Discussion Paper 11 (DP11): Eastside Impacts of Thinning and Implementation Schedules on Fire Hazard Reduction Effectiveness, Carbon Storage, and Economics

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Introduction

Many overstocked forests in the Inland West are experiencing uncharacteristic insect damage and wildfire. The effectiveness of fuel removal treatments to reduce this hazard has been well documented in numerous recent publications (Agee 1993, Graham et al. 2004, Kalabokidis and Omi 1998, Keyes and O'Hara 2002, Omi and Martinson 2002, Peterson et al. 2005, Pollet and Omi 2002, Sandberg et al. 2001). The relative costs and benefits of thinning treatments to reduce wildfire as compared to a no management alternative should include both market economics and the avoided costs of fighting fires, carbon storage, habitat, and other non-market values (Mason et al 2006). An absence of consistent methodologies for assessing these values has constrained institutional adoption, with the adverse impact of defaulting to no action with consequent failure to reduce fire hazard. We provide here a brief demonstration of an accounting framework that includes the consequences of fire hazard reduction treatments and the timing of their implementation relative to fires and hence on avoided future costs as well as carbon release, an important environmental consideration impacted by fire. A more detailed description is available in RTI Working Paper No. 6 (Lippke et al 2006). Research, currently underway by the Consortium for Research on Renewable Industrial Materials (CORRIM 2004), will provide life cycle data on the atmospheric carbon implications of forest resource use in the Inland West. These new analyses will ultimately support more accurate carbon accounting for Inland West forest biomass and associated fossil fuel offsets.

Methodology

While the process of developing thinning treatments to reduce fire hazard is straight forward, evaluating the effectiveness is more complex, as fire events will interact with treatment schedules. One cannot simulate the future of a treatment without considering the dynamic fire response, which itself will be treatment-sensitive to the timing and magnitude of hazard reduction treatment implementation across the landscape. Therefore we have provided a summary of a simulation for the Okanogan National Forest (ONF) to demonstrate how effective certain treatments could be in reducing fire hazard and also how the pace of phasing in these treatments results in reduced fire fighting costs, acres burned, revenue and carbon as some of the more important values of interest.

Integrated computer technologies make it possible to simulate forest stand growth starting with tree list inventory measures. Impacts of management treatments or disturbance events can be tracked for any outputs that can be quantitatively associated with changes in the tree list inventory. For this analysis, inventory data from the Current Vegetation Survey (CVS) were assembled for the Okanogan National Forest (ONF) to demonstrate fuel reductions in an Inland forest landscape with moderate to high fire hazard. Sample plots were analyzed for stand structure characteristics and relative fire hazard (Hardy 2005). A high, moderate, or low fire hazard classification was assigned for each plot based on the Severe Crowning Index assessment from the Fire and Fuels Extension model, FFE (Crookston et al 2002), linked to the Forest Vegetation Simulator, FVS (Dixon et al 2003), within the Landscape Management System, LMS, (McCarter et al 1998). Alternative fuel reduction treatment pathways were simulated to create post-treatment inventory data representative of vegetation conditions at five-year increments within the 50-year simulation period. A fire disturbance scheduling model (rate of ignition) was developed based upon prior research on unburned refugia patterns. The probability of fire on high fire hazard stands was selected to result in 18% unburned refugia in 50 years, moderate hazard stands at half that rate and low hazard stands did not receive burn simulations. Of the 764,000 acres sampled, almost 80% were initially found to have a moderate or high fire hazard level with 30% at the high level. Fire disturbances were introduced across the virtual landscape based on the rate of burn and evaluation of the stand level fire hazard rating. LMS with FVS-FFE was used to simulate growth, treatments, and fire, and to produce per acre output metrics including acres burned, economics, carbon stored and other ecological metrics.

Thinning Treatments

A range of forest treatment intensities were evaluated. A light intensity treatment simulation removed only trees equal to or less than 9 inches in diameter at breast height **(9&under).** A more aggressive thinning treatment was designed to reduce forest density while retaining the largest trees and achieving a basal area target of 45 square feet per acre **(BA45).** Simulated harvests of trees 12 inches in diameter at breast height (DBH) and larger **(12&over)** were developed to provide an upper bound for revenue production. Fire as a likely natural disturbance for a no action scenario **(NA)** was simulated and produced standing dead and dying trees with volumes calibrated from recent fire results. Contrasting scenarios were developed for immediate treatment of all moderate and high hazard acres and treatments phased-in over a 25-year period to demonstrate the impact of not being able to treat all stands simultaneously. The entire simulation period of interest for both scheduling scenarios was 50 years.

Net economic returns were estimated using logging costs and log market values from recent surveys (Mason et al. 2003). The mean net return from the **9&under** thinning was found to be $-316/acre (below cost), for **BA45** mean harvest revenues were found to be $+61/acre (very close to costs), **12&over** thinning produced $1489 of mean net revenue per acre, and **NA** with no harvest produced no revenue. The fire fighting cost for each treatment scenario was estimated to be $1000/acre based on the average fire fighting cost for the ONF for the last decade. A 5% discount rate was used to convert all future anticipated fire fighting cost liability exposures to present value dollars.

Fire Probability Model

The fire probability model allows burn rates to be set each period for each plot dependent on the treatment and fire hazard classification. Prior study results have estimated that unburned pre-settlement refugia, usually found in the forest mosaic on north slopes and in moist areas, accounted for very small percentages of the forest area in some areas to as much as 20% of an entire landscape in other areas (Olson 2000, Camp et al 1996). A 14% burn rate every five-year period approaches a 20% refugia target in 50 years as shown in Figure DP11.1. However, in conjunction with lower burn rates on the moderate hazard acres and no burn on low hazard acres, 30% of the total forest acres for this simulation remain unburned across the total ONF. While actual fires will be governed by weather conditions and spill over into some lower hazard stands, plots with lower fuel loads have been shown to be unlikely to experience crown fires which is the governing criteria for fire in these simulations (Omni and Martinson 2002).

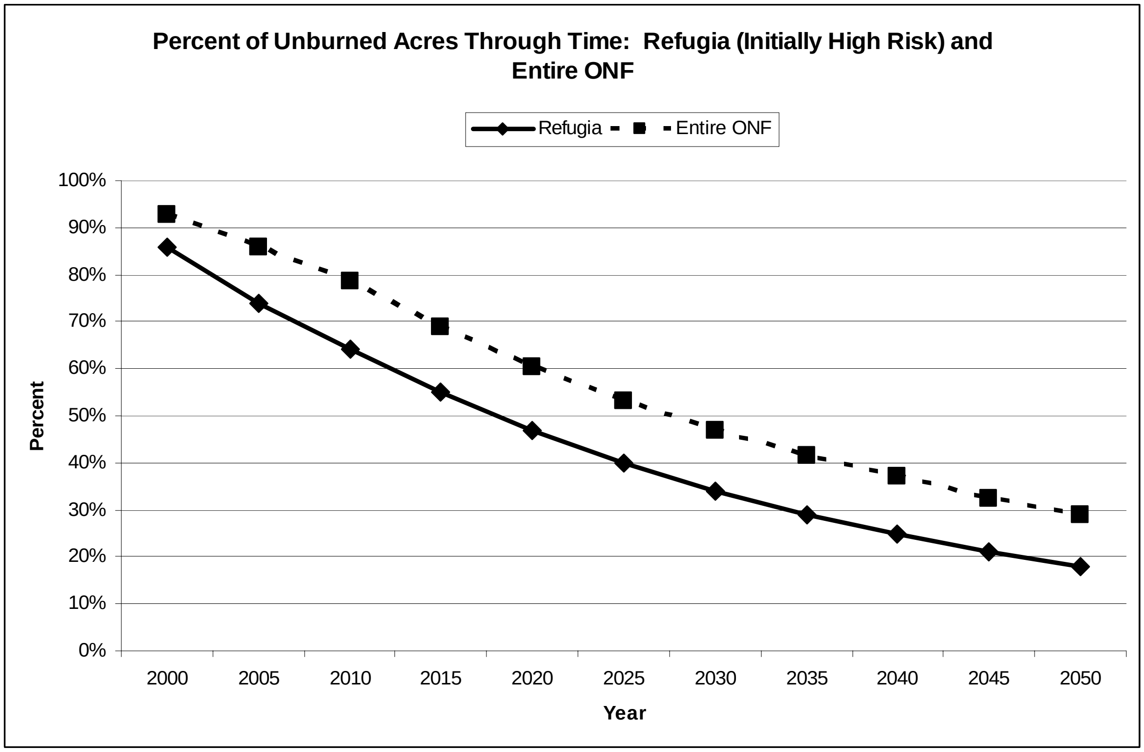


Figure DP11.1: Unburned Okanogan National Forest and High Fire Hazard Refugia through time with no thinning treatments.

Fire Hazard Reduction

The No Action alternative results in a steady rate of fires and new burned acres that maintains 25-30% of the acres in both the low and high hazard category much like the initial condition (Figures DP11.2 and DP11.3). Results for the Immediate treatment simulation are shown in Figures DP11.2 and DP11.3 on the left. The BA45 treatment eliminates high hazard acres for almost 45 years but re-growth after treatment will transition these acres back into higher hazard status in absence of future treatments to remove the recovering undergrowth. Similarly those acres initially categorized as low hazard move into moderate and high hazard categories as a result of stand growth. Neither the 9&Under or the 12&Over treatment reduce the ladder fuels sufficiently to lower hazard levels substantively.

For the 25 Yr Phase-In period the share of acres in the Low Hazard class after a BA45 treatment remains twice as high as the alternatives for about a 25-year interval (Figures DP11.2 and DP11.3 on the right). Some low hazard acres are maintained even under the No Action alternative as a direct result of fires reducing the number of high and moderate hazard acres.

If all high hazard acres could be treated with BA45 immediately, the acres burned each period would fall to low levels for 20 years but without continued treatments the rate of burn would begin to increase again from 20 to 40 years (Figure DP11.4 on the left). For the 25Yr Phase-In, the rate of burn is cut almost in half from 60,000 acres per year to 30,000 per year (Figure DP11.4 on the right).

If forests are thinned heavily from below to remove ladder fuels, and understory re-growth is periodically burned or otherwise removed, stands are more likely to grow into sustainable savanna conditions. These stands would be characterized by sparse densities of large overstory conifers with high crown bulk density and thick bark that is resistant to fire damage (Everett, 2005).

Average values, presented for review in this paper, are offered for relative comparisons of landscape trends and treatment performance. Actual planning for comprehensive landscape-level hazard reduction analysis would logically include a mix of customized treatment intensities sensitive to site specific stand conditions and public values at risk.

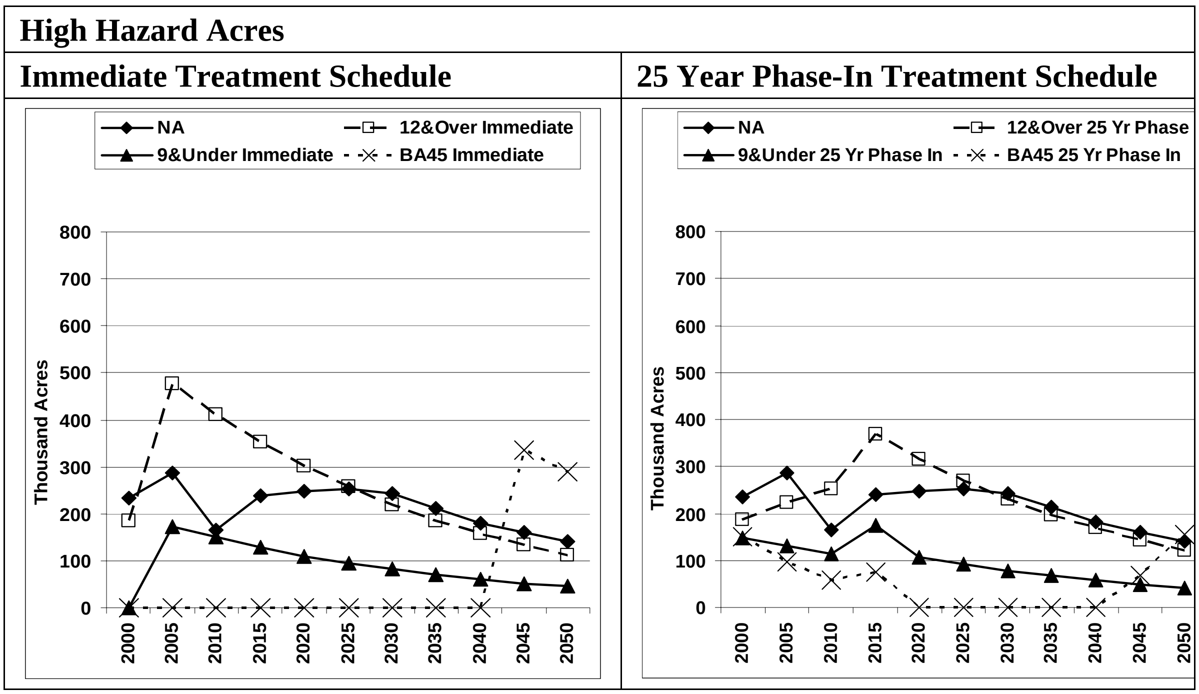


Figure DP11.2: High hazard acres in each five-year period by landscape scenario.

Low Hazard Acres

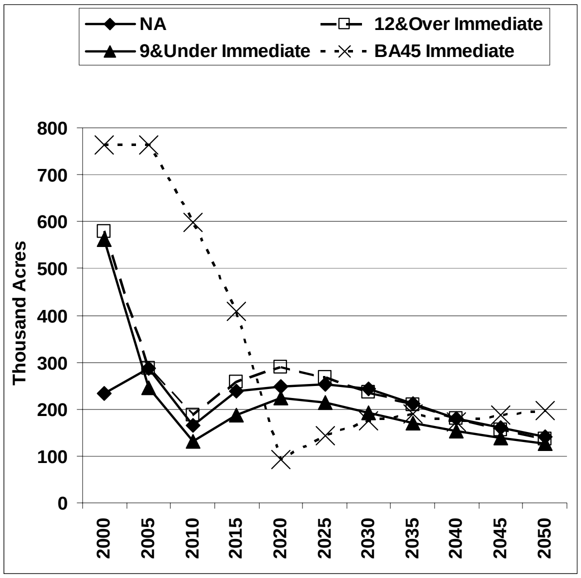
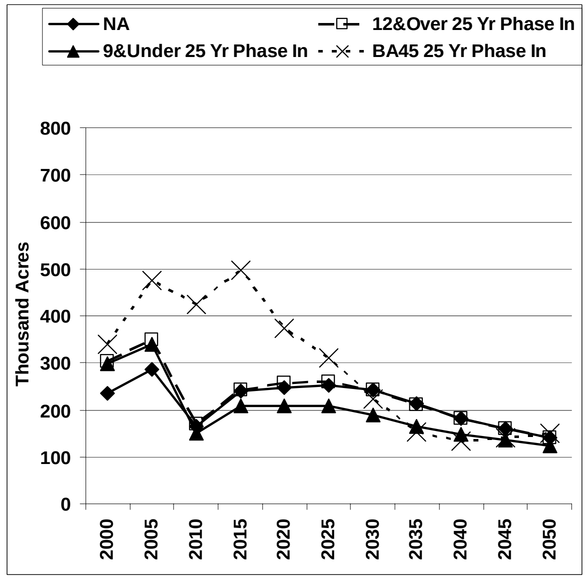
Immediate Treatment Schedule	**25 Year Phase-In Treatment Schedule**
	

Figure DP11.3: Low hazard acres in each five-year period by landscape scenario.

Periodic Acres Burned

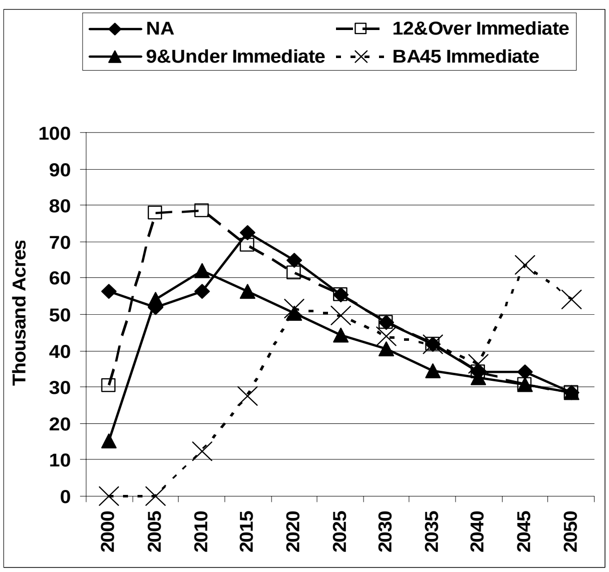
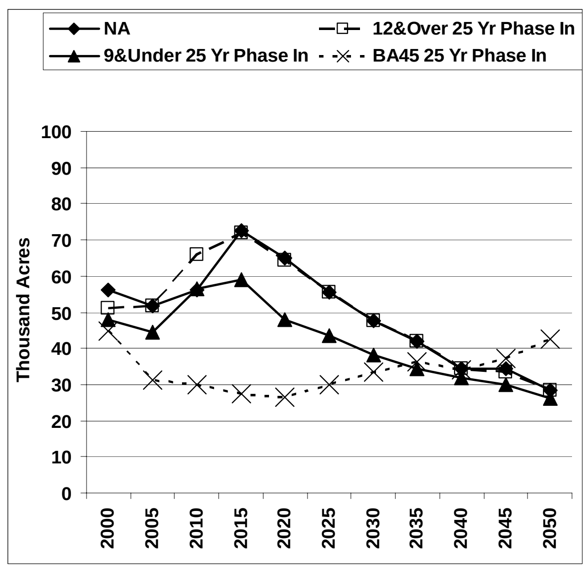
Immediate Treatment Schedule	**25 Year Phase In Treatment Schedule**
	

Figure DP11.4: Acres burned in each five-year period by landscape scenario.

Carbon

Carbon estimates were developed for management alternatives to include forest carbon, products carbon net of emissions from energy, and the carbon displaced by use of wood building products instead of more polluting building product alternatives (Lippke et al 2004). For the No Action simulation, Figure DP11.5 shows increasing carbon stored in the standing forest biomass until 2015 and, coincident with increased fires, decreasing carbon during the latter time periods (2015 – 2050) with nearly five million metric tons of carbon released into the atmosphere during the analysis period due to forest fire events. As a benchmark for comparison that is approximately equivalent to the annual carbon emissions from 2.5 million sport utility vehicles (Environmental Protection Agency 2006).

All treatment scenarios remove carbon from the forest, resulting in lower mean carbon in the forest during the early periods (2000 – 2020). However, the BA45 and 9&Under scenarios resulted in more carbon in the forest by 2050 as a result of reduced fire hazard. When the carbon stored in products and avoided emissions are included all treatment scenarios result in less total carbon released to the atmosphere than the No Action scenario (Figure DP11.6). The No Action scenario results in higher burn rates than any of the other treatment scenarios essentially capping the potential for carbon storage in the forest well below that which might be anticipated in the absence of high fire hazard. Wildfire simulations in untreated stands increase carbon emissions relative to treatments that capture carbon in products and avoided fossil fuel use through substitution and displacement channels.

In comparing the treatment scenarios, it is apparent that while the 12&Over treatment moves larger volumes of carbon into long-lived products quickly, it does not reduce fires as effectively as the BA45 treatment. Over the total period BA45 stores and offsets about an average of 6.5 million metric tons per decade more than NA while the 12&Over treatment results in an average storage and offset of 8.5 million metric tons per decade more than NA. Since carbon stored increases with time with fewer fires, BA45 stores and offsets 12 million metric tons more carbon than NA by the end of the period.

When comparing treatments to NA in percentage terms ***the increase in the mean total carbon storage is substantial (26% during the total analysis period, 38% during the later period between 2025 and 2050, and more than 50% by the end of the 50 year period)***. Figure DP11.6 demonstrates that the high carbon in forest biomass associated with the NA alternative cannot continue to increase. Over time the High and Moderate hazard classes (highest biomass and carbon stores) will experience forest fires with subsequent carbon releases.

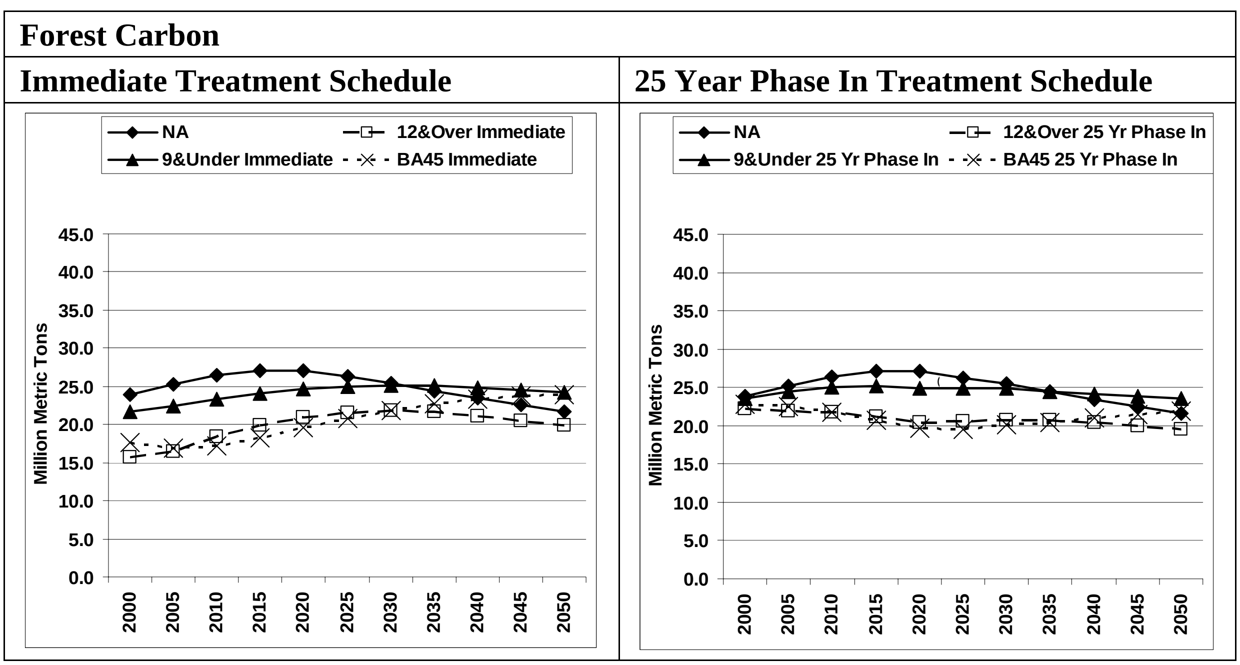


Figure DP11.5: Forest carbon over time by landscape scenario

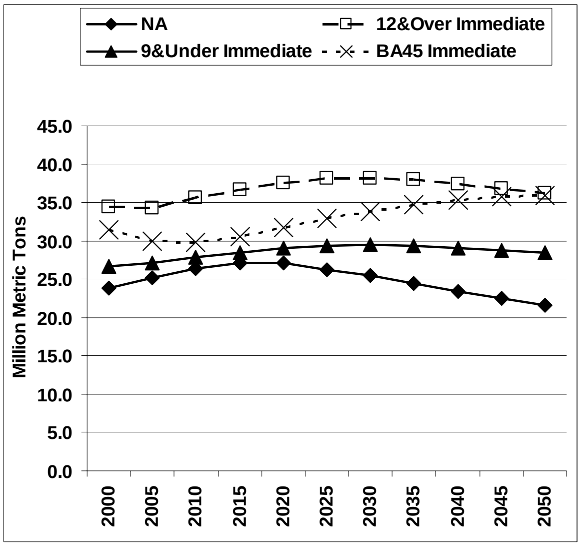
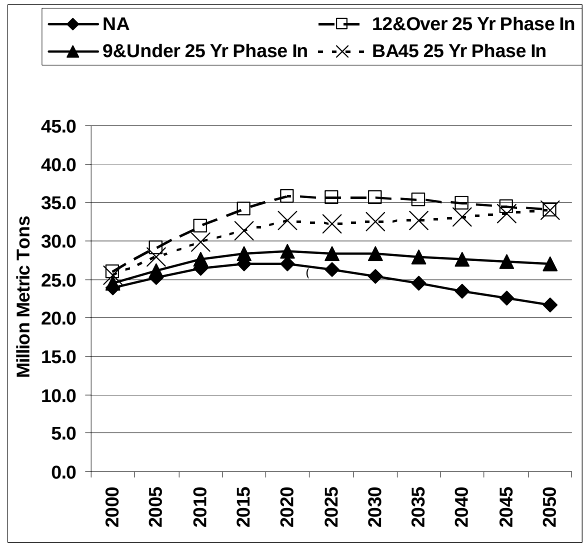
Total Carbon (Forest, Products, Substitution)	
Immediate Treatment Schedule	**25 Year Phase In Treatment Schedule**
	

Figure DP11.6: Total carbon (forest, products, substitution) over time by landscape scenario

The CORRIM analysis on life cycle inventories and assessment (LCI/LCA) for all stages of processing highlights the significance of using life cycle information to better understand where and how carbon is stored and offset (Bowyer et al 2004). These dynamic fire simulations demonstrate the significance of treatments and their timing on fire and consequently on the more complete assessment of carbon pools.

Economics

An analysis of the economic trade-offs between 25 Yr Phase-In scenarios is summarized in (Table DP11.1). The simulations show that failure to reduce fuel loads (NA scenario) results in a public cost exposure for fire suppression activities through the simulation period of approximately $237 million (net present value) due to estimated recurring fire fighting cost liabilities. Warming weather conditions may elevate hazards and increase future wildfire cost exposures further.

Analysis of harvest returns net of fuels treatment costs, as mentioned above, indicates that treatment alternatives will result in net negative or positive revenue depending upon the amount and value of merchantable logs removed in the treatment simulation. The composite economic analyses for the treatment scenarios presented here examined the interaction between reducing firefighting costs by lowering hazard classification and incurring additional treatment costs or generating revenue from log and slash removals. The 12&Over scenarios (25 Yr Phase-In) resulted in the only Total Value positive returns, due to the high value of wood removed. However, the 12&Over treatments were least successful at fire hazard reduction and resulted in the most acres burned. Log revenues removed early in the period were of sufficient magnitude to absorb high fire fighting costs.

Table DP11.1: Summary of economic impacts from 25 Yr Phase-In Treatments.

25 Yr Phase-In Treatments:		NA (fire)	9 & Under	12 & Over	BA45
Carbon	Mil. Tonnes	24.9	27.4	33.4	31.4
Burn	000;s acres	544	460	546	374
Fire Cost	$ mils NPV	237	202	237	147
Harvest $	$ mils NPV	0	-100	457	20
Total Value	$ NPV	-237	-302	220	-127

The 9&Under scenarios (25 Yr Phase-In) result in negative treatment values and provide only marginal fire hazard reduction. While the net present value of firefighting costs is reduced compared to NA, the 9&Under scenarios produce the largest overall public cost after treatment expenditures are included ($302 million).

The BA45 scenarios (25 Yr Phase-In) produce marginal but positive average thinning treatment returns of $61/acre. Therefore, differences from NA are almost entirely caused by the reduced fire hazard with consequent avoided firefighting costs. The BA45 scenarios resulted in significant reduction of net present public cost exposure as compared to NA: $110 million less for BA45 25 Yr Phase-In. Note that, while the BA45 scenarios appear most successful in achieving the range of management objectives considered, the BA45 scenarios still result in costs greater than revenue. However, the difference between the magnitude of the positive return generated by the 12&Over Immediate (in spite of higher fire fighting expenses) and the BA45 may indicate that modification in this treatment prescription to increase merchantable timber removals could provide a cost neutral hazard reduction option while still maximizing carbon storage and restoring large diameter fire resistant savannah-like forest conditions more reminiscent of pre-Europen settlement forests. As with other management objectives, the cost of delaying treatments can be quantified, as total savings are reduced by nearly 40% for BA45 25 Yr Phase-In as compared to the BA45 Immediate treatments.

It is noteworthy that Washington Department of Natural Resources fire suppression costs (due in part to closer proximity to settlements and more aggressive response) are approximately $2000 per acre or roughly twice as high as Forest Service costs thereby comparatively increasing the public benefit of hazard reduction treatments on state and private forests (WADNR 2004). If, in addition to fire fighting costs, other avoided costs such as fatalities, facility losses, and regeneration costs are included, the treatment schedule with the least number of acres burned will provide the most favorable economic result (Mason et al 2006). Emerging carbon markets (credits) could also contribute value to offset fuels removal treatment costs.

Conclusions

The intensity of fuel reduction thinning treatments and their timing are important factors in landscape fire hazard reduction. The No Action alternative results in more acres burned, higher future costs, and less total carbon stored. Phased-in treatment schedules over 25 years were only able to reduce the acres burned by half. Hazard reduction benefits from thinning are not permanent as re-growth results in increased hazard within about 25 years. Periodic re-entries for fuels removals will be required to keep the fire hazard contained.

The accounting required to accurately assess comparative carbon emissions reductions for fire hazard treatments in Inland West forests was demonstrated. In the long-term, maximizing carbon storage in the standing forest biomass will likely be most successfully achieved by the reduction of fire hazard and the number of acres burned. Simulations also demonstrate that while fire reduction treatments remove carbon from the forests, much of the forest carbon removed remains stored in long-lived products while displacing more polluting product alternatives. When total carbon accounting is considered, the NA scenario results in significantly greater carbon emissions to the atmosphere than all treatment scenarios.

The ability to use emerging forestry modeling capabilities such as FVS and FFE to predict forest vegetation growth, treatment impacts, and relative fire hazard, with any of the tree list analyses modules developed for LMS, such as carbon accounting, provides many advantages. Modeling of forest landscape conditions over time with FVS and LMS creates consistency between multiple modeling and planning scales. In addition to large landscape analysis, FVS and LMS also are designed to support site-specific, individual stand management operational planning. Forest attribute analysis can be customized for local conditions and extended to consider the treatment-associated impacts on stand structure, habitats, forest health, and other public values.

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