Examining Economic Benefits of Wood to Energy Products across the Kaibab and Coconino National Forests

Christian Larson

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Executive Summary

Past land management practices have left ponderosa pine forests in northern Arizona in need of restoration. The Four Forest Restoration Initiative (4FRI) will attempt to address this need by treating more than 2 million acres of forest over the next 20 years. This paper intends to answer the question of whether biomass technologies will benefit land management agencies by reducing catastrophic wildfire hazards, offsetting treatment costs, and providing economic gains in the region. Past research on small-diameter ponderosa pine harvesting demonstrates that resource extraction and transportation costs will result in net economic losses for restoration treatment activities. Previous studies suggest that small-diameter biomass removal may not be economically viable due to low financial value in the wood market, though government incentives designed to stimulate and encourage renewable resource energy investment can provide impetus to drive economic development.

United States Forest Service Field Inventory and Analysis data was analyzed to examine current biomass potential across the initial 10-year contract of the Four Forest Restoration Initiative. Future biomass harvest predictions used the Forest Vegetation Simulator modeling to determine expected thinning treatments over the course of the Four Forest Restoration Initiative. A net present value analysis (NPV), using a realistic alternate rate of return, projected costs and anticipated revenues for restoration treatments. This accounting intended to show the financial realities that potential wood product and utilization industry leaders will face over the expected life of the first stewardship contract. We determined that small diameter biomass utilization alone will not offset treatment costs to the U.S. Forest Service; however, when factoring potential avoided wildfire suppression costs into our analysis,

net gains were realized. Net present values for private wood products and utilization industry showed negative NPVs across biomass utilization technologies, though the potential exists for profitable businesses with marginal price improvement in wood pellet markets.

Introduction

Due to past land use and management practices, ponderosa pine forests in the Southwest have become exceptionally dense and unhealthy (Covington and Moore 1994, Cooper 1960, Fulé *et al.* 1997). In particular, the exclusion of natural fire regimes and extensive grazing have significantly altered the ecological diversity of ponderosa pine forests and led to a significant buildup of biomass within these forest types (Covington and Moore 1994, Kolb *et al.* 1994, Swetnam and Baisan 1996). For example, Covington and Moore (1994) found that there are areas along the Coconino Plateau where current stand densities are greater than 800 trees/ac. To put these current density numbers into perspective, pre-settlement stand conditions ranged between 25 and 100 trees/ha (Allen *et al.* 2002). Current stand density levels are known to significantly increase high-severity crown fire potential, threatening ecological diversity and local community welfare across the landscape (Moore *et al.* 1999). Recent intense wildfire activity, notably the Rodeo-Chediski in 2002 and the Wallow fire in 2011, are symptoms of decades of fire suppression and exclusion that have only become recognized in the last 20 years (Westerling *et al.* 2006, Covington and Moore 1994). Perhaps the silver lining to recent intense wildfire activity in the Southwest has been renewed determination to reduce fuel loads in forested areas.

The proper management and restoration of fire-prone landscapes in the western United States has been, and continues to be, a very contentious issue (Noss *et al.* 2006). Failure to come to broad consensus on a landscape level restoration framework has resulted in serious deficiencies in completing needed ecological work (Hjerpe *et al.* 2009). Proactive local partnerships have formed with the intention of thinning ponderosa forests in the Southwest, only to see restoration goals held up by bureaucratic requirements, legal challenges, or abandoned altogether (Lenart 2006). By their very nature, collaborative efforts require building consensus among numerous local, state and federal agencies (often with differing objectives), private industry, and the general public. Bringing so many divergent groups together for a common cause can take significant time, even years, that ultimately delays the actual work to be addressed.

Frequently, the high cost of fuel reduction treatments is cited as the most significant obstacle to restoration in the Southwest (Hjerpe *et al.* 2009). Current literature regarding the economic viability of the thinning treatments in Arizona shows that thinning is financially imprudent in the region, largely due to unprofitable small diameter wood markets. Data from 2001 show that the average cost of mechanical thinning treatments by the Forest Service is $70/dry ton, whereas the market value of this same removed biomass was only $25 to $35/dry ton (Levan-Green and Livingston 2001). Similarly, Kim (2010) noted that the Coconino National Forest reported operational treatment costs (not including planning or administration costs) of $200/ac for burning and $300/ac for mechanical thinning. Diameter limits that effectively ban all removal of tree stems greater than 16 inches (which have the most value per tree) has been shown to reduce contractor profits by 22-176%, causing net losses among some thinning contractors (Larson and Mirth 2001). Across the states of Arizona and New Mexico, lumber output has dropped 76% from 1966 to 2002 (Morgan *et al*. 2006). Much of this decrease is the result of reduced forested land availability for traditional logging due to endangered species listings that protect large diameter trees for habitat use. Locally, the lack of biomass processing capacity within the greater Flagstaff region has led to pile burning what could have been useable woody biomass (Hjerpe and Kim 2008).

In Arizona, the Four Forest Restoration Initiative (4FRI) formed as a broad public/private collaborative organization designed to actively manage the four national forests (Coconino, Apache-Sitgreaves, Tonto, and Kaibab) straddling the Mogollon Rim (Figure 1). Initial thinning and restoration treatments are projected to begin in 2013, and the total project is anticipated to span 20 years, treating up to 50,000 acres per year (USDA Forest Service 2011). Due to the large temporal and spatial scale of the initiative, potential economic benefits to impacted communities are substantial. For example, Hjerpe and Kim (2008) found that the economic impacts of restoration activities across parts of New Mexico and Arizona were responsible for $40 million in revenue and 500 jobs during 2005 alone. Full implementation of the 4FRI has the potential to generate up to 14,820 new jobs (Kim 2010). Given the state of the economy in Arizona at present, the opportunity to create jobs and simultaneously restore forest health is important (Wu *et al.* 2011).

The broad intent of the 4FRI is to restore a currently unhealthy forest ecosystem (UDSA Forest Service 2011). Ideally, private industry contracts to thin the landscape will offset the costs incurred by the Forest Service and result in faster restoration across the proposed treatment areas, however, current wood markets are not conductive to the utilization of small-diameter trees due to low prices. The Forest Service does not have the capital available to fund the full scope of the proposed treatments internally, meaning that private, for profit industry involvement is imperative to the success of the project. The Forest Service is aware of this reality and has been in discussion with the Four Forest Restoration Initiative stakeholder group, who has made the suggestion that in an effort to ensure adequate supply of biomass to contractors, thinning contracts need to be awarded via large spatial scale projects (Four Forest Restoration Initiative Stakeholder Group 2010). Grouping contracts has the added benefit of lowering administration costs incurred by the Forest Service due to economies of scale (Four Forest Restoration Initiative Stakeholder Group 2010), while providing sufficient quantities of woody material required by private industry to encourage investment. Biomass utilization has the potential to significantly offset treatment costs to the Forest Service, who will not be required to engage in thinning activities themselves, while providing for new industry and needed jobs within the region.

For the purposes of this study, biomass will be considered any woody plant materials used for energy. Biomass currently is the largest source of domestically available renewable energy in the United States, accounting for 3% of the total energy consumed in the US (Perlack *et al.* 2005). In 2002, the Biomass Technical Advisory Committee predicted that biomass consumption among electric companies will double every decade through 2030 (BTAC, 2002). The United States Department of Agriculture and the Department of Energy conducted a study in 2005 and found that up to 30% of America's current oil consumption can be replaced by using biomass energy sources such as woody material, agricultural waste, or landfill materials, instead (Perlack *et al.* 2005). Given that more than 50% of our current oil needs are met through imports, the role that moving to biomass fueled energy production could have on both rural and urban economies is substantial.

Studies of the role that biomass utilization can play in small diameter thinning projects have primarily focused on traditional methods that involve costly transportation and processing facility construction costs (Gan and Smith 2006, Hjerpe 2006). Due to low market values for small diameter woody biomass, lack of nearby energy facilities, and transportation costs that can reach or exceed 50% of total processing cost, small diameter biomass utilization for energy production is seen as financially uncertain (Pan *et al.* 2008, Hjerpe 2009, Perez-Verdin *et al.* 2008). Subsidizing restoration treatments to encourage private industry involvement in thinning projects have been shown to result in net revenue losses (Fried *et al.* 2008), further highlighting the difficulty in encouraging private industry investment in restoration activities. The focus of this study is, therefore, to investigate rapidly advancing biomass utilization technology to determine if an alternate biomass strategy is financially feasible, given economies of scale expected to be realized by 4FRI restoration.

This paper will address four main objectives:

1) *Quantify amount of woody biomass from forest restoration efforts based on anticipated treatment scenarios under the Four Forest Restoration Initiative.*
2) *Quantify available energy from woody biomass derived from restoration activities using various biomass forms and technologies.*
3) *Determine and compare the market value of wood-based energy products and avoided treatment costs of wood residues in the form of avoided fire suppression costs.*
4) *Assess the economic potential of utilizing woody biomass as energy and examine potential economic benefits of this approach.*

Methods

Study Area

The study area consists of the initial Environmental Impact Statement (EIS) area within the 4FRI, spanning 988,764 acres across the Kaibab and Coconino National Forests (Figure 1). This study is primarily concerned with the ponderosa pine forest type, as this species dominates the landscape across the 4FRI project area. Minor components of aspen, juniper, pinon pine, and Gambel oak are also present, though these species will not be considered in biomass estimates. In an effort to restore heterogeneity across the landscape, the 4FRI will utilize an array of treatments applied across the first EIS area. Forty-six unique treatment types arranged in a mosaic pattern will be implemented, including even-aged and uneven-aged thinnings, thin from below treatments, and savanna maintenance activities designed to remove encroaching woody species on naturally open areas.

Due to diameter caps and wildlife considerations, restoration treatments in the region typically leave trees with a DBH of 16" or more; therefore we will assume that thinning projects will only utilize biomass smaller than 16". Roadless areas, steeply sloped areas, designated Wilderness Areas, and identified endangered species habitat zones (*i.e.* Mexican Spotted Owl) will be excluded from consideration in the analysis, due to expected legal, financial, and ethical concerns (Hampton *et al.* 2008). Restoration treatments are anticipated to first begin in the densest stands, due to the high fire hazard represented by thickets of small diameter trees (Covington *et al.* 1997, Covington *et al.* 1994, Fulé *et al.* 1997).

Three different treatment alternatives, in addition to a no-action alternative, have been proposed for the initial EIS, with alternative C being selected as the preferred treatment. In total, alternative C will mechanically thin 434,001 acres from which biomass numbers will be generated for this study. Alternative B is slightly less aggressive, with mechanical treatments decreasing to 388,489 acres and diameter limits lowering to 16 inches in select areas when compared to the 18 inch limit in similar areas under treatment alternative C. The last treatment alternative (alternative D) is virtually identical in mechanical treatment scenarios as alternative B, with the key difference being reduced prescribed burn acreage in alternative D. Alternative A, being the "no action" treatment, will not be discussed in this paper, with the exception of demonstrating how proposed treatments will impact forest structure. Table 1 highlights each treatment alternative by dominant thinning type within each respective alternative.

Biomass Conversion Technologies

Two primary biomass utilization technologies will be examined: chipping/grinding on site and wood pellets. Chipped material is harvested, ground into small, uniformly-sized particles on site, and shipped via truck to processing facilities where it can be used in direct heat generation or in a co-generated power plant to supplement fossil fuel consumption. Chips are among the least expensive biomass products to manufacture, with the disadvantage being that energy density is low and transportation costs per unit of energy are correspondingly high. Woody material chipped in-woods will be ‘dirty’, meaning that bark will also be present in chipped biomass. Wood pellets are compressed wood residues (using materials like sawdust and chips) that are manufactured to uniform sizes for use in a variety of heating/energy scenarios. Energy density for wood pellets is significantly improved over chipped biomass, due to densification and very low moisture content. Pellet production has grown dramatically in recent years, with worldwide production rising more than 50% between 2007 and 2009 alone; much of this growth is due to home heating installations and competitive pricing relative to more traditional heating methods such as heating oil, electricity, and propane (Pirraglia *et al.* 2010). Currently, biomass utilization facilities exist within the larger 4FRI area, including a pellet production plant in Show Low, Arizona and a biomass power facility near Snowflake, Arizona. Due to the impending closure of the adjacent paper mill that provided biomass waste residue as fuel to the power plant, the Snowflake facility will need to increase use of woody biomass to maintain current production levels in the absence of biomass waste residues. The Snowflake power facility is able to utilize ‘dirty’ wood chips, meaning that additional chipping processing costs that remove bark will not be incurred (Patrick Rappold, personal communication, 11/29/2012).

FIA/FVS Modeling

Current and future biomass estimates will use existing plot data from the U.S. Forest Service Field Inventory and Analysis (FIA) database, as this represents the most complete dataset across the study area (www.fia.fs.fed.us/). Field Inventory and Analysis is a continuously updated nationwide forest inventory system that provides a snapshot of current forest conditions and includes a wide array of detailed forest attributes that will be utilized in our analysis, including basal area, trees per acre, diameter classes, and stand density index (Crookston and Dixon 2005). Because the exact locations of FIA plots are deliberately "fuzzed" to protect each plot's integrity, a GIS layer was created encompassing the boundary of the 4FRI project area, with a second layer showing all FIA plots within Arizona. The FIA plot layer was then clipped to the study area boundary layer to produce a final dataset that includes only plots that fell within the 4FRI project area.

FIA plot data were input into the Forest Vegetation Simulator (FVS), Central Rockies Variant, by Forest Service personnel (www.fs.fed.us/fmsc/fvs/) to estimate both current volumes and future growth of forest conditions. A complete dataset, including thinning treatment scenarios B, C, and D was supplied by Neil McCusker, silviculturist with the US Forest Service 4FRI team in Flagstaff, Arizona for analysis (Neil McCusker, personal communication, 08/30/2012). The FVS is a Forest Service developed growth and yield modeling application that is capable of estimating a wide array of user-defined silvicultural operations using existing FIA plot data as a baseline (Crookston and Dixon 2005). Due to the broad suite of available modeling options that it can accommodate virtually any American forest type and treatment option, the FVS is currently the most widely used forest simulation software available (Vegh *et al.* 2012). Each treatment alternative (including alternative A, to compare and contrast the impacts of alternative B, C, and D) was modeled utilizing the complete suite of treatment options to be completed under each alternative. Data supplied by the Forest Service included the FVS modeling for the time period before treatments were scheduled to begin (2010), as well as future growth simulations for future years (2020, 2030, and 2050). FVS models did not include 2040 in the simulation. This method sufficiently accounted for the broad spectrum of restoration thinning scenarios often utilized in the Southwest (Hunter *et al.* 2007). Further, as these treatment scenarios are based on restoration options that will be implemented in the immediate future, the corresponding results are more robust when compared to hypothetical treatment scenarios designed to account for common treatments in the region.

Spatial data utilizing the ArcGIS 10 geographic information system was provided by Mark Nigrelli, GIS specialist with the US Forest Service 4FRI team. Spatial data of each treatment alternative, such as prescription type locations, acres treated by each prescription, and locations of dense forest stands was compiled and analyzed to determine average basal area, trees per acre, and stand density index under each treatment scenario. Locations that were not on Forest Service lands and previously completed or underway thinning projects were removed from final analysis in this study. Columns that represented each stand condition (basal area, trees per acre, and stand density index) were summed individually and divided by the total area in each treatment alternative to determine pre- and post-treatment conditions. Alternate A, the no action scenario, was included in this analysis to demonstrate the impact that each treatment alternative would have across the study site when compared to no landscape restoration activities. Table 2 shows basal areas increasing steadily from 115 to 152 ft^2/ac between 2010 and 2050 under alternative A, the no action scenario. Alternatives B and C showed 2010 basal areas (before thinning treatments) of between 120 and 125 ft^2/ac, dropping significantly by 2020 (after treatments have taken place) to 63 ft^2/ac in alternative B and 61 ft^2/ac under alternative C. By 2050, basal area values had increased, but were still much lower than the no treatment scenario, ranging from 93 ft^2/ac in alternative B to 90 ft^2/ac in alternative C. Similar trends were found in trees per acre and stand density index values across treatment alternatives as thinning treatments significantly reduced forest density in the near term, with slowing rising metrics thereafter. By 2050, basal areas across the study area continued to be below the levels seen pre-treatment.

To calculate net present value (NPV) and perform discounted cash flow analysis of thinning treatments, we used a 4% discount rate, representing the federal government's long-term investment on

National Forests (Huang and Sorensen 2011). The NPV of treatments signifies the present value of a treatment's benefits minus the present value of its costs. Timber stumpage prices are estimated to be $1 per hundred cubic feet (CCF) for pulpwood (<9" dbh) and $5 per hundred cubic feet for sawlogs (10" dbh or greater), according to the latest timber cut and sold report from the U.S. Forest Service (U.S. Forest Service 2012). Labor costs are estimated to increase by 1.5% per year over the course of the project (Council of Economic Advisors 2009). Revenues to the U.S. Forest Service are expected to total $22/ac (gross) across the study site (Dick Fleishman, U.S. Forest Service, personal communication). Administrative costs to the U.S. Forest Service, including planning, preparation, administration, and monitoring, are estimated to be $360/ac (Four Forest Restoration Initiative Stakeholder Group 2010). However, optimization and consolidation of administrative costs that takes into account economies of scale of landscape-level restoration has been estimated at $176.46/ac (Four Forest Restoration Initiative Stakeholder Group 2010). Therefore, NPV calculations will model both current administrative cost estimate ($360/ac) and a best case scenario ($176.46/ac), utilizing potential cost declines resulting from the scope of the project. Because total acreage to be mechanically treated varies by treatment year (see Table 7), we treated each year as a percentage of the aggregate total of treatments to determine NPV values by year, summing NPV values in Tables 5 and 6. For example, year one of the initial contract is scheduled to remove 10,000 acres out of a total contract of 300,000 acres, representing 3% of the total area to be treated over the life of the contract.

Determining operational costs of thinning is difficult due to widely ranging factors that impact treatment costs, such as topography, road access, specific treatment to be applied, hauling distances, and forest structural differences. Therefore, a wide range of assumed operational costs were used, ranging from the Coconino National Forest's own estimate of $300/ac (Kim 2010) to the $557 to $836/ac reported by Arizona Forest Restoration Products (Arizona Forest Resources Task Group 2010).

Alternately, Pan et al. (2008) estimated production costs that averaged $55.27/bone dry ton on ponderosa pine thinning projects in the White Mountains of Arizona. NPV calculations for our analysis utilized the $557-$836/ac figure given by the Arizona Forest Resources Task Group (2010) to give a broad range of potential operational costs. Production cost analysis used a low and high cost scenario, with $557/ac used under low cost conditions and $836/ac assumed as the high cost scenario. Harvesting and chipping costs were calculated using data supplied by Patrick Rappold, Wood Utilization and Marketing Specialist with the Arizona State Forestry Division, at $292/ac. Avoided fire suppression costs used high risk and moderate risk categories, with costs ranging from $534/ac using high cost numbers to $257/ac under the moderate cost scenario (Mason *et al.* 2006). Revenues for the two studied biomass utilization options were assumed to be $175/green ton for pellets (moonlightsales.com) and $86/green ton for chips (RISI 2007). Both revenue figures represent wholesale prices.

Energy content of removed biomass was estimated in British Thermal Units (btus). Utilizing figures retrieved from the California Energy Commission (energy.ca.gov), total removals of woody material (expressed in cubic feet) were converted into cords, as btu ratings for cords was readily available. While each cord of wood occupies 128ft^3, approximately 90ft^3 of actual wood is available in each cord after accounting for airspace between logs. The California Energy Commission rates each cord of ponderosa pine at 21.7 million btus; with this number being multiplied by the available cords from restoration treatments.

Results

Total removals of woody material across all size classes were 366,159,083 ft^3 in alternative B, 367,737,184 ft^3 in alternative C, and 366,156,436 ft^3 in alternative D (Table 3). FVS simulations show that under treatment alternative C, the preferred scenario by the 4FRI stakeholder group, estimated biomass removals for woody plants 5" and less in diameter is 6,565,334 ft^3 (see Table 3). Treatment alternative B contains 6,675,412 ft^3 of material <5" dbh. When adding trees between 5-12" dbh to material available for biomass utilization, estimated biomass totals range from 138,309,596 ft^3 in alternative B to 138,420,950 ft^3 under alternative C, demonstrating that the smallest diameter trees are a small component in overall removals, when examining total biomass removed. However, small diameter trees are a crucial factor when determining severe fire potential; removing small trees can greatly decrease the likelihood of severe fire by limiting ladder fuels (Snider *et al.* 2006, Roccaforte *et al.* 2008).

Table 4 shows that while available btus are modest in the <5" dbh class, energy available significantly improves when the 5-12" dbh class is included. Treatment alternative B contains 792,184 million and 16,413,459 million btus in the <5" and 5-12" diameter classes respectively, while treatment alternative C contains 779,121 million and 16,426,674 million btus in these diameter classes.

Net present value (NPV) figures have been broken down into two categories: from the perspective of the US Forest Service and from the perspective of private industry. Under the best case scenario, where costs are assumed at $176.46/ac for Forest Service administration of 4FRI, NPV values were determined to result in an average loss of $1,252.81/ac. Under the current cost scenario where costs are given at $360/ac, NPV values showed an average loss of $2,741.48/ac. When adding avoided fire suppression costs to the U.S. Forest Service NPV in the analysis, the result was a net loss of $718.36/ac and $996.14/ac under low administration costs with high and moderate avoided fire cost scenarios, respectively. Using high administrative costs, net present values ranged between -$2207.03 and -$2484.81 under high and moderate avoided fire cost assumptions.

NPV values to private industry contractors who remove biomass materials were examined under three utilization scenarios, selling biomass as pulpwood and sawlogs, as chipped material and sawlogs, or as wood pellets and sawlogs (Table 5). Each scenario was calculated under high cost and low cost biomass removal option. Under the pulpwood and sawlog scenario, NPV values were -$447.50/ac assuming low costs and -$598.84/ac under the high removal cost scenario. Chipped material and sawlogs saw NPV values range from -$253.42/ac for low cost and -$404.76/ac for high cost options. Pellets and sawlogs most closely approached break-even, with values of -$45.57/ac and -$196.91/ac under the low and high cost scenarios, respectively. Although we did not include large diameter trees in the analysis, it can be hypothesized that the logging of large trees would have had a significant positive impact on NPV values.

Discussion

This analysis suggests that the use of biomass technologies alone does not completely offset treatment costs within the 4FRI project area. However, the price of pulpwood and sawlog material, combined with needed state and national government incentives that encourage renewable energy alternatives to fossil fuels will ultimately determine profitability to private industry. At present, biomass utilization would likely be best used by private industry to provide energy needs at small scales, such as providing heat to facilities, rather than in large scale ventures where financial considerations are not favorable. With lower administrative costs expected to result from landscape level restoration, the US Forest Service will offset some, but not all of the expense that restoration activities entail. Project level NEPA analysis that covers entire project areas spanning hundreds of thousands of acres represents a significant step forward in forest administration that may result in reduced Forest Service overhead expenses that further lower per unit costs. To make the Four Forest Restoration Initiative financially attractive to the Forest Service, larger diameter timber production would likely need to be included in order to increase expected revenues. However, reintroduction of traditional logging in the region is highly controversial and would almost assuredly by litigated by environmental groups. Due to existing wood utilization markets in the Show Low and Snowflake areas, achieving financial sustainability within the southern 4FRI area (the 3rd 10-year contract) is more attainable at present.

Converting biomass into British thermal units results in exceptionally large numeric values that are frequently difficult to understand and put into practical context. One btu is the energy content released when a single match is ignited; the values obtained in our analysis range from billions to trillions of btus. For illustration, alternative C, with an estimated energy potential of more than 17 trillion btus, could act as an equivalent substitute to approximately 2.97 million barrels of oil over the 10 year life of restoration activities. Given that fossil fuel consumption worldwide continues to increase while the availability of these same resources continue to decrease, turning global attention to the importance of developing renewable fuel alternatives needs to become a priority in the immediate future. The development of clean energy solutions designed to offset fossil fuel consumption has the potential not only to reduce dependence on foreign oil, the opportunity to incubate renewable energy technologies can also provide significant economic investment in local communities. Economic incentives to utility entities that encourage the use of renewable energy sources to provide power is one example of government/public efforts to stimulate renewable energy use that biomass utilization can benefit from.

Economic stimulation to the local economy under the 4FRI has recently been modeled using input-output analysis software. Input-output economic models utilize locality-specific economic data to determine anticipated future benefits of new projects. Using input-output methodology, Jaworski (2012), in her report on the economic benefits of the first 10-year contract of 4FRI, found that 646 private sector jobs would be supported on an average annual basis, irrespective of treatment alternative chosen. A study by Northern Arizona University determined full-time equivalent (FTE) employment gains to be 361 jobs for the first 10-year contract. The differences between these two employment estimates can be attributed to the different assumptions made in each case. The study by Northern Arizona University, however, did not include all indirect economic influences. Secondary economic gains resulting from increased local personal incomes that would likely increase overall employment as disposable income gains would lead to higher employment in the housing, restaurant, and service industries. Employment figures calculated by Jaworski (2012) did include these secondary employment gains, resulting in higher reported job creation. Further, Jaworski (2012) estimates both part time and full time employment gains from restoration activities, while the Northern Arizona University study focused solely on full time employment. Input-output models (such as IMPLAN) typically assume that economic conditions will remain the same over the length of the study period, meaning that income estimations are frequently underestimated.

The financial gains from restoration activities, coupled with avoidance of landscape-level wildfire costs, lends credence to the notion that initial restoration costs are less expensive overall when long term geographic scales are considered (Wu *et al.*, 2011). The significant financial constraints associated with the commercial use of small-diameter wood products are a major challenge to biomass utilization. However, due to the size of the proposed treatment area, economies of scale are likely to reduce per unit restoration costs. High transportation costs, coupled with the lack of sufficient biomass processing facilities in the 4FRI project area, are perhaps larger issues than low woody biomass prices in the current market. The awarding of the first 10-year contract to Pioneer Forest Products, who intend to build a wood processing facility in Winslow, Arizona, has the potential to reinvigorate the logging industry in northern Arizona and provide substantial economic benefits. This study has shown that landscape-scale contracts have the potential to produce economic incentives that can make small diameter thinning projects feasible by avoiding catastrophic wildfire events and producing biomass products for energy use. Utilizing landscape restoration techniques found in the 4FRI, forested regions throughout the West have a blueprint from which to model successful future projects.

Works Cited

Allen, Craig D., Melissa Savage, Donald A. Falk, Kieran F. Suckling, Thomas W. Swetnam, Todd Schulke, Peter B. Stacey, Penelope Morgan, Martos Hoffman, and Jon T. Klingel. "Ecological Restoration of Southwestern ponderosa pine ecosystems: A broad perspective." *Ecological Applications* (2002): 12(5): 1418-1433.

Arizona Forest Resources Task Group. "Arizona forest resource assessment: A collaborative analysis of forest-related conditions, trends, threats, and opportunities." 18 June 2010. *http://www.azsf.az.gov/userfiles/file/Arizona%20Forest%20Resource%20Assessment-2010.pdf.* 18 November 2012.

Bergman, Richard, and John Zerbe. *Primer on Wood Biomass for Energy*. Madison, WI: USDA, Forest Service, Forest Products Laboratory, 2004.

BIOMASS Technical Advisory Committee. "Vision for Biomass." 2002.

Cooper, Charles F. "Changes in vegetation, structure, and growth of Southwestern pine forests since white settlement." *Ecological Monographs* (1960): Vol. 30, No. 2. pp. 129-164.

Covington, W. W., R. L. Everett, R. Steele, L. L. Irwin, T. A. Daer, and A. N. D. Auclair. "Historical and anticipated changes in forest ecosystems of the Inland West of the United States." *Journal of Sustainable Forestry* (1994): 2: 13-63.

Covington, W. Wallace, and Margaret M. Moore. "Southwestern Ponderosa Forest Structure: changes since Euro-American settlement." *Journal of Forestry* (1994): 92:39-47.

Covington, W.Wallace, Peter Z. Fule, Margaret M. Moore, Stephen C. Hart, Thomas E. Kolb, Joy N. Mast, Stephen S. Sackett, and Michael R. Wagner. "Restoring ecosystem health in ponderosa pine forests of the Southwest." *Journal of Forestry* (1997): 95:23-29.

Crookston, Nicholas L., and Gary E. Dixon. "The Forest Vegetation Simulator: A review of its structure, content, and applications." *Computers and Electronics in Agriculture* (2005): 49:60-80.

Dixon, Gary E. *Essential FVS: A User's Guide to the Forest Vegetation Simulator*. General Technical Manual. Fort Collins, CO: USDA, Forest Service, 2002.

Four Forest Restoration Initiative Stakeholder Group. *Four Forest Restoration Initiative Landscape Strategy, Economics and Utilization Analysis*. Flagstaff, AZ: Four Forest Restoation Initiative, 2010.

Fried, J.S., Barbour, R.J., Fight, R., Christensen, G., Pinjuv, G. *Small diameter timber alchemy: Can utilization pay the way towards fire resistant forests?* Gen. Tech. Rep. PSW-GTR-189. Albany, California: United States Forest Service, 2008.

Fule, Peter Z., W. Wallace Covington, and Margaret M. Moore. "Determining reference conditions for ecosystem management of outhwestern ponderosa pine forests." *Ecological Applications* (1997): 7:895-908.

Gan J, and Smith CT. "Availability of logging residues and potential for electricity production and carbon displacement in the US." *Biomass and Bioenergy* (2006): 30(12):1011–1020.

Hampton, H. M., S. E. Sesnie, B. G. Dickson, J. M. Rundall, T. D. Sisk, G. B. Snider, and J. D. Bailey. *Analysis of small-diameter wood supply in northern Arizona*. Flagstaff, AZ: Forest Ecosystem Restoration Analysis Project, Center for Environmental Sciences and Education, Northern Arizona University, 2008.

Hjerpe, Evan E., and Yeon-Su Kim. "Economic impacts of Southwestern national forest fuels reductions." *Journal of Forestry* (2008): 106:311-316.

Hjerpe, Evan, Jesse Abrams, and Dennis R. Becker. "Socioeconomic barriers and the role of biomass utilization in southwestern ponderosa pine restoration." *Ecological Restoration* (2009): 27:169-177.

Huang, Ching-Hsun, and Christopher Sorensen. "The economic value of selling carbon credits from restored forests: A case study from the Navajo Nation's tribal forests." *Western Journal of Applied Forestry* (2011): 26:37-45.

Hunter, M. E., W. D. Shepperd, L. B. Lentile, J. E. Lundquist, M. G. Andreu, J. L. Butler, and F. W. Smith. *A comprehensive guide to fuels treatment practives for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest*. Fort Collins, CO: USDA, Forest Service. General Technical Report GTR-198, 2007. 93p.

Jaworski, Delilah. "Four-Forest Restoration Initiative Draft Socioeconomic Resource Report." Economic report . 2012.

Kim, Yeon-Su. *Ecological restoration as economic stimulus: a regional analysis*. Flagstaff, AZ: Ecological Restoration Institute, 2010.

Kolb, T. E., M. R. Wagner, and W. W. Covington. "Concepts of forest health." *Journal of Forestry* (1994): 92:10-15.

Larson, Debra, and Richard Mirth. "Projected economic impacts of a 16-inch tree cutting cap for ponderosa pine forests within the greater Flagstaff urban-wildlands." Ogden, UT: USDA, Forest Service, 2001. 154-160.

Lenart, Melanie. "Collaborative stewardship to prevent wildfires." *Environment* (2006): 48:9-21.

Levan-Green, Susan L., and Jean Livingston. "Exploring the uses for small-diameter trees." *Forest Products Journal, Vol. 51, No. 9* (2001): 10-21.

Mason, Larry C., Bruce R. Lippke, Kevin W. Zobrist, Thomas D. Bloxton Jr., Kevin R. Cedar, Jeffrey M. Comnick, James B. McCarter, and Heather K. Rodgers. "Investments in Fuel Removals to Avoid Forest Fires Result in Sunstantial Benefits." *Journal of Forestry* (2006): 27-31.

Moore, Margaret M., W. Wallace Covington, and Peter Z. Fule. "Reference conditions and ecological restoration: a southwestern ponderosa pine perspective." *Ecological Applications* (1999): 9:1266-1277.

Morgan, Todd A., Thale Dillon, Chalres E. Keegan, III, Alfred L. Chase, and Mike T. Thompson. *The Four Corners timber harvest and forest products industry, 2002*. Resource Bulletin RMRS-RB-7. Fort Collins, CO: US Depatment of Agriculture, Forest Service, Rocky Mountain Research Station, 2006. 64p.

Noss, Reed F., Jerry F. Franklin, William L. Baker, Tania Schoennagel, and Peter B. Moyle. "Managing fire-prone forests in the western United States." *Frontiers in Ecology and the Environment* (2006): 4:481-487.

Pan, Fei, Han-Sup Han, Leonard R. Johnson, and William J. Elliot. "Production and cost of harvesting, processing, and transporting small-diameter (≤ 5 inches) trees for energy." *Forest Products Journal* (2008): 58(5):47-53.

Perez-Verdin, Gustavo, Donald L. Grebner, Ian A. Munn, Changyou Sun, and Stephen C. Grado. "Economic impacts of woody biomass utilization for bioenergy in Mississippi." *Forest Products Journal* (2008): Vol 58. No.11. pp.75-83.

Perlack, Robert D., Anthony F. Turhollow, Robin L. Graham, Bryce J. Stokes, and Donald C. Erbach. *Biomass as Feedstock for A bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply*. Joint study. Oak Ridge, TN: US Department of Energy and the US Department of Agriculture, 2005.

Pirraglia, Adrian, Ronalds Gonzalez, and Daniel Saloni. "Wood Pellets: An Expanding Market Opportunity." 2010. *http://biomassmagazine.com/articles/3853/wood-pellets-an-expanding-market-opportunity/.* 02 December 2012.

RISI. "World Timber Price Quarterly, A Quarterly Update on Global Timber Prices." Quarterly Report. 2007. Document.

Roccaforte, John P., Peter Z. Fule, and W. Wallace Covington. "Landscape-scale changes in canopy fuels and potential fire behaviour following ponderosa pine restoration treatments." *Internation Journal of Wildland Fire* (2008): 17:293-303.

Swetnam, T. and Baisan, C. "Historical fire regime patterns in the southwestern United States since AD 1700. In: CD Allen (ed) Fire Effects in Southwestern Fortest : Proceedings of the 2nd La Mesa Fire Symposium." General Technical Report RM-GTR-286. pp. 11-32. 1996.

United States Forest Service. "2012 Timber cut and sold on national forests, Region 3, Coconino National Forest." 14 November 2012. *http://www.fs.fed.us/forestmanagement/documents/sold-harvest/reports/2012/2012_Q4_CandS_R03.pdf.* Report. 18 November 2012.

USDA, Forest Service. *Proposed action for Four-Forest Restoration Initiative: Coconino and Kaibab National Forest, Coconino County, Arizona*. Proposed action. Washington, DC: United States Department of Agriculture, 2011.

Vegh, T., C. Huang, and A.J. Finkral. "Carbon Credit Possibilities and Economic Implications of Fuel Redduction Treatments." *Western Journal of Applied Forestry* (2012): In print.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. "Warming and earlier spring increase western U.S. forest wildfire activity." *Science* (2006): 313: 940-943.

Wu, Tong, Yeon-Su Kim, and Matthew D. Hurteau. "Investing in natural capital: using economic incentives to overcome barriers to forest restoration." *Restoration Ecology* (2011): 19:441-445.

Table 1. This table highlights the major treatment activities that will occur in alternatives B and C. Prescribed fire is the most significant difference between treatments. Values are stated in acres.

	Alternative A[1]	Alternative B	Alternative C	Alternative D
Prescribed Fire only	N/A	199,435	159,211	178,753
Intermediate Thin	N/A	58,826	58,663	58,826
Savanna	N/A	45,469	45,469	45,469
Uneven Aged Thin (Groupy/Clumpy	N/A	158,492	152,997	158,492
MSO Treatments	N/A	84,177	82,377	84,177

[1] No action scenario that follows current management plan

Table 2. Comparison of treatment alternatives by basal area, trees per acre, and stand density index. 2010 represents averages pre-treatment, while 2020, 2030, and 2050 columns represent post-treatment figures for alternatives B and C.

Alternative	2010	2020	2030	2050
		Basal Area (ft^2/acre)		
A	115.65	126.60	136.53	152.34
B	125.63	63.57	71.94	93.44
C	120.15	61.29	69.44	90.19
		Trees Per Acre		
A	192.72	181.17	166.93	140.35
B	197.66	106.59	102.91	95.01
C	195.03	101.72	98.28	90.85
		Stand Density Index		
A	176.26	185.72	192.44	198.99
B	193.63	85.95	93.63	117.05
C	185.60	83.05	90.58	113.19

Table 3. Estimated removals over the 10-year contract using FVS for each treatment alternative and size class. Numbers are in cubic feet (ft^3).

	Size Class			
Alternative	0-5 inches	5-12 inches	>12 inches	Total
B	6,675,412	138,309,596	221,174,075	366,159,083
C	6,565,334	138,420,950	222,750,900	367,737,184
D	6,675,412	138,308,702	221,172,321	366,156,436

Table 4. Conversion of available biomass in cubic feet to British Thermal Units (BTU) to determine energy potential. Units are in millions.

	Size Class		
Alternative	0-5 inches	5-12 inches	Total
B	792,184	16,413,459	17,205,643
C	779,121	16,426,674	17,205,795
D	792,184	16,413,353	17,205,537

Table 5. NPV ($/ac) calculations to contractors under low/high cost scenarios. Costs assumed at $849/acre in low scenario and $1128/acre under high cost conditions. Assumed costs include treatment, processing, and transportation to biomass facility. With the exception of loss/acre, all values are aggregate totals for the entire project life.

	Wood Products		
	Pulp and Sawlogs	Chips and Sawlogs	Pellets and Sawlogs
Low Cost Assumption:			
Present Value of Total Revenues	$5,650,577	$89,879,869	$180,089,249
Present Value of Total Costs	$199,866,386	$199,866,386	$199,866,386
NPV	($194,215,809)	($109,986,518)	($19,777,137)
Loss/acre	($448)	($253)	($46)
High Cost Assumption:			
Present Value of Total Revenues	$5,650,577	$89,879,869	$180,089,249
Present Value of Total Costs	$265,546,860	$265,546,860	$265,546,860
NPV	($259,896,283)	($175,666,991)	($85,457,611)
Loss/acre	($599)	($405)	($197)

Table 6. NPV ($/ac) calculations to US Forest Service under low/high cost scenarios. Costs assumed at $176.46/acre in low scenario and $360/acre under high cost conditions. Assumed costs include all administrative costs over the 10 year life of the project.

Net Present Values to US Forest Service under low cost scenario		Net Present Values to US Forest Service under high cost scenario	
Present Value or Total Revenues	$178.44	Present Value or Total Revenues	$178.44
Present Value of Total Costs	$1,431.25	Present Value of Total Costs	$2,919.92
Net Present Value	($1,252.81)	Net Present Value	($2,741.48)
Fire Suppression cost avoided, high risk	$534.45	Fire Suppression cost avoided, high risk	$534.45
Fire Suppression cost avoided, moderate risk	$256.67	Fire Suppression cost avoided, moderate risk	$256.67
NPV including avoided fire suppression costs, high risk	($718.36)	NPV including avoided fire suppression costs	($2,207.03)
NPV including avoided fire suppression costs, moderate risk	($996.14)	NPV including avoided fire suppression costs, moderate risk	($2,484.81)

Table 7. Anticipated schedule of thinning treatments during the first 10 year contract. Low initial treatments anticipate start-up of industry and processing facilities in the region.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Mechanically Thinned (ac)	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000

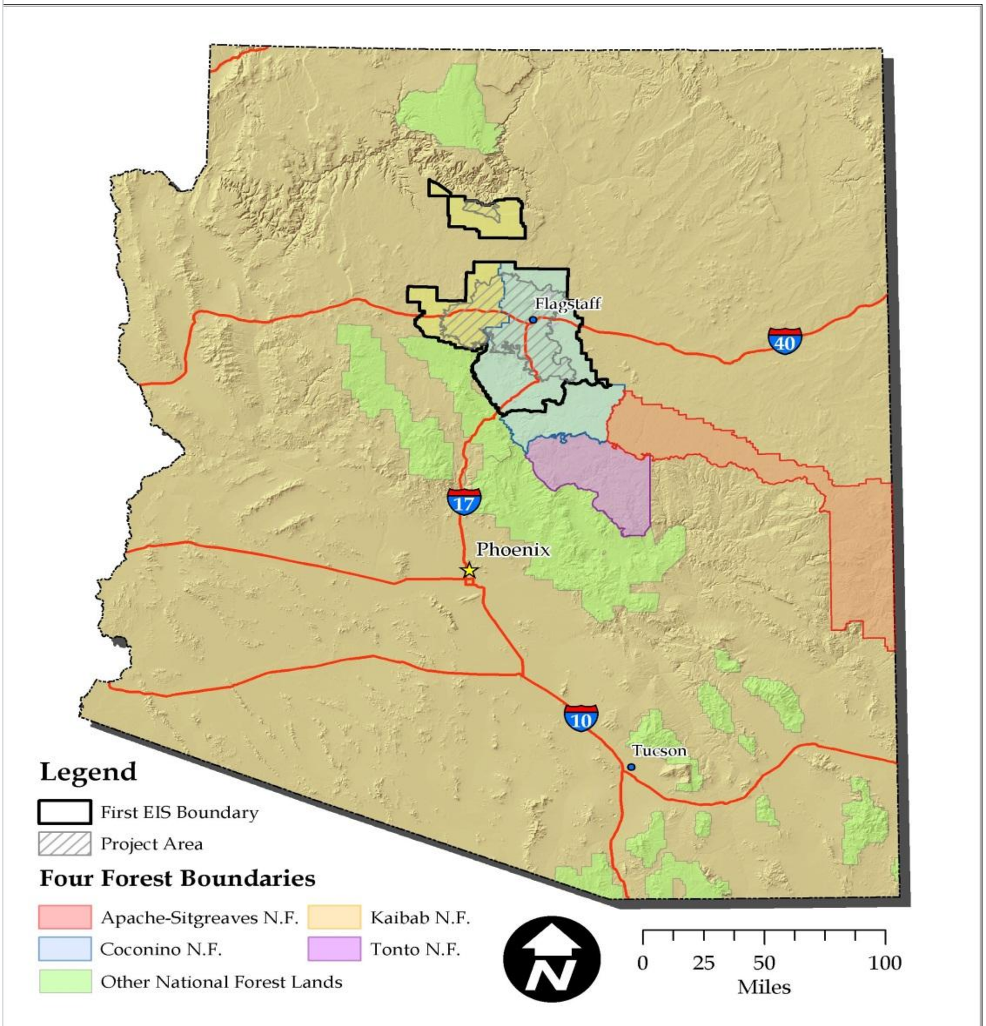

Figure 1. Study area, outlined in black, relative to the entire 4FRI project area (highlighted in red, purple, light blue, and yellow). Image from http://www.fs.usda.gov/Internet/FSE_MEDIA/stelprdb5358222.jpg

Appendix A

Net Present Value tables for the US Forest Service and logging contractors over the first contract of the Four Forest Restoration Initiative.

Table 1. Net Present Values for the US Forest Service under assumed best case scenario. Values are measured per acre.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
Revenue												
fixed income	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00		
PV	$21.15	$20.34	$19.56	$18.81	$18.08	$17.39	$16.72	$16.08	$15.46	$14.86		
											PV of TR	$178.44
Costs												
Low cost, administration	$176.46	$176.46	$176.46	$176.46	$176.46	$176.46	$176.46	$176.46	$176.46	$176.46		
PV	$169.67	$163.15	$156.87	$150.84	$145.04	$139.46	$134.10	$128.94	$123.98	$119.21		
											PV of TC	$1,431.25
NPV	($148.52)	($142.81)	($137.31)	($132.03)	($126.95)	($122.07)	($117.38)	($112.86)	($108.52)	($104.35)		
											NPV	($1,252.81)
Avoided Fire Suppression Costs	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00		
	$362.50	$348.56	$335.15	$322.26	$309.87	$297.95	$286.49	$275.47	$264.88	$254.69		
NPV with avoided fire costs	$213.98	$205.75	$197.84	$190.23	$182.91	$175.88	$169.11	$162.61	$156.35	$150.34		
											NPV assuming avoided fire suppression costs	$1,805.00

Table 2. Net Present Values for the US Forest Service under current cost estimate scenario by treatment year. Values are measured per acre.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
Revenue												
Fixed Income	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00		
PV	$21.15	$20.34	$19.56	$18.81	$18.08	$17.39	$16.72	$16.08	$15.46	$14.86		
											PV of TR	$178.44
Costs												
Current Cost, administration	$360.00	$360.00	$360.00	$360.00	$360.00	$360.00	$360.00	$360.00	$360.00	$360.00		
PV	$346.15	$332.84	$320.04	$307.73	$295.89	$284.51	$273.57	$263.05	$252.93	$243.20		
											PV of TC	$2,919.92
NPV	($325.00)	($312.50)	($300.48)	($288.92)	($277.81)	($267.13)	($256.85)	($246.97)	($237.47)	($228.34)		
											NPV	($2,741.48)
Avoided Fire Suppression Costs	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00	$377.00		
	$362.50	$348.56	$335.15	$322.26	$309.87	$297.95	$286.49	$275.47	$264.88	$254.69		
NPV with avoided fire costs	$37.50	$36.06	$34.67	$33.34	$32.06	$30.82	$29.64	$28.50	$27.40	$26.35		
											NPV assuming avoided fire suppression costs	$316.32

Table 3. Net Present Values for the logging contractors under low cost estimate scenario by treatment year, assuming removed biomass is sold as pulp and sawlogs, respectively. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
	3%	5%	10%	10%	10%	12%	12%	12%	13%	13%		
Revenues												
Pulp ($/ac)	$39,885	$38,351	$36,876	$35,458	$34,094	$32,783	$31,522	$30,310	$29,144	$28,023		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Pulp+saw($/ac)	$361,302	$347,406	$334,044	$321,196	$308,842	$296,964	$285,542	$1,503,015	$264,000	$1,628,267		
											PV of TR	$5,650,577
Acres removed	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000		
Cost	$8,490,000	$12,735,000	$25,470,000	$25,470,000	$25,470,000	$29,715,000	$29,715,000	$29,715,000	$33,960,000	$33,960,000		
PV	$8,163,462	$11,774,223	$22,642,737	$21,771,863	$20,934,483	$23,484,196	$22,580,958	$21,712,459	$23,859,846	$22,942,159		
											PV of TC	$199,866,386
											NPV	($194,215,809)
											Loss/acre	($447.50)

Table 4. Net Present Values for the logging contractors under low cost estimate scenario by treatment year, assuming removed biomass is sold as wood pellets and sawlogs. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2,013	2,014	2,015	2,016	2,017	2,018	2,019	2,020	2,021	2,022		
	0	0	0	0	0	0	0	0	0	0		
Revenues												
Pellets	$21,027,981	$20,219,213	$19,441,551	$18,693,799	$17,974,806	$17,283,468	$16,618,719	$15,979,538	$15,364,940	$14,773,981		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Pellets+sawlog	$21,349,398	$20,528,267	$19,738,718	$18,979,537	$18,249,555	$17,547,649	$16,872,739	$16,223,788	$15,599,796	$14,999,804		
											PV of TR	180,089,249
Acres removed	$10,000	$15,000	$30,000	$30,000	$30,000	$35,000	$35,000	$35,000	$40,000	$40,000		
Cost	$8,490,000	$12,735,000	$25,470,000	$25,470,000	$25,470,000	$29,715,000	$29,715,000	$29,715,000	$33,960,000	$33,960,000		
PV	$8,163,462	$11,774,223	$22,642,737	$21,771,863	$20,934,483	$23,484,196	$22,580,958	$21,712,459	$23,859,846	$22,942,159		
											PV of TC	199,866,386
											NPV	(19,777,137)
											Loss/acre	(46)

Table 5. Net Present Values for the logging contractors under low cost estimate scenario by treatment year, assuming removed biomass is sold as wood chips and sawlogs. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2,013	2,014	2,015	2,016	2,017	2,018	2,019	2,020	2,021	2,022		
	0	0	0	0	0	0	0	0	0	0		
Revenues												
Chips	$10,333,751	$9,936,299	$9,554,133	$9,186,667	$8,833,333	$8,493,590	$8,166,913	$7,852,801	$7,550,770	$7,260,356		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Chips+sawlog	$10,655,167	$10,245,353	$9,851,301	$9,472,405	$9,108,082	$8,757,771	$8,420,933	$8,097,051	$7,785,626	$7,486,179		
											PV of TR	$89,879,869
Acres removed	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000		
Cost	$8,490,000	$12,735,000	$25,470,000	$25,470,000	$25,470,000	$29,715,000	$29,715,000	$29,715,000	$33,960,000	$33,960,000		
PV	$8,163,462	$11,774,223	$22,642,737	$21,771,863	$20,934,483	$23,484,196	$22,580,958	$21,712,459	$23,859,846	$22,942,159		
											PV of TC	$199,866,386
											NPV	($109,986,518)
											Loss/acre	($253)

Table 6. Net Present Values for the logging contractors under high cost estimate scenario by treatment year, assuming removed biomass is sold as pulpwood and sawlogs. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
	3%	5%	10%	10%	10%	12%	12%	12%	13%	13%		
Revenues												
Pulp ($/ac)	$39,885	$38,351	$36,876	$35,458	$34,094	$32,783	$31,522	$30,310	$29,144	$28,023		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Pulp+saw($/ac)	$361,302	$347,406	$334,044	$321,196	$308,842	$296,964	$285,542	$1,503,015	$264,000	$1,628,267		
											PV of TR	5,650,577
Acres removed	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000		
Cost	$11,280,000	$16,920,000	$33,840,000	$33,840,000	$33,840,000	$39,480,000	$39,480,000	$39,480,000	$45,120,000	$45,120,000		
PV	$10,846,154	$15,643,491	$30,083,637	$28,926,574	$27,814,013	$31,201,617	$30,001,555	$28,847,649	$31,700,714	$30,481,455		
											PV of TC	265,546,860
											NPV	(259,896,283)
											Loss/acre	(599)

Table 7. Net Present Values for the logging contractors under high cost estimate scenario by treatment year, assuming removed biomass is sold as wood pellets and sawlogs. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
	3%	5%	10%	10%	10%	12%	12%	12%	13%	13%		
Revenues												
Pellets	$21,027,981	$20,219,213	$19,441,551	$18,693,799	$17,974,806	$17,283,468	$16,618,719	$15,979,538	$15,364,940	$14,773,981		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Pellests+sawlog	$21,349,398	$20,528,267	$19,738,718	$18,979,537	$18,249,555	$17,547,649	$16,872,739	$16,223,788	$15,599,796	$14,999,804		
											PV of TR	$180,089,249
Acres removed	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000		
Cost	$11,280,000	$16,920,000	$33,840,000	$33,840,000	$33,840,000	$39,480,000	$39,480,000	$39,480,000	$45,120,000	$45,120,000		
PV	$10,846,154	$15,643,491	$30,083,637	$28,926,574	$27,814,013	$31,201,617	$30,001,555	$28,847,649	$31,700,714	$30,481,455		
											PV of TC	$265,546,860
											NPV	($85,457,611)
											Loss/acre	($197)

Table 8. Net Present Values for the logging contractors under high cost estimate scenario by treatment year, assuming removed biomass is sold as wood chips and sawlogs. Dollar values are measured per year, with NPV value over life of 10 year contract. Percentages shown represent percentage each year's harvest represents of the total 300,000 acre project.

Contract year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
	3%	5%	10%	10%	10%	12%	12%	12%	13%	13%		
Revenues												
Chips	$10,333,751	$9,936,299	$9,554,133	$9,186,667	$8,833,333	$8,493,590	$8,166,913	$7,852,801	$7,550,770	$7,260,356		
Sawlog ($/ac)	$321,416	$309,054	$297,168	$285,738	$274,748	$264,181	$254,020	$244,250	$234,856	$225,823		
Chips+sawlog	$10,655,167	$10,245,353	$9,851,301	$9,472,405	$9,108,082	$8,757,771	$8,420,933	$8,097,051	$7,785,626	$7,486,179		
											PV of TR	$89,879,869
Acres removed	10,000	15,000	30,000	30,000	30,000	35,000	35,000	35,000	40,000	40,000		
Cost	$11,280,000	$16,920,000	$33,840,000	$33,840,000	$33,840,000	$39,480,000	$39,480,000	$39,480,000	$45,120,000	$45,120,000		
PV	$10,846,154	$15,643,491	$30,083,637	$28,926,574	$27,814,013	$31,201,617	$30,001,555	$28,847,649	$31,700,714	$30,481,455		
											PV of TC	$265,546,860
											NPV	($175,666,991)
											Loss/acre	($405)