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Modeling Regional Economic Contributions of Forest Restoration: a Case Study of the Four Forest Restoration Initiative

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Abstract

Forest restoration positively affects rural economies by facilitating employment and income generation with logging, wood utilization, and other restoration activities. To investigate economic effects and modeling of forest restoration, a regional contribution analysis of the Four Forest Restoration Initiative (4FRI) in Arizona was conducted. With over 12,000 acres mechanically thinned in 2017, 4FRI treatments led to the processing of 400,000 green tons of sawlogs and biomass. Restoration activities spurred more than 900 full-time equivalent jobs in the region, $50 million in regional labor income, and affected over 140 different industry sectors in the region. When compared to the US Forest Service Treatments for Restoration Economic Analysis Tool model estimates for 4FRI economic contributions, we found that using primary data from 4FRI contractors provided more conservative results. Primary considerations for modeling forest restoration contributions include contractor surveys, appropriate investigation of the regional context, methodological transparency in bridging restoration expenditures to input-output models, and consideration of how to enhance restoration contributions.

Study Implications: A leading wildfire management strategy is restoring forests by thinning trees and conducting prescribed burns, especially in wildland-urban interfaces, to allow fire to play its more natural role and to lessen wildfire severity. Although forest restoration provides substantial economic impacts to adjacent communities and stimulates logging and sawmilling industry sectors, the economics of forest restoration are quite different from the economics of traditional timber production and thus require novel and greater understanding among forest managers. Regional economic contribution analysis of forest-restoration projects provides forest managers and stakeholders with key economic information about woody byproduct utilization and small diameter wood markets, and illuminates how comprehensive restoration spurs widespread economic activity across more industrial sectors as compared to traditional timber production. Incorporating high-resolution primary data for restoration contribution analysis and providing for methodological transparency can facilitate modeling refinements and can also offer critical insight into strategies for enhancing regional contributions and increasing sources of restoration funding.

Keywords: forest restoration, economic contribution analysis, biomass utilization, regional modeling, 4FRI

Large-scale forest restoration in fire-adapted forests of the American West is being conducted to help communities and landscapes adapt to more natural wildfire regimes. Tree thinning and controlled burns are the primary techniques being used to help restore arid Western forests (Covington et al. 1997), although comprehensive forest restoration includes many other on-the-ground labor activities including culvert placements, road decommissioning, reintroducing native plants, and removing exotics (Ellison et al. 2010). With millions of acres potentially in need of restoration, thinning and restoration activities require large investments in workforce and wood utilization to realize major accomplishments. Restoration activities have tremendous effects on community economics by generating regional employment, income, and other economic impacts, often in places that have experienced widespread reductions in logging and milling infrastructure over the last three decades (Hibbard and Karle 2002). Restoration also yields community benefits in terms of reducing catastrophic wildfire risk, protecting local water supplies, and enhancing a broad set of ecosystem services (Dubay et al. 2013).

Despite the importance of forest restoration for rural economies, there is little monitoring of detailed economic contributions experienced by at-risk forested communities (Daniels et al. 2018). Best practices for modeling the economic impacts and contributions of forest restoration are also limited because of the newness of restoration programs and the stark economic differences between forest restoration and traditional timber production. Forest restoration is differentiated from traditional timber production based on its overarching objective of recreating more natural overstory and understory conditions that can help reintroduce fire into fire-adapted forests. Traditional timber production, on the other hand, has been focused on maximizing timber revenues and regulating forests. Thinned trees under a restoration approach are primarily small diameter, creating an economic disadvantage for wood-products businesses due to increased costs of handling logs and substandard physical characteristics (Hjerpe et al. 2009).

To provide for greater economic monitoring and modeling of forest restoration impacts, we investigated the economic contributions from a large-scale restoration program in northern Arizona, the Four Forest Restoration Initiative (4FRI). The 4FRI is the largest forest restoration effort in the US and a showcase project of the US Forest Service (USFS) Collaborative Forest Landscape Restoration Program (CFLRP). Given the prominence and federal support for the 4FRI, there is a need to understand its regional economic contributions and to generalize methods used to help model forest restoration contributions in other regions.

Background

At the beginning of the 21st century, the USFS began to transition to ecosystem management, forest restoration, and wildfire fuels reduction after decades of sustained-yield timber production and fire suppression (e.g., Davis et al. 2018). The evolution of public forest management towards forest stewardship and restoration has changed the type of economic values and impacts that come from the forest; these range from commodity timber production to numerous nonmarket economic services that invoke both direct use and passive use values (Robbins and Daniels 2012). Despite the change in commodity focus, ecological restoration has become a significant industry, generating $10 billion annually in US output and 126,000 jobs (BenDor et al. 2015). Case studies in the Northwest have shown that forest and watershed restoration support approximately 16 jobs per million dollars of investment (Nielsen-Pincus and Moseley 2013).

Stewardship contracting, where goods such as woody biomass are offered for services such as restoration thinning, is playing a greater role in public lands forest restoration. As opposed to traditional timber sales, stewardship contracts allow for a greater retention of receipts locally, where the profits from sale of woody byproducts are used for other local restoration projects instead of being retained by the US Treasury. Stewardship contracts are increasingly being incorporated as funding mechanisms for other restoration activities that may not produce salable products, such as trail relocation, road decommissioning, and the eradication of invasive species.

Previous research has been conducted on the economic impacts of forest stewardship contracts involving holistic restoration approaches. Kerkvliet (2010) estimated the regional economic impacts of the Clearwater Stewardship Project in Montana and found an increase of $23 million in regional expenditures on restoration activities. He noted that the incorporation of other restoration activities resulted in spreading impacts across a greater number of regional sectors due to the inclusion of watershed restoration activities, monitoring, and administration. Daniels et al. (2018) examined the regional economic contribution of two stewardship projects in Oregon that included forest and watershed restoration activities, combined with traditional timber commercial and precommercial thinning activities. They also found impacts spread across a greater number of regional industries than traditional timber sale contracts. Shrestha and Mehmood (2018) interviewed primary contractors for the Shortleaf-Bluestem Community Restoration CFLR project to determine local capture of contracts and estimate regional and national economic impacts of the project, finding that 94 percent of the total restoration investment was spent within the regional economic area.

In Arizona, piecemeal forest restoration stewardship contracts have been ongoing since the early 2000s and, beginning in 2004, the White Mountain Stewardship Project in eastern Arizona has been the largest and longest stewardship contract to date (Mottek Lucas et al. 2017). These earlier stewardship contracts, including the Fort Valley pilot stewardship contract near Flagstaff, helped lay the groundwork for 4FRI. Hjerpe and Kim (2008) investigated the regional economic impact of these earlier Arizona and Southwest stewardship contracts and found that $40 million of output (total sales) and 500 regional jobs were generated across five national forests.

Building on the success of previous stewardship contracts, the CFLRP was congressionally established in 2009 to provide long-term funding for science-based ecosystem restoration programs jointly proposed by the USFS and local collaborators. The CFLRP is a competitive program, requiring review boards to allocate funds to the highest priority restoration landscapes and to the proposals that illustrated the greatest amount of collaboration and social acceptability. There are currently twenty-three CFLRP projects across the country, all of which are in fire-adapted landscapes (Schultz et al. 2017). An innovative component of the CFLRP is its requirements for project-level multiparty monitoring, a component too often neglected in forest management projects (Schultz et al. 2014). Although the intent of the CFLRP is to broadly encourage ecological, economic, and social sustainability, three of the five national indicators of success for the program revolve around economic impacts, fire costs, and leveraged funds (Bixler and Kittler 2015). The economics of forest restoration play a central role in determining the value and the future of the CFLRP.

Modeling Forest Restoration Economic Contributions

The previously referenced literature included individual case studies of the regional economic contributions of USFS stewardship contracts, where forest restoration was often a main component, but primary considerations for modeling economic contributions of forest restoration have not yet been proposed. Generalizing best practices for forest restoration contribution analysis is needed and these case studies provide a good starting point for assembling primary considerations. Further case studies from the gray literature and from the USFS Treatments for Restoration Economic Analysis Tool (TREAT) are also valuable for constructing recommendations for forest restoration contribution analysis.

Previous estimates of regional economic contributions of 4FRI have been presented in required annual CFLRP reports (fiscal year [FY] 2012–2017).[1] Annual estimates of regional CFLRP contributions are prepared by local USFS staff and then analyzed by USFS economists using TREAT modeling software. TREAT incorporates prepackaged regional input-output tables from impact analysis for planning (IMPLAN) but includes modifications germane to logging and wood production industries and restoration service providers. Specifically, the latest version of TREAT uses restoration production functions as detailed from national surveys conducted by the University of Oregon Ecosystem Workforce Program (EWP) (e.g., Nielson-Pincus and Moseley 2013, Kooistra and Moseley 2019). The TREAT model also incorporates direct employment and income response coefficients for logging and wood utilization based on regional surveys of forest and mill operators (Sorenson et al. 2015).

The EWP has conducted several economic studies concerning forest restoration, particularly in Oregon. Ellison and Huber-Stearns (2019) conducted social and economic monitoring of the Lakeview Stewardship CFLR Project, which included an estimate of economic contributions using the TREAT model and local capture rate of contracts. This analysis built upon earlier EWP studies by White et al. (2015a) and Rosenburg et al. (2018). Likewise, White et al. (2015b) reported on social and economic monitoring for the Southern Blues Restoration Coalition Project, another CFLR project in Oregon, and forest-restoration projects in central and eastern Oregon (White et al. 2016). In terms of modeling restoration contributions, these researchers typically collected expenditure and contract information from Forest Service records on service and timber contracts (e.g., the Federal Procurement Data System, the Timber Information Management System, and the Forest Activity Tracking System) and used these as inputs for IMPLAN.

An important methodological contribution of the referenced EWP studies is their approach and focus on estimating local capture rates by parsing contractor addresses and places of business. McIver (2016) has also examined USFS contracts and agreements to determine local capture rates for CFLR projects on the Colville National Forest in Washington and the Southwestern Crown of the Continent in Montana (McIver 2013). Understanding the local capture of work for forest-restoration projects is essential for determining the amount of economic activity that is leaked from the region (leakage) and is a prerequisite for accurately modeling regional economic contributions (Shrestha and Mehmood 2018). Whereas identifying expenditures within the regional economy is important for any type of economic contribution analysis, it is even more critical when examining forest restoration due to its novelty, lack of existing restoration businesses, and evolving Forest Service approaches to packaging timber sales and restoration contracts. With fewer businesses and less diversity of services, rural areas have a more difficult time providing the services and labor needed for restoration projects than urban areas, and the portion of local contracting has been decreasing (Moseley and Reyes 2008). In Arizona, for example, all equipment purchases from a federal biomass utilization grant program (WoodyBUG) were from out-of-state suppliers, due to a lack of regional equipment manufacturing (Davis et al. 2014).

Using USFS contracts and agreements to understand the economic contributions of forest restoration is a necessary first step in conducting regional economic contribution analysis. However, relying solely on USFS contract and agreement analysis can be risky because of inconsistent and disparate data entry across national forests. Analyses relying on sale and contract reporting often apply those activities in the initiation year or spread them evenly across project years. That approach does not capture annual variation in economic activity. As noted by White et al. (2016), restoration contractors often have three or more years after contract initiation to harvest purchased timber. Interviewing contractors can provide best estimates of actual economic activity each year and is a means to ground-truth and verify data collected from USFS-derived metrics. Following up with contractor interviews and surveys, as done by Daniels et al. (2018) and Shrestha and Mehmood (2018), provides the highest resolution for estimated regional contributions.

Because of the nascent rise of forest restoration as a pivotal wildfire management strategy, the various businesses that are impacted are not well known. Economic contribution analysis is conducted by entering changes in final demand, or an economic shock, by industry sector for a specified regional economy. For economic contributions of forest restoration, analysts must match restoration expenditures by activity to changes in final demand for specific industry sectors such as the logging sector, the sawmill sector, and the environmental consulting service sector. The allocation of restoration expenditures to industry sectors is critically important as it represents the final process by which all effects, multipliers, and total contributions are estimated within an input-output (I-O) model.

When dealing with newer economic activities such as forest restoration, transparency in illustrating changes in final demand becomes even more important by allowing for scientific replication. Unfortunately, several existing contribution analyses of forest restoration, including TREAT and the EWP analyses, do not illustrate the final bridging of restoration expenditures used to initiate their contribution analysis, which leads to a black box approach. This black box approach hinders the ability for replication and methodological refinements and limits the widespread use of potentially innovative restoration contribution analysis add-ons like the EWP production functions and the timber and logging direct-response coefficients.

Finally, the existing literature on economic contributions of forest-restoration projects has been presented as the monitoring of baselines with little discussion of how regional economic contributions can be enhanced via greater wood utilization. However, if contractors are also surveyed by wood harvest volumes and types of wood products, along with employment data, economists will have much greater insight into small-diameter wood utilization strategies. We recommend that economists go beyond the presentation of monitoring baselines when conducting forest restoration contribution analyses and also consider and discuss opportunities for increasing regional contributions.

By synthesizing existing approaches to estimating regional economic contributions of forest restoration and building on this foundation, we propose a set of primary considerations for modeling forest restoration contributions. General guidelines for modeling regional economic contributions of forest restoration include the following: (1) when possible, survey all primary contractors (e.g., Daniels et al. 2018, Shrestha and Mehmood 2018), (2) appropriate treatment of regional context and local capture rates (e.g., McIver 2013, White et al. 2016, Ellison and Huber-Stearns 2019), (3) methodological transparency in bridging final demand changes to I-O model sectors (e.g., Table 1 in Kerkvliet 2010 and in Shrestha and Mehmood 2018), and (4) discussion of methods to enhance regional economic contributions, such as woody byproduct utilization strategies (e.g., Hjerpe and Kim 2008). To demonstrate primary considerations for contribution analysis of forest restoration, we incorporated these guidelines into our 4FRI case study and present this below.

Methods

We conducted a literature review and synthesis of existing information on 4FRI economics from the USFS and stakeholders. We collected primary economic data from regional operators and the USFS to analyze contributions of 4FRI-related projects. Primary data were uploaded into IMPLAN economic modeling software. We conducted regional economic contribution analysis of contractor activities including logging, road building, trucking, milling, and biomass utilization, along with other restoration activities conducted by the USFS and private businesses such as prescribed fire, road decommissioning, and environmental planning.

Study Site

Restoration activities associated with 4FRI are being conducted on four Arizona national forests: the Apache-Sitgreaves, the Coconino, the Kaibab, and the Tonto. These national forests stretch from central Arizona near the towns of Williams and Flagstaff across to eastern Arizona and the White Mountain towns of Snowflake, Heber-Overgaard, and Nutrioso (see Figure 1). Restoration efforts take place primarily in five Arizona counties: Apache, Coconino, Gila, Greenlee, and Navajo. These five counties contain the fire-adapted communities most affected by ponderosa pine (*pinus ponderosa)* restoration. Because most of the restoration workforce for 4FRI are located in these counties, we used them as our IMPLAN regional economic impact zone for the contribution analysis.

One project not directly administered or funded as part of the 4FRI was included. The Flagstaff Watershed Protection Project (FWPP) is a partnership effort between the Arizona Department of Forestry & Fire Management, the City of Flagstaff, and the Coconino National Forest. In 2012, Flagstaff city voters approved a $10 million bond to restore forests on city, state, and national forest lands to reduce risk of severe wildfire and postfire flooding and to preserve the water supply in two critical watersheds that the City of Flagstaff relies on.[2] Considering that only a small portion of acres being treated for the FWPP are on city and state lands, the USFS included FWPP acres in their accomplishment reports and subsequent 4FRI CFLRP annual report.

Table 1. Regional 4FRI mechanical thinning and wood utilization employment for FY 2017

IMPLAN Sector Number	Description	FTE Annual Jobs
16	Commercial logging	57.7
19	Support activities for agriculture and forestry	13.6
47	Electric power generation - biomass	25
64	Maintenance and repair construction of highways, streets, bridges, and tunnels	5.2
134	Sawmills	87.2
145	All other miscellaneous wood product manufacturing	8
411	Truck transportation	25.4
Total		**222.1**

FTE, full-time equivalent; IMPLAN, impact analysis for planning.

Data Collection

To determine regional economic contributions of 4FRI-related activities, we collected data on expenditures and employment in FY 2017 (October 2016–September 2017) in three areas: thinning and wood utilization, other restoration activities such as restoring wetlands connectivity and road decommissioning, and regional USFS activities that include National Environmental Policy Act (NEPA) planning, site preparation, and prescribed fire. Due to differing contracting mechanisms and whether restoration activities were conducted in-house by the USFS, each set of regional contributions required separate data collection methods that are detailed below.

Thinning and Wood Utilization

Regional thinning operators were surveyed to understand their economic impacts. We developed, pretested, and implemented a survey of primary USFS thinning contractors for 4FRI activities in FY 2017. Contractors were identified from meetings with USFS managers and from publicly available 4FRI USFS monthly updates that summarize mechanical thinning, prescribed fire,

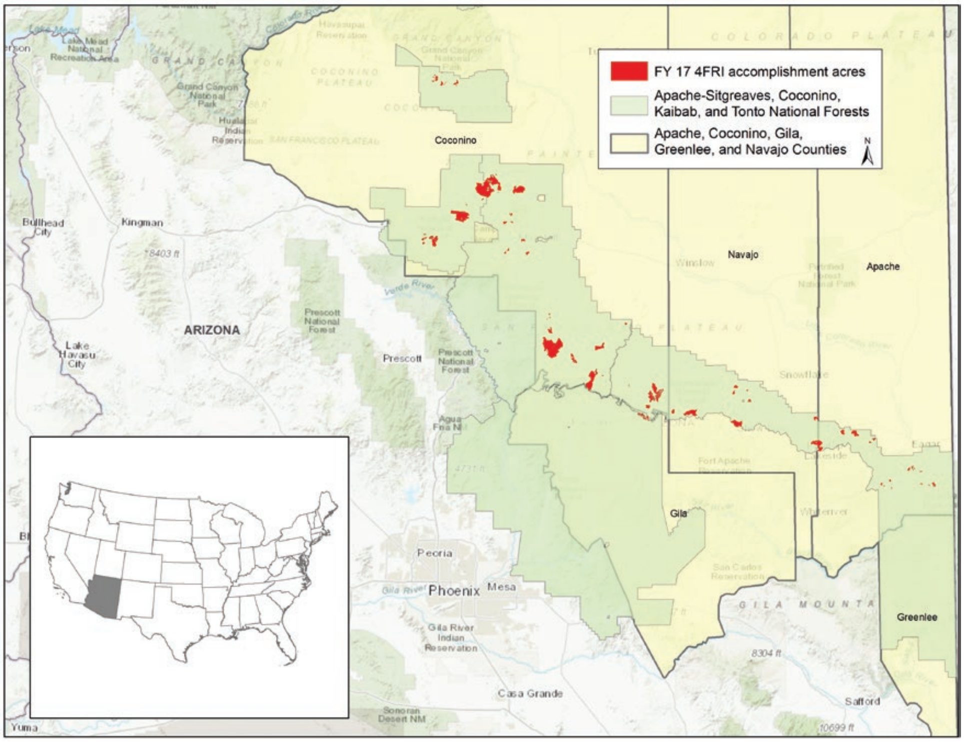

Figure 1. 4FRI regional economic contribution zone.

and NEPA contracts. Operators were contacted both by telephone and email and were asked to participate in our economic contribution survey. When applicable, Dillman survey methods were employed, including multiple follow-up requests for participation and assisting with survey completion. The survey was conducted during the fall and winter months of 2017 and 2018. In total, nine FY 2017 primary thinning contractors were identified, and all completed the survey.

Survey questions centered on acres thinned, employment, and wood utilization. Contractors were asked to detail volumes of wood harvested and types of wood products produced. All survey questions were focused on outcomes from actual acres thinned in FY 2017. Primary contractors were asked to estimate 4FRI-related employment and wood utilization for their businesses and for any of their subcontractors who conducted thinning work and subsequent wood utilization. For all employment questions, contractors were asked to estimate the number of jobs that were conducted within the regional economic impact zone and the percentage of employees who live within the region. Contractors were asked to estimate full-time equivalent (FTE) employment, or the number of months fully employed, for the following activities:

- logging and in-woods chipping
- road construction/decommissioning and culvert repair
- technical assistance
- administration and management of contracts
- trucking of logs and biomass
- off-site wood milling and processing

Survey data was ground-truthed, or triangulated, with other known sources of logging and utilization jobs in northern Arizona, such as mill ownership, in order to verify contractor responses. In some cases, contractors were called and asked to correct initial estimates that appeared to be outliers based on information from key informants who were familiar with the range of data. In these cases, survey participants misinterpreted the survey questions being asked. Table 1 illustrates the FTE employment for mechanical thinning and wood utilization from 4FRI.

Other Restoration Activities

To estimate the regional contributions of nonthinning restoration activities, we acquired a list of all other restoration activities contracted out by the USFS for FY 2017 4FRI projects and identified expenditure amounts and business names. To isolate restoration contractors that are regionally based businesses, we conducted a web search of all business names to determine contractor addresses and whether they had regional offices located within the five-county regional economic impact zone. Because northern Arizona is rural, it is impossible for the USFS to fill all restoration contract needs with local operators. However, because numerous 'other' restoration contractors were determined to be local, it appeared that the USFS was trying to spur regional economic contributions when possible. All of the 'other' restoration expenditures come from FY 2017 executed contracts.

Restoration contract expenditures were restricted to regional operators and were tallied among three broad categories (Nielsen-Pincus and Moseley 2013):

- Equipment-intensive, which includes excavation, construction, concrete and materials, and road building and decommissioning.
- Labor-intensive, which includes hand thinning, invasive plant removal, and trail work.
- Technical, which includes forestry consulting, archeology services, biological assessments, NEPA work, and research.

The other restoration expenditures were then bridged to the appropriate regional economic sector defined in IMPLAN. Our bridge of other restoration expenditures to the appropriate IMPLAN sector is in line with previous published forest restoration impact/contribution analyses (e.g., Hjerpe and Kim 2008, Kerkvliet 2010, Shrestha and Mehmood 2018) and is generally different than the bridge approach used by the USFS in TREAT modeling and by the University of Oregon EWP restoration studies (e.g., Nielsen-Pincus and Moseley 2013, White et al. 2015a).[3] Table 2 shows the final list of regional expenditures by the USFS for other restoration work by IMPLAN sector. These expenditures were part of the final demand change, along with mechanical thinning, wood utilization, and USFS restoration jobs, used to initiate the contribution analysis. Expenditures were converted to FTE employment and IMPLAN full- and part-time jobs estimates in each category as detailed in the contribution analysis methods (see Table 3).

Table 2. Regional 4FRI 'Other' Restoration Contract Expenditures for FY 2017

IMPLAN Sector Number	Description	Contracting Expenditures
16	Logging	$396,608
19	Support activities for agriculture and forestry	$136,032
56	Construction of new highways and streets	$825,459
64	Maintenance and repair construction of highways, streets, bridges, and tunnels	$150,163
455	Environmental and other technical consulting services	$634,887
456	Scientific research and development services	$31,872
469	Landscape and horticultural services	$256,872
531	Other state and local government enterprises	$12,012
Total		**$2,443,903**

IMPLAN, impact analysis for planning

USFS Prep and Prescribed Fire

To estimate the amount of regional, annual employment generated by the USFS for 4FRI activities conducted 'in-house' (i.e., not contracted out), USFS managers provided a list of FTE jobs associated with 4FRI restoration work for the fiscal year of 2017. Although numerous USFS staff work on 4FRI planning in both the regional office (Albuquerque, New Mexico) and the national office (Washington, DC), we limited USFS annual 4FRI employment to staff working in offices adjacent to the four national forests. Particularly in rural communities such as those near the 4FRI landscape, year-round USFS jobs play an important role in regional economies.

In total, approximately 258 FTE USFS jobs focused on 4FRI planning and implementation were sustained in the regional economic contribution zone in FY 2017 (see Table 3). These jobs represent a diverse suite of restoration activities ranging from NEPA planning to timber management to conducting prescribed burns. However, for the regional economic contribution analysis, they were entered under one IMPLAN sector (#535): employment and payroll of federal government, non-military.

Regional Economic Contribution Analysis

The CFLRP funds and other USFS funds used for restoration trigger output and employment in several regional industry sectors, including forestry, logging, and sawmills. The regional restoration expenditures spur initial or direct effects in the industry sectors such as contract sales for services. These direct effects, in turn, generate indirect effects on other industries that provide the supplies and basic services required for the final products and services. For example, logging companies performing restoration thinning purchase heavy

Table 3. Final Demand Change for Regional 4FRI Activities in FY 2017

IMPLAN Sector Number	Description	IMPLAN Full- and Part-time Jobs	FTE Jobs
16	Logging	71.3	61.7
19	Support activities for agriculture and forestry	20.6	17.7
47	Electric power generation - biomass	25.4	25.0
56	Construction of new highways and streets	5.4	5.2
64	Maintenance and repair construction of highways, streets, bridges	6.5	6.2
134	Sawmills	90.0	87.2
145	All other miscellaneous wood product manufacturing	8.3	8.0
411	Truck transportation	26.8	25.4
455	Environmental and other technical consulting services	10.4	9.8
456	Scientific research and development services	0.1	0.1
469	Landscape and horticultural services	5.8	5.4
531	Other state and local government enterprises	0.2	0.1
535	Employment and payroll of federal government, nonmilitary	265.2	258.0
Total		**536.0**	**510.0**

FTE, full-time equivalent; IMPLAN, impact analysis for planning

equipment such as forwarders and feller-bunchers, fuel to run equipment, and electronic tablets for matching restoration prescriptions in the field. Finally, induced effects are spurred when logging sides spend their paychecks locally on goods and services like lunches and entertainment. The combination of direct, indirect, and induced effects creates the total effect that initial 4FRI restoration expenditures have on the regional economy.

Regional economic contribution analysis (ECA) is a method of tracking the backward linkages of indirect and induced effects spurred by restoration expenditures throughout a regional economy. Regional ECA is similar to economic impact analysis in tracing initial changes in final demand throughout the regional economy but is more appropriate for activities that are recurring every year as opposed to the gain (or loss) of a new economic activity (Watson et al. 2007). A good delineation for determining whether economic impacts or contributions are the appropriate measure for a particular set of activities is the timing of the project. With projecting *ex ante* economic activities, generally, employing economic impact analysis is best. On the other hand, in tracking *ex post* economic activities, economic contribution analysis is generally considered to be the preferred method (Watson et al. 2015).

Regional ECA is conducted within an I-O model, where the production of all industries is presented in a matrix and all industries are both buyers and sellers of goods and services. The I-O model is predicated on the Leontief Inverse, or an equation allowing for the balancing of the social accounting matrix when inputs are applied to a particular sector (Isard et al. 1998). IMPLAN originated as a Forest Service model and is well suited for regional analyses (Crihfield and Campbell 1991). However, it is important to acknowledge a few of IMPLAN's limitations. First, IMPLAN and I-O models give only a partial view of overall economic values, focusing on market impacts and neglecting societal costs and benefits. IMPLAN is a static I-O model, as opposed to some of the more expensive dynamic computable general equilibrium models. Due to assumptions of fixed technology and lack of supply constraints, industry relationships tend to be more linear in the software, and results generated in IMPLAN represent a snapshot in time.

Contribution analysis is conducted by entering initial changes in final demand transacted within the regional economy. In IMPLAN, changes in final demand can be entered as sales expenditures or as employment. IMPLAN regional economic data provides output, employment, labor income, and value-added equivalents by individual industry sectors based on the initial final demand changes entered. We used employment to initiate the contribution analysis. Because we had to conduct data collection in three different areas, the primary data obtained were in different units ranging from job estimates to contract expenditures. To streamline the inputs for the contribution analysis, we converted all 4FRI contributions to employment estimates. 'Other' restoration activity expenditures were converted to IMPLAN full- and part-time jobs by dividing total contract expenditures in each sector by the average output per job for each sector presented in the IMPLAN study area data (i.e., the five-county regional economic impact zone). Survey data on thinning and wood utilization, along with USFS preparation and prescribed fire, were collected as FTE employment. Thus, we also converted these FTE data into IMPLAN full- and part-time jobs by applying IMPLAN conversion ratios specific to each industrial sector.[4]

To estimate regional contributions of 4FRI activities, total employment from the three regional final demand components were entered into IMPLAN's impact analysis under the appropriate industry sector. Table 3 illustrates final demand change by sector.

Results

Restoration activities associated with 4FRI are dispersed across four Arizona national forests and five Arizona counties. With the dramatic decrease in logging and timber production in the 1990s, Arizona wood product industries experienced sharp declines in economic importance that was particularly pronounced in rural forested communities. However, wood utilization from 4FRI projects is now helping to generate jobs and income within the region.

Wood Utilization

In FY 2017, approximately 12,450 acres of ponderosa pine were mechanically thinned across northern Arizona.[5] Survey results indicate that operators removed almost 400,000 green tons, or 115,000 ccf, of sawlogs and biomass from these treated acres.

Figures 2 and 3 illustrate wood removal rates as documented from our survey of primary 4FRI contractors. On a per acre basis, approximately 32 green tons were removed, or a little more than 9 ccf per acre. About 20 tons were in the form of sawlogs and about 12 tons were biomass.

Typical mechanical thinning projects start with thinning and sorting of sawlogs and slash. Most operators grind and chip slash at the restoration site and then transport material to processing sites. Trucking of material is a large cost for wood utilizers, particularly when dealing with low-quality wood and traveling long distances to mills. Finding market outlets for small diameter ponderosa pine can be difficult. On the east side of 4FRI (White Mountain region), wood processing from restoration projects is largely conducted within the White Mountains due to the existence of a small but vertically integrated and clustered wood products industry. The west side of 4FRI activities (greater Flagstaff region) has much less milling and wood products infrastructure, which in turn limits marketing and utilization options. Many of the sawlogs from the 4FRI west side leave the region with limited or no processing. Figure 4 illustrates the primary wood products coming from 4FRI thinning, showing both regional and out-of-region pathways for restoration woody byproducts.

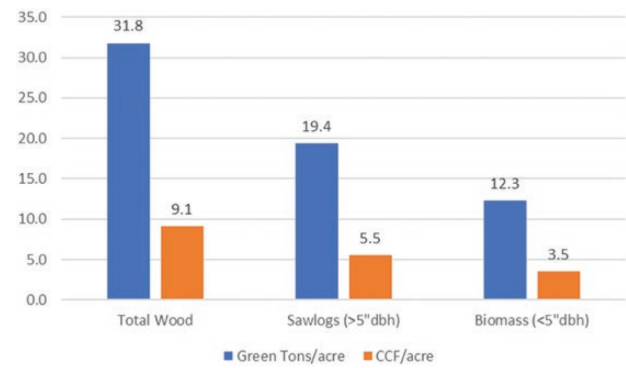

Figure 3. Wood removed per acre for 4FRI FY 2017.

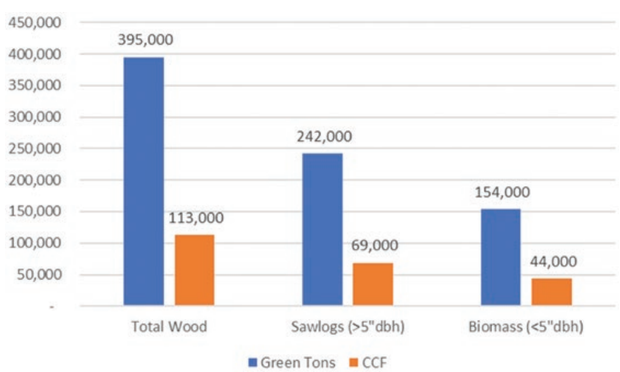

Figure 2. Total wood removed for 4FRI acres FY 2017.

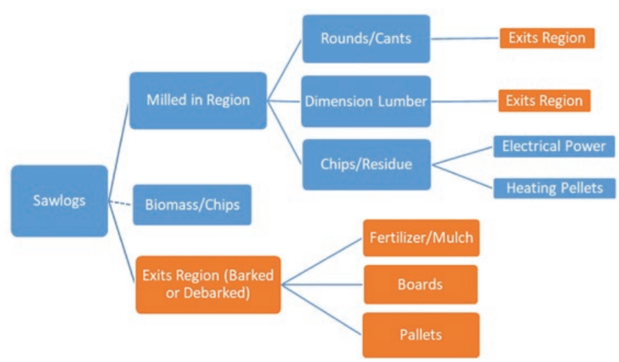

Figure 4. Typical flow of 4FRI wood utilization (blue boxes indicate regional economic contributions).

In FY 2017, thinning for 4FRI led to the regional production of 18 million board feet (mmbf) of rounds or cants and 10 mmbf of dimension lumber. Biomass from 4FRI projects collectively provided over 100,000 tons of chips and residue for electricity generation, approximately 18,000 tons of material for heating pellets, and some 20,000 tons for conversion into fertilizer and landscaping mulch.[6]

Regional Economic Contributions

Including indirect and induced effects, 4FRI activities provided approximately 960 full- and part-time jobs in FY 2017. For every direct job generated, another 0.8 jobs were supported, with a regional employment multiplier of 1.79. About $100 million of direct regional output was spurred by all 4FRI activities in FY 2017. This regional output in turn generated another $46 million in output when including total effects for a regional output multiplier of 1.46. In total, 4FRI activities contributed $50 million in annual regional labor income. Table 4 illustrates total effects and multiplier effects for employment, labor income, total value added, and output.

In terms of regional employment, the federal USFS land managers that plan and implement restoration activities account for over 250 FTE annual jobs to prepare the largest forest landscape restoration program in the US (see Table 5). In terms of nonfederal job creation, 4FRI activities are most impactful on the logging and wood utilization sectors. When including indirect and induced effects, commercial logging generates over 150 full- and part-time jobs and sawmills spur almost one hundred full- and part-time jobs. Support activities for 4FRI forest restoration, trucking of woody byproducts, and the biomass power plant contribute another one hundred full- and part-time jobs to the regional economy.

Discussion

Logging and wood utilization provide numerous good-paying jobs throughout northern Arizona. Combined with the important year-round USFS jobs and other restoration contractors, the 4FRI has a large economic footprint to accompany its ecological footprint. In FY 2017, 4FRI restoration activities led to 536 direct full- and part-time jobs and approximately $100 million in direct regional output (958 full- and part-time jobs and $144 million in regional output when including multiplier effects). Over 140 separate industry sectors were affected by 4FRI activities in this fiscal year.

The FY 2017 CFLRP annual report for 4FRI has TREAT estimates of regional economic contributions. The overall project estimates include activity funded directly from CFLRP budget line items and matching funds. The FY 2017 4FRI annual report includes 13,108 acres of mechanical harvest. When including other hand-thinning acres, 327 full- and part-time jobs were reported for the timber harvesting component and 185 full- and part-time jobs for the mill processing component. 'Other' forest and watershed restoration were reported to contribute about 50 full- and part-time annual jobs, and another 331 full- and part-time jobs were contributed for implementation and monitoring of 4FRI activities by USFS staff. In total, almost nine hundred direct full- and part-time jobs were estimated in TREAT.

Regional Contribution Considerations for Forest Restoration and 4FRI

When utilizing primary employment data collected from 4FRI wood contractors, our resulting economic contributions are quite a bit less than the 4FRI annual report estimates analyzed in the TREAT model. The differences are accounted for in the different methods used in our contribution analysis. Surveying

Table 4. Total 4FRI Regional Economic Contributions for FY 2017 ($2017)

Impact Type	Employment[a]	Labor Income	Total Value Added[b]	Output
Direct Effect	536	$35,886,339	$55,791,608	$98,460,186
Indirect Effect	238	$8,130,931	$11,056,039	$22,794,086
Induced Effect	184	$6,356,022	$12,473,210	$22,839,887
Total Effect	**958**	**$50,373,292**	**$79,320,857**	**$144,094,159**
Multiplier Effect	**1.79**	**1.40**	**1.42**	**1.46**

Source: IMPLAN3, Northern Arizona Region 2016, Type social accounting matrix (SAM) Multipliers
[a]Includes full- and part-time jobs.
[b]Value added is the difference between an industry's total output and its intermediate inputs. It includes employee compensation, taxes, and surplus.

Table 5. Top Ten Regional Employment for 4FRI FY 2017 ($2017)

Description	Total Employment[a]	Total Labor Income	Total Value Added	Total Output
Employment and payroll of federal government	265.2	$24,321,200	$31,501,009	$31,501,007
Commercial logging	156.2	$6,825,055	$7,340,017	$13,547,127
Sawmills	92.1	$2,483,640	$2,684,270	$21,812,472
Support activities for agriculture and forestry	38.9	$571,022	$634,655	$1,112,463
Truck transportation	31.7	$2,207,149	$2,758,931	$5,660,667
Electric power generation - Biomass	25.4	$2,611,361	$14,208,380	$30,201,791
All other crop farming	22.6	$8,564	$16,200	$44,302
Full-service restaurants	18.3	$462,714	$514,828	$947,564
Wholesale trade	15.7	$538,430	$1,276,722	$2,546,097
Limited-service restaurants	14.6	$299,683	$693,013	$1,224,368

Source: IMPLAN3, Northern Arizona Region 2016, Type SAM Multipliers, Total effects include indirect and induced
[a]Includes full- and part-time jobs.

local operators, as done in this study, provides higher resolution data on wood harvested, employment, and leakage associated with 4FRI thinning. The TREAT model incorporates regional response coefficients to determine direct logging and sawmill employment per unit of harvested wood. These response coefficients originate from regional, multistate surveys of logging and wood-processing companies (Sorenson et al. 2015) that are largely comprised of traditional timber production estimates—not only small-diameter wood utilization estimates that come from restoration treatments.

A comparison of employment to volume harvested ratios for our case study and for the employment estimates used in TREAT from Sorenson et al. (2015) illustrates differences between directly surveying operators and using multistate regional averages. In Sorenson et al. (2015), employment estimates for timber harvesting and processing are calculated on a million-cubic-feet (MMCF) basis for eleven separate regions across the country. Employment estimates from the Four Corners region, comprised of Arizona, New Mexico, Colorado, and Utah, are used to model economic contributions for 4FRI in TREAT. Sorenson et al. (2015) estimate that the Four Corners region sustains approximately thirty-two logging jobs per 1 MMCF of timber harvested, the highest of any region in the US. Our survey of operators found that every 1 MMCF of logs harvested for 4FRI in FY 2017 resulted in only six logging jobs, which is much less than the TREAT estimates. Sorenson et al. (2015) suggest that the Four Corners logging-jobs-to-harvest ratio is high due to a greater use of stewardship contracting in the region, which includes "multiple objectives and activities in addition to logging". The large logging-job estimates in TREAT is the single biggest difference between our 4FRI contribution analysis results and the TREAT model estimates.

We suspect our logging-jobs-to-volume-harvested ratio is lower than Sorenson et al.'s (2015) estimates due mostly to the mechanized nature of 4FRI restoration treatments. The Sorenson et al. (2015) direct-response coefficients for logging in the Four Corners region include both traditional selective harvests and various restoration treatments, leading to higher estimates of logging jobs per unit of harvest. With gentler terrain than most Western forests and uniform second growth ponderosa pine that has generally grown back as a plantation-like monoculture, 4FRI treatments are primarily conducted via mechanized harvesting. Additionally, dense stands of small-diameter trees and biomass removal requirements result in high levels of harvested volume per acre in northern Arizona. Greater volume harvested per acre, along with greater mechanization, decrease the jobs-to-volume-harvested coefficients as compared to other timber production where selective harvest and greater care (and more human labor) will be taken for harvesting larger diameter and more valuable logs.

Other measures of the relationship between employment and wood utilization for our 4FRI analysis, such as jobs per unit of wood utilized for softwood sawmills, sawmill residue, and electric power generation are fairly similar to reported ratios for the Four Corners region provided by Sorenson et al. (2015), once similar amounts of in-region wood processing are compared.[7] However, other components of restoration thinning and wood utilization, such as forestry support services and log hauling/trucking, are not included in the Sorenson et al. (2015) study and are only indirectly included in TREAT analysis. By surveying contractors, we found that over 10 percent of regional thinning and wood utilization jobs for 4FRI were associated with truck transportation of logs. These important employment estimates should be included as direct-response coefficients in future TREAT analyses and should be emphasized for regions that have limited processing capacity and long haul distances to mills.

An important concept for modeling regional economic contributions of forest restoration is evaluating the amount of leakage of expenditures from the region, or alternatively, the local capture rate of restoration expenditures, and using this information to strategize how to enhance regional contributions. In rural areas, such as northern Arizona, a portion of restoration expenditures will immediately leak out of the region because of a lack of manufacturing of equipment, technical services, and fuel production in the region. That is, rural counties cannot be expected to produce all the equipment, services, fuel, etc., necessary to complete 4FRI activities. Likewise, when dealing with large-scale land treatments on public lands, a good portion of federal funds will necessarily be expended outside of the region. However, increasing regional wood processing options can be a focal point for decreasing leakage of restoration contributions. Currently, the majority of sawlogs and biomass on the west side of 4FRI is processed outside of the regional economic contribution zone because of a lack of wood utilization infrastructure. Overall, approximately 65 percent of sawlogs from FY 2017 4FRI treatments were processed within the five-county region, leading to a 35 percent leakage rate for primary wood utilization. Increasing primary wood processing opportunities adjacent to 4FRI communities would decrease leakage of economic contributions and add value to small-diameter ponderosa pine slated for thinning.

In terms of enhancing regional economic contributions via greater wood utilization, we have used our collected data to impart a few observations. The most important component of wood utilization that is currently missing on the west side of 4FRI is a processing facility within a reasonable haul distance that can use small trees, chips, slash, and residue. Based on our collected data, logging operators and mills on the east side of the 4FRI footprint have consistently processed much more wood per acre within the region than their counterparts on the west side, leading to greater capture rates of regional economic contributions. This is because the White Mountain Stewardship Project assisted in reestablishing wood-processing infrastructure on the east side of the state. Conversely, the absence of an earlier large-scale stewardship project near Flagstaff deterred infrastructure development in the central and west sides of the state. In particular, the Apache-Sitgreaves National Forest region on the east side contains a greater number of family-owned businesses (Mottek Lucas et al. 2017), intermittent tribal timber processing that allows for market outlets for large-diameter trees, and most importantly for 4FRI, the region has a 27 megawatt biomass power plant.

Although the importance of a keystone bioenergy plant for rural economic wood utilization is recognized, it cannot be overstated how vital it is to develop a profitable vertically integrated wood-industry cluster (Mottek Lucas et al. 2017). Consequently, as rural communities with high forest-restoration needs and low levels of wood utilization infrastructure begin large-scale restoration programs, prioritizing the development of a collaboratively funded processing facility, such as a biomass plant, is key to ensuring the development and success of a wood-products-industry cluster. High-production, small-diameter sawmills are also critical to success, but mills and other processing options are likely to follow a large biomass processing facility. Although any large processor of small-diameter pine would be a welcome addition, a biomass power plant has advantages of uploading product directly to existing power grids, and woody biomass electricity generation in northern Arizona has been shown to result in avoided environmental and health damage costs when compared to current coal use (Huang and Bagdon 2018). Additionally, haul distances are not only a concern for getting logs to the mill but are also important in the marketing of final wood products. Northern Arizona rural towns are generally far from large markets, limiting the economic feasibility (and possibility) of large facilities, like those found in the eastern US that make composite products, such as oriented strand board and plywood.

Conclusion

As indicated in the Discussion section, there are a few primary considerations for modeling forest restoration economic contributions. Foremost among these considerations is directly surveying primary contractors, including an appropriate investigation of the regional context, including methodological transparency as related to bridging restoration expenditures to I-O industry sectors, and consideration of methods to enhance economic contributions. Using TREAT models to assess the economic contributions of CFLR projects provides an important overview of restoration economics that is streamlined to allow for comparisons among projects. However, dedicating resources to acquire primary local data can better capture the unique regional contexts of each project and allow for higher resolution when examining regional wood infrastructure, products, and local capture rates.

A detailed economic monitoring approach that includes surveying primary contractors is unlikely to be completed annually, such as TREAT applications, but should be prioritized intermittently for CFLR and other forest restoration projects. Accordingly, administering periodic contractor surveys is recommended as a valuable tool that can be used to inform and adjust TREAT direct-response coefficients. As noted by Shrestha and Mehmood (2018), getting a census of all primary contractors for a forest-restoration project can be difficult as private contractors are often reluctant to provide information. The USFS may want to consider improving the exchange of information with industry to improve the feasibility of restoration contracts and the accuracy of required monitoring. Ultimately, surveying primary contractors can allow for the tracking of woody byproducts from stump to store, or stump to power grid, and presents a more realistic picture of direct effects in contribution analysis.

In terms of monitoring 4FRI regional economic contributions, our review of past trends and our results show that overall restoration accomplishments have seen limited growth since the inception of the 4FRI and remain well below original project objectives and forecasts. 4FRI foundational documents called for thinning up to one million acres over 20 years, ramping up to 50,000 acres per year. If treated acres were closer to original projections, regional economic contributions would be much greater. With both the social license and agency support generally in place, wood supply is no longer an issue. The clear barrier to ramping up 4FRI mechanical thinning accomplishments is the expectation that processing and utilizing small-diameter ponderosa pine for wood products can fully pay for restoration (Hjerpe et al. 2009). This simply is not the case and illustrates a lack of understanding and monetizing the numerous other benefits and services afforded by forest restoration.

Supplementary Materials

Supplementary data are available at *Journal of Forestry* online. Supplemental Image 1. Small diameter ponderosa pine thinning on Observatory Mesa, southwest of Flagstaff, AZ.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Endnotes

1. Available at: https://www.fs.usda.gov/detailfull/4fri/home/?cid=stelprdb5346432
2. For more information see: http://flagstaffwatershedprotection.org/.
3. Specific bridging of other restoration expenditures to changes in final demand for IMPLAN sectors is not clearly shown in the TREAT User's Manual nor in the University of Oregon's EWP studies. Some bridging is shown in Nielsen-Pincus and Moseley (2010), but it is unclear how much restoration expenditures (i.e., changes in final demand) were specifically allocated to which IMPLAN sectors.
4. IMPLAN sector conversions from full- and part-time jobs to FTE jobs, or vice versa, are available here: https://implanhelp.zendesk.com/hc/en-us/articles/115002997573-536-Sector-Bridges-and-Conversions.
5. This total includes 1,460 acres of non-USFS lands that were part of the Flagstaff Watershed Protection Project.
6. Most of the fertilizer/mulch is processed outside the region and is not included in our regional contribution analysis.
7. Based on input from local USFS staff, the 2017 4FRI TREAT analysis assumed that 96% of volume harvested was processed inside the regional economic impact zone. Our survey of primary contractors reveals that only about 65% of sawlogs was processed inside the regional economic impact zone.

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