn Research Forest with the objective of meeting production goals and the flexibility of additional work hours or equipment, as in the second management scenario in this analysis, produced the smallest decrease in total net revenue at 1.7 percent. This management scenario would most likely represent the options available to a larger industrial landowner. Although a 1.7 percent decrease in total net revenue may not seem significant, at a large company it may represent a considerable dollar value and be worth investing as an opportunity cost.

Table 3. ~ *The relationship between harvesting and hauling costs, timber production, and average total net revenue for the 20-year harvest plan for each management scenario.*

	Harvesting and hauling costs	
Timber production	No change	Increase per m^3
No change	Without wet-weather restrictions $35,488,481	Scenario 2 $35,251,429
Decrease	Scenario 3 $29,116,979	Scenario 1 $30,046,257

Implications

The opportunity cost associated with restricted timber hauling and harvesting is potentially a resource that could be made available to improve aggregate road surfaces to minimize hauling restrictions during wet-weather. In this study the opportunity costs were 1.7 to 18 percent of the total net revenue for McDonald-Dunn Research Forest with 20 simulations of the 20-year harvest plan. Although 1.7 to 18 percent of the net revenue from the first year of harvesting may not be enough to improve all haul roads, over time improving the road surfaces may result in increases in production and net revenue.

The opportunity costs may be even greater in all scenarios. This analysis only considered labor working during the hours that equipment was in use. In actuality, some employees may be salaried and require pay regardless of the number of hours that they are unable to work due to wet-weather restrictions.

The opportunity costs will also vary with different regulations. Daily precipitation of 5 mm was assumed as the threshold value at which harvesting and hauling activities were suspended. This value was chosen to make the undefined regulations on the saturation of soil in the *California Forest Practice Rules* consistent with operational practices to facilitate this analysis. In areas with different regulations, harvesting and hauling activities may be suspended with more or less precipitation. Even within California the regulations may be interpreted differently. One landowner the authors spoke with sus-

pended all activities with any amount of precipitation. The more restrictive the regulations, the greater the opportunity costs could be.

Critical Points

A limitation of this analysis is that annual timber production was reduced in the first and third scenario and the value of the timber that was left standing was not considered. This timber has not been "lost." An assumption made in this analysis was that it would be harvested at a future period when it will not be worth as much and as such, the analysis did not include any future benefit from allowing unharvested timber to continue to grow.

This analysis did not consider the fluctuation of market log prices during the winter season; only an average log price for Douglas-fir from the McDonald-Dunn Research Forest during the dry season. Analysis of the past 10 years of saw log prices of Douglas-fir in real prices (adjusted for inflation using the Producer Price Index) from the region showed seasonal fluctuations. Saw logs were consistently priced highest in the fourth quarter after the wet season had begun and the demand for timber was still high.

Further Investigation

This analysis found that the opportunity costs associated with wet-weather restrictions can be significant depending on the management objectives and equipment flexibility. Further investigation is needed to determine how the opportunity costs can be best used to upgrade the road system for use during wet weather. Future analysis and research should focus on determining what aspects of the road need to be upgraded to allow for wet-weather use and the costs associated with such upgrades. If the road can be upgraded, it will be useable in all weather.

As regulations for wet-weather hauling continue to become more restrictive, the log supply will continue to decrease and the demand and price for logs during the winter season will continue to increase. Forest landowners wishing to profit from the winter log market should consider opportunity costs of upgrading their road surfaces for wet-weather hauling.

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