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Keeping Eyes on the Prize: Laying the Groundwork for Sustainable Biomass Utilization in the Southwest

Outside of the city of Pinetop-Lakeside, Arizona, there is an area of the Apache-Sitgreaves National Forest where large, widely spaced ponderosa pine trees stand like sentinels. Between these solitary trees are randomly spaced clumps of younger ponderosa pine (*Pinus ponderosa*). In the understory, a mixture of grass, shrubs, and gambel oak (*Quercus gambelii*). "Park-like" could describe this setting.

This is a pine forest that resembles those of pre-European settlements in the Southwest. Its defining characteristic is most noticeable when wildfire moves through: flames travel along the ground, burning the grass and consuming the smaller-diameter trees and shrubs. Without large amounts of downed woody material and ladder fuels to increase the wildfire's intensity, the fire can't penetrate the thick, fire-adapted bark of ponderosa pine to kill it. And the

Dense, untreated forest showing the understory and ladder fuels that contribute to high wildfire risk.

Thinned forest following treatment showing large diameter trees and park like understory, which is more resilient to wildfire.

Woody biomass from thinning being chipped and collected on San Juan National Forest in Colorado.

Woody biomass ready to be used as fuel in a biopower plant in Arizona.

In the Southwest, a thinning treatment to restore forest health and resiliency involves more than just thinning the forest to reduce the number of trees on the landscape (1, 2). There must also be an available contractor workforce (3) and options for disposing of the woody biomass that do not result in negative environmental or public health effects (4). Expanding markets for woody biomass, such as for bioenergy and bioproducts, would spur more investments in expanding the contractor workforce and improving environmental and public health outcomes. USDA Forest Service photos by Nate Anderson and Beth Dodson.

lack of dense trees extending into the crowns of the larger trees means the flames are unable to reach the canopy.

This section of the forest is fire-adapted, unlike its counterpart 20 miles away where the forest is densely stocked, without canopy gaps between the pines. Its understory is thick with gambel oak and ponderosa pine saplings instead of grass. When a wildfire does come through, this understory of saplings allows the flames to climb into the crowns and travel through the treetops. With this plentiful woody fuel, the wildfire's intensity can overwhelm the canopy and bark's protection. When the wildfire is finally extinguished, the forest is filled with downed or standing dead and heavily damaged pines.

In the Southwest, there are millions of acres of ponderosa pine forest, just like the second scene, that lack wildfire resilience after decades of livestock grazing, removal of wildfire from the landscape, and removal of large, fire-resistant trees. Many of these forests are the watersheds for downstream communities or are within the wildland-urban interface. This is why the USDA Forest Service is prioritizing the restoration of these forests. In Arizona alone, the USDA Forest Service's Four Forest Restoration Initiative spans 2.4 million acres of national forests, including the Apache-Sitgreaves.

SUMMARY

In the Southwest United States, many ponderosa pine forests no longer resemble the pre-European settlement forests that were adapted to frequent, low-severity wildfires. The cumulative effects of fire suppression, livestock grazing, high-grading, and insect outbreaks have created conditions that frequently result in high-severity wildfires.

Thinning treatments are one method to restore forest health and resiliency. However, these treatments result in large volumes of unmerchantable logs, limbs, and tops as a byproduct. This woody biomass has little to no value in the current forest products market and is often piled and burned for disposal because leaving it on the ground can increase the wildfire hazard. Pile burning can negatively impact air quality in the surrounding communities and can also result in burn scars and other negative environmental effects. Expanding markets for woody biomass, such as for bioenergy and bioproducts, would spur more investments in restoration treatments that mitigate wildfire risks and improve forest health.

Studying the feasibility of developing a biomass market in the region was made possible by grant funding from the USDA-NIFA's Biomass Research and Development Initiative and involved researchers with the USDA Forest Service Rocky Mountain Research Station (RMRS), the University of Montana, Virginia Tech, and Northern Arizona University. They analyzed the economics of forest operations, evaluated post-treatment ecological forest response, and quantified the public health benefits of shifting to forest-based bioenergy from fossil fuels.

The research team found that improving the efficiencies of forest operations could lower the costs of restoration treatments, and negative ecological impacts could be mitigated by matching the correct equipment to the site conditions. The effects of restoration treatments were observable on the landscape 5 years post-treatment, which further supports investment in these treatments. There were also net economic and public health benefits recognized by using biomass for bioenergy. This new research suggests that restoration treatments are a worthwhile investment to reduce wildfire hazards, but there are tradeoffs to consider when developing forest-based bioenergy.

This forest restoration work involves implementing forest treatments to remove smaller-diameter trees and both reduce the number of trees on the landscape and increase the spacing between remaining trees. This is typically accomplished using prescribed fire, mechanical thinning, or both, with the help of hand crews and heavy equipment. This is where forest operations research comes in. "Though the objectives are different in these fuel treatments compared to a traditional timber harvest or commercial thinning, we can use a lot of the same tools and engineering approaches to accomplish the objectives efficiently," explains Nate Anderson, a research forester with RMRS.

Prescribed burning is a critical tool in the forest restoration toolbox, but it isn't an option in some areas, because "in many places it's just not safe to allow a fire to burn or conduct prescribed burning under current forest conditions," explains Elizabeth "Beth" Dodson, a professor of forest operations at the University of Montana. "In a lot of places, in order to allow fire to serve its natural role, we have to conduct a mechanical pretreatment first.”

However, there are two significant challenges to carrying out these mechanical pretreatments using logging equipment traditionally used for timber harvesting. First, these treatments can be costly. When timber production is the primary objective, thinning costs are typically offset, either partially or completely, by harvesting merchantable trees to sell to local sawmills or forest products companies. In the Pacific Northwest and parts of the Rocky Mountains, there is a robust forestry industry to purchase merchantable timber and produce high-value forest products, such as lumber. In the Southwest, these treatments generally do not produce a mix of products that generate enough revenue to fully cover the cost of treatments, and in many places across the West, the forestry industry is struggling.

“Unfortunately, the whole forest industry in the Southwest is precarious,” Dodson says. “Most of the trees growing in the study region are ponderosa pine, which is a low-value wood as a lumber species.”

Second, thinning treatments generate large volumes of woody biomass—non-merchantable, smaller-diameter trees, limbs, and treetops—as a byproduct. This material cannot remain on site because it increases the wildfire risk and is very slow to decompose in dry landscapes. In this situation, forest managers will typically burn the slash for disposal; however, this produces smoke that negatively affects air quality for the surrounding communities and can produce long-term burn scars in the soil that can be colonized by invasive species. Pile burning also produces a more potent mix of greenhouse gases than biomass boilers fitted with modern emissions controls. Furthermore, open burning is often limited to certain times of year and can be very tightly regulated in sensitive airsheds.

One option for removing the woody biomass from the forest is selling it for use as a renewable fuel that displaces the burning of coal or natural gas for heat, electricity, or both (called “combined heat and power” or CHP). This has the added benefit of generating revenues that offset treatment costs. In Snowflake, Arizona, biomass company NovoBioPower purchases woody biomass generated from thinning projects on national forests and converts it into electricity that is purchased by two utility companies: Arizona Public Services and the Salt River Project.

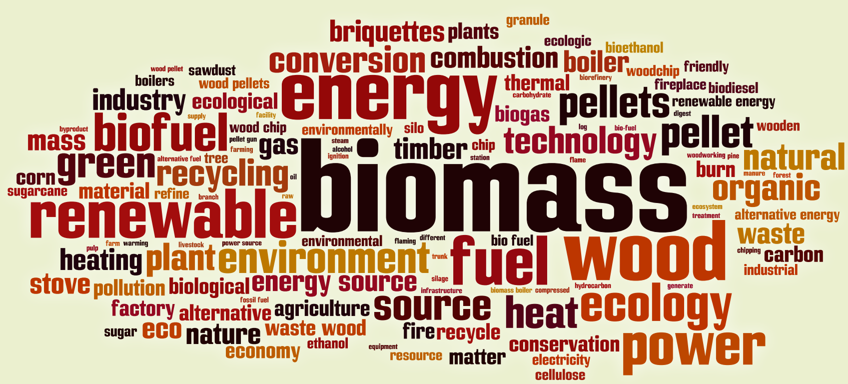
Given the ecological and public health benefits gained from conducting thinning treatments and its ample stocks of woody biomass for the foreseeable future, the Southwest region could

What is the Biomass Research and Development Initiative?

The Biomass Research and Development Initiative, or BRDI, is a collaboration between the U.S. Department of Energy’s Office of Biomass Programs and the U.S. Department of Agriculture’s National Institute of Food and Agriculture. This collaboration provides grant funding for projects that address research, development, and demonstration of biofuels and bio-based products and methods, practices, and technologies for their production.

The USDA Forest Service is a partner in BRDI because bio-based products and biofuels can be produced using woody biomass from National Forest System lands. Woody biomass from National Forests and National Grasslands is a byproduct of land management, including timber harvest, thinning, and restoration. It is harvested in accordance with applicable laws and would not otherwise be used for higher-value products.

To learn more visit the BRDI website.



be well-positioned to develop a forest-based bioenergy industry. That is what Dodson and a team of researchers with RMRS, the University of Montana, Northern Arizona University (NAU), and Virginia Tech observed. But how feasible is it?

With funding provided by the Biomass Research and Development Initiative, the team studied the sustainability and feasibility of expanding the use of woody biomass in northern Arizona, New Mexico, and southern Colorado for electricity and other uses. What was unique to their approach was assessing the public health impacts of forest-based bioenergy; previous bioenergy studies primarily focused on the financial feasibility of establishing biomass power plants in the region.

“Science and research are often so siloed,” Anderson explains. “These large integrated projects, which bring teams with different technical expertise—economics, forest operations, and social science—aren’t often funded, so it’s a rare opportunity and a pleasure to work on a project like this.”

In all, the research team included five principal investigators and their graduate students. Dodson and Anderson led the analysis of the forest operations carrying out the thinning treatments, including their productivity and costs. The ecological effects of thinning treatments were studied by Mike Battaglia, a research forester with RMRS, and John Goodburn, an associate professor at the University of Montana, together with their graduate students. Ching-Hsun Huang, formerly with NAU and now a professor at Virginia Tech, led the team that analyzed the public health impacts of a forest-based, bioenergy industry.

Forest operations research often involves intensive field study of logging equipment to collect time study data that can be used to quantify the productivity and cost of different machines and system configurations under various conditions. USDA Forest Service photo by Nate Anderson.

Within the study area, the team worked with land managers to select research sites that would meet their research objectives. These sites were on the Apache-Sitgreaves and Coconino National Forests (Arizona), the Santa Fe and Cibola National Forests (New Mexico), and the Bosque del Oso state wildlife area (Colorado). They had success finding local contractors in each state who had experience with thinning treatments and were willing to participate in a research study.

“The one thing that was really awesome about this project was the interaction we had with the National Forest System managers helping us find the sites and providing us access, and also the loggers and the operators,” says Battaglia, “That was a nice added bonus of the project.”

On each site, the contractors employed different types of forest operations to achieve thinning objectives: two sites conducted a whole-tree harvest with the woody biomass processed and hauled away for bioenergy; two sites conducted a whole-tree harvest with the woody biomass burned in piles; and one site used in-woods processing with lop-and-scatter, where the woody biomass was distributed throughout the forest. These treatment types allowed the team to compare the tradeoffs of each management scenario and harvest system.

Comparison of treatment types

Forest treatment	Biomass treatment	Ecological factors	Public health factors
No operations	High stocks of standing biomass. No log or biomass removals. No bioenergy production.	High risk of severe wildfire, maximum biomass retention, baseline site ecology.	Potential for high wildfire emissions. No emissions from pile burning. Power plant stack emissions from fossil fuel.
Whole-tree harvesting with biomass harvest	Logs and biomass are harvested. Biomass is used as fuel to produce electricity.	Reduced risk of severe wildfire, less biomass left on site, potential impacts to site ecology.	Lower wildfire emissions. Less emissions from pile burning. Power plant emissions from biomass.
Whole-tree harvesting with pile burning	Logs are harvested. Biomass is piled and burned for disposal.	Reduced risk of severe wildfire, less biomass left on site, potential impacts on site ecology, potential impacts from pile burning.	Lower wildfire emissions. More emissions from pile burning. Power plant emissions from fossil fuel.
In-woods processing with lop-and-scatter	Logs are harvested. Biomass is retained and distributed on site, no biomass harvest. Can be followed by a broadcast burn.	Reduced risk of severe wildfire, more biomass left on site, potential impacts on site ecology, potential impacts from broadcast burning.	Lower wildfire emissions. More emissions from broadcast burning and decomposition. Power plant emissions from fossil fuel.

What follows is an overview of the team's key findings that can inform the development of a forest-based biomass industry in the Southwest.

Forest Operations—It's Systematic

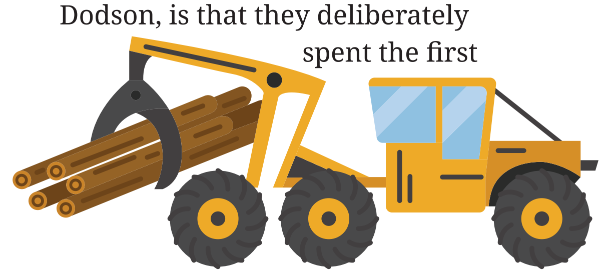
The cost of forest operations is a significant portion of the total cost of thinning. Although there are common operational models readily available for land managers to estimate costs, many of these models are based on the assumption of harvesting green timber that has reached economic maturity or is harvested during a commercial thinning of an even-aged stand. Many were also developed in regions with a robust forestry industry, such as the Pacific Northwest or the Southeast, using the latest high productivity harvesting equipment.

Neither of these conditions are applicable to fuel treatments and restoration in the Southwest. "From an operational standpoint, these thinning prescriptions are difficult to implement and are more costly, especially if we're looking at steep slopes and complex residual stand conditions, rather than evenly spaced trees, across the landscape," explains Anderson. "And the current margins on this work do not support investment in the most advanced forest machines, which tend to be expensive but are also very productive," he adds.

To provide land managers a cost-estimate model applicable to their management needs and contractor capacity, Anderson and Dodson, together with graduate students Lucas Townsend and Mary-Ellen Reyna, collected productivity data on different harvesting systems being used at the study sites. Although there are other costs associated with thinning treatments, such as project planning and road maintenence, harvesting is frequently the highest cost. When biomass and logs are harvested, trucking can also add significantly to the cost of production, especially when distances are long, over low-standard forest roads to facilities.

Over a 2-year period, with stopwatches in hand, the team conducted time and motion studies of the operators as they carried out the work. Data collection included thousands of precise measurements of different elements of machine movements, such as how long it took the skidder to bring a felled tree to the landing or how long it took the processor to buck and stack the log.

One of the unique parts of the team's approach, explained Dodson, is that they deliberately spent the first



A skidder bringing cut trees to the landing where they will be processed into biomass and sawlogs.

A processor and grapple loader working together to process trees brought to the landing by a skidder.

Even if the primary objective of these types of treatments is not to generate revenue from the sale of timber and biomass, it is possible to reduce the cost of forest operations by tailoring harvest systems to specific fuel treatments and forest restoration needs. Working with the contractors when laying out the project area can also increase the efficiency of the harvest operation. USDA Forest Service photos by Nate Anderson.

field season studying “business as usual.” The team then provided the contractors with suggestions for how to improve their operations and be more efficient while still meeting restoration objectives and minimizing site damage. During the second field season, the team observed the improved operations. “In most cases, the contractors had already made changes to their operations based on our conversations in the field during the first year of observations,” Dodson says.

With this data, the team developed a productivity model upon which “What-if” scenarios could be run by land managers. A manager could ask, “What if we increased the allowable cut tree size by 2 inches in diameter or decrease it by 2 inches in diameter? What does that mean in terms of how long it’s going to take to bring it to the landing and how much is it going to cost the operator?” Dodson says.

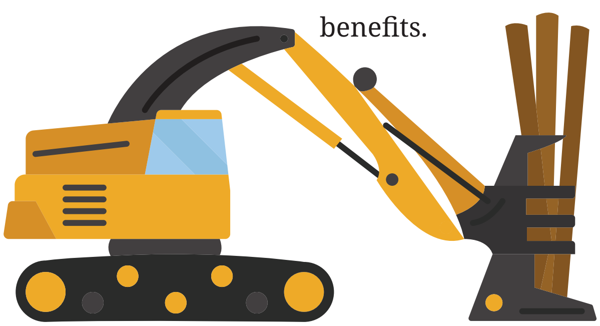
One significant takeaway from their observations is that various systems of machines can be optimized to make an operation more efficient. For example, in the first year a contractor had a harvester cutting and processing the trees and a skidder then brought the logs to the landing. In the second year, he purchased a feller-buncher to fell the trees, and then the skidder brought the whole tree to the landing for processing. “And that became a much more efficient system overall in part because it was better balanced [in terms of workflow],” Dodson says.

Anderson adds, “Relatively minor changes in the way operators choose equipment and configure it on site, or deploy operators on the landscape, can actually make the difference between being profitable or unprofitable.” However, equipment and systems that make harvesting more efficient can be expensive, and uncertainty in both supply and demand make it difficult for contractors to finance new equipment; brand-new feller-bunchers can run $400,000–$600,000 and used feller-bunchers can still cost six figures.

What land managers can do to improve efficiency and reduce treatment costs is pair equipment to the stand and site conditions, advises Dodson. What might this look like? "For example, if I know everyone who will bid on the sale has a rubber tire feller-buncher, I'm going to make sure I concentrate my leave areas, for example, on the slopes [because these tires don't work well on slopes]," she says.

Both Anderson and Dodson make the important point that the primary objective of these types of treatments is not to generate revenue from the sale of timber and biomass. "We have to set up these sales and these stewardship agreements to make sure that everybody's keeping their eye on the prize," Anderson says, "which is getting these treatments done where we can treat larger areas at lower costs to reduce the wildfire hazard at meaningful scales."

"Without looking at the tradeoffs, these treatments can be really expensive," adds Dodson. "The benefits that you're getting from a public health standpoint can be significant if, for example, you utilize the material to offset the use of coal to generate electricity." This is in addition to other nonmarket benefits.



KEY FINDINGS

- Although restoration treatments may not pay for themselves financially, there are nonmonetary and related nonmarket benefits gained by mitigating wildfire risk with forest treatments.
- After a thinning project is awarded, working with the contractor to determine treatment design can improve efficiencies and lower costs of forest operations, including biomass harvest.
- This is the only study in the southwestern region linking the benefits of forest thinning treatments and utilization of woody biomass as renewable energy to public health implications.
- The effects of forest management and bioenergy extend beyond the borders of national forests and even beyond the state in which the forest is located. For example, displacing natural gas and coal with woody biomass resulted in improved air quality in neighboring states.
- Coal displacement health benefits ranged from $216 million to $594 million per year, with an average benefit ranging from $2.75 to $5.40 per MWh under the modeled bioenergy scenarios.
- Natural gas displacement health benefits ranged from $13 million to $46 million per year, with an average benefit ranging between $0.31 to $0.76 per MWh under the modeled bioenergy scenarios.

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–Nate Anderson,
USDA Forest Service
Research Forester

"We are also protecting values tied to water supply, recreation, wildlife habitat, biodiversity and forest carbon—even if those aren't included in the price of biomass," Anderson explains.

Modern forest operations research can tailor harvest systems to specific fuel treatment and forest restoration needs. This could increase productivity and drive down the cost of not just logs and biomass, but also the cost of protecting ecosystem services and other values at risk.

Ecological Impacts—A Sweet Spot for Biomass Removal

Prior to the contractors implementing the thinning treatments, a team consisting of Battaglia, Goodburn, and Graham Worley-Hood, a graduate student in Goodburn's lab, visited the sites to collect ecological data to use in comparing pre- and post-treatment site conditions.

One of the reasons that Battaglia joined the study was its woody biomass focus. "It always bothered me that we would have these big piles of slash that we would just burn in the forest," he says. "Maybe this project could provide some insight into different ways that we might be able to get that material to be used for bioenergy."

An ongoing question around thinning treatments is how long the treatments remain effective in reducing wildfire risk. An additional concern is increased soil compaction because of the equipment making more trips to retrieve the biomass material compared to logs only; this soil compaction could affect revegetation and increase erosion due to water runoff.

In 2017, on each plot, the team collected measurements of standing trees, downed wood, understory vegetation, and soil density. Although the study sites were dominated by ponderosa pine, the understory differed along the landscape gradient. "There were sites where the understory was grassy herbaceous, which switched into a needle layer and less ground cover," says Battaglia. "Then there were areas that had the gambel oak, which became more contiguous than it would have been historically if there was fire."

The following year they returned and collected post-treatment data. Visually, it looked as though they were achieving the management objectives, Battaglia observed. "Going to the same site after it had

The thinning treatments met the management objectives of creating multiple-age forest that were clumpy and had openings. Results from the Forest Vegetation Simulator and its Fire and Fuels Extension model found that there was a complete elimination of active crown fire potential because of these treatments. On the retrospective sites, the team found a reduction in active crown fire lasted at least 5 to 10 years after treatment; however, there is evidence showing slightly elevated levels of passive crown fire potential at these retrospective sites. Photos courtesy of Graham Worley-Hood, Alaska Fire Service.

been cut, to me it appeared they were doing a really good job at trying to meet the intent of those prescriptions of opening up the canopy and creating multiple-age forests that were clumpy and had openings," he says, adding, "you could see the forest through the trees."

This data was input into the Forest Vegetation Simulator (FVS) and its Fire and Fuels Extension to model how the thinning treatments affected forest structure, fuels, and potential fire behavior. A reason for modeling was to simulate stand development and changes in fire behavior over time since this study had a limited timeframe.

The model results were promising, according to Worley-Hood. "At all of our harvest units there was a complete elimination of active crown fire potential," he says. "The fire no longer was projected to move from tree to tree based on the weather conditions and wind speed we used in our simulations." Their scenarios included a general fire season, a prescribed fire, and an extreme scenario based on the weather conditions seen in the larger fire incidents in the early 2000s.

In regard to fire behavior, the model showed the mortality would be in the smaller-diameter trees, which is an explicit objective of the treatments. "We're not going to stop fire, it's inevitable, but we're trying to alter the fire behavior," Battaglia says.

Another benefit of retaining larger trees when the smaller-diameter trees burn is the larger trees will serve as a seed source to revegetate the stand. However, the model did show torching potential at some of the plots. Worley-Hood suggests that could be attributed to more saplings being retained on the landscape at some sites.

The response of surface fuels following treatment was mixed. There was an increase in the small-diameter surface fuels (i.e., less than a 3-inch diameter), also known as fine woody debris. Coarse woody debris (i.e., greater than a 3-inch diameter) did not increase with treatment, except at lop-and-scatter sites. And following treatment, the lop-and-scatter sites were the only sites that met Region 3's desired level of coarse woody debris within a forest. Although it might seem counterintuitive to want coarse woody debris on the ground because it adds to surface fuel, it provides a habitat for organisms that are dependent on dead wood and releases nutrients into the soil as it decays, among other ecological benefits. In fact, this is one of the most important aspects of sustainability when it comes to biomass harvesting, and the Forest Service has worked with contractors to establish best management practices for biomass retention. The goal is removing enough biomass to achieve the treatment goals, but not so much that it degrades site productivity or biodiversity.

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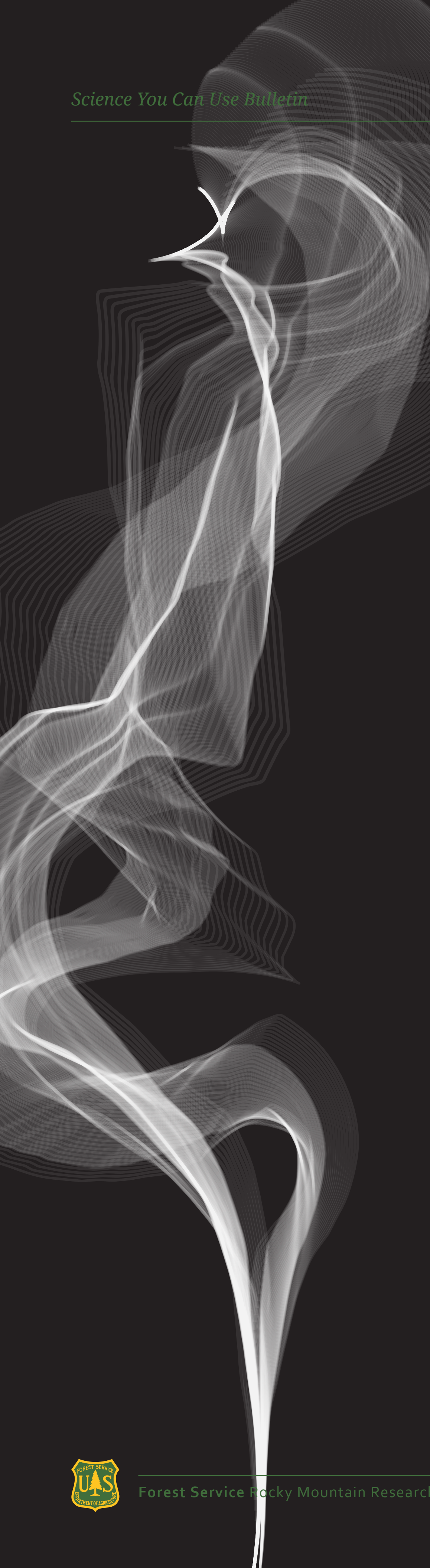
Additionally, researchers collected data on stands in the same area that had been treated 5 to 10 years earlier to determine how long the treatment effects were retained. Worley-Hood admits that these sites aren't a true representation of pre- and post-treatment conditions because the team didn't collect the same pretreatment data on these retrospective stands, but there were important takeaways that could be useful for managers. "Over time, treatments lose their difference in appearance [compared to recently treated stands] and they essentially become more dominated by grass and understory fuel types with that increased sunlight to the forest floor."

Goodburn observed that on these retrospective sites there was substantial recovery of the understory flora in terms of the diversity of plant species and the relative coverage of native shrubs and nonwoody forbs and grasses. “The associated increase in forage for wildlife is, of course, another key objective of these types of restoration treatments, in addition to reduced fire hazard,” Goodburn noted. “One-year post-treatment, we observed increases in some disturbance-related invasives. For example, nonnative thistle species did not appear to persist at higher levels in the retrospective sites, relative to pretreatment.”

When looking at potential fire behavior within the retrospective sites, the team found that a reduction in active crown fire lasted at least 5 to 10 years after treatment. However, they also found evidence showing slightly elevated levels of passive crown fire potential at these retrospective sites, which possibly is related to increases in understory vegetation. This illustrates the importance of pairing mechanical treatments like those implemented on the study sites with prescribed burning to reintroduce periodic low-intensity fire to these forests and maintain their resilient condition.

While much of the focus is on treating these stands to reduce wildfire severity, there are also safety considerations for a park-like forest. “It would be easier for fire fighters to suppress fires in these forest structures rather than an untreated area because the fire will be less intense, canopies are more open,” says Battaglia, adding, “if a wildfire were to happen in these stands—in terms of suppression costs—it would be less expensive in treated versus untreated stands.”

The effects of treatment can be long lasting. This study site is characteristic of stand conditions 5 to 10 years after treatment, showing park-like conditions that are resilient to wildfire.Courtesy photo by Graham Worley-Hood, Alaska Fire Service.



Emissions and Public Health—All Smoke is Not Created Equal

In recent years, attention has turned to the public health effects that large-scale wildfires have on air quality, particularly in the release of particulates in smoke that can exacerbate asthma and other health conditions. Although pile burning is done to mitigate the risk of large-scale wildfires, and generally, it produces more dispersed and less severe smoke conditions than wildfires, this management activity is a contributor to poor air quality, especially during spring and fall burning seasons.

However, if this woody biomass is burned for bioenergy and displaces the use of coal or natural gas, do the same poor air quality issues exist? And are there improved health outcomes by burning woody biomass for energy instead of coal and natural gas, not only in the Southwest but the rest of the United States?

“To our knowledge, this is the only study, only analysis in the southwestern region trying to link the benefits of forest thinning treatments and utilization of woody biomass to be used for renewable energy to public health implications,” says Ching-Hsun Huang, a professor at Virginia Tech.

She and graduate student McKenna Hedgepeth adopted a bottom-up approach to this question by modeling hypothetical scenarios of locating biomass power plants within the study area that would replace the current coal and natural gas plants or retrofitting the existing plants to burn woody biomass. Some locations were based on previously proposed projects that hadn’t actually been built. They also developed a bioenergy scenario based upon an assumption where the states increased the amount of electricity produced from biomass as outlined in their Renewable Portfolio Standards (RPS) to increase net electricity generation from renewable energy within a certain time period.

For these scenarios, Hedgepeth had to track down emissions data for both the burning of fossil fuels and woody biomass. One difficulty they ran into was a lack of emissions data for pile burning and woody biomass electricity generation. Another difficulty was not finding an air quality model developed for forest management activities, such as pile burning.

The team adapted two U.S. Environmental Protection Agency models to their research questions: the CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) and Environmental Benefits Mapping and Program Analysis (BenMAP). COBRA allows users to “estimate the air quality and health benefits of different emissions scenarios.”

NovoBioPower is one of the few bioenergy plants operational in the Southwest. From woody biomass generated from thinning projects on national forests, it produces electricity that is purchased by two utility companies: Arizona Public Services and the Salt River Project. Photos courtesy of Beth Dodson, University of Montana.

These data could then be imported into BenMAP, which estimates the “health impacts and economic value of changes in air quality.” These health impacts include deaths, illnesses, and days missed of work and school.

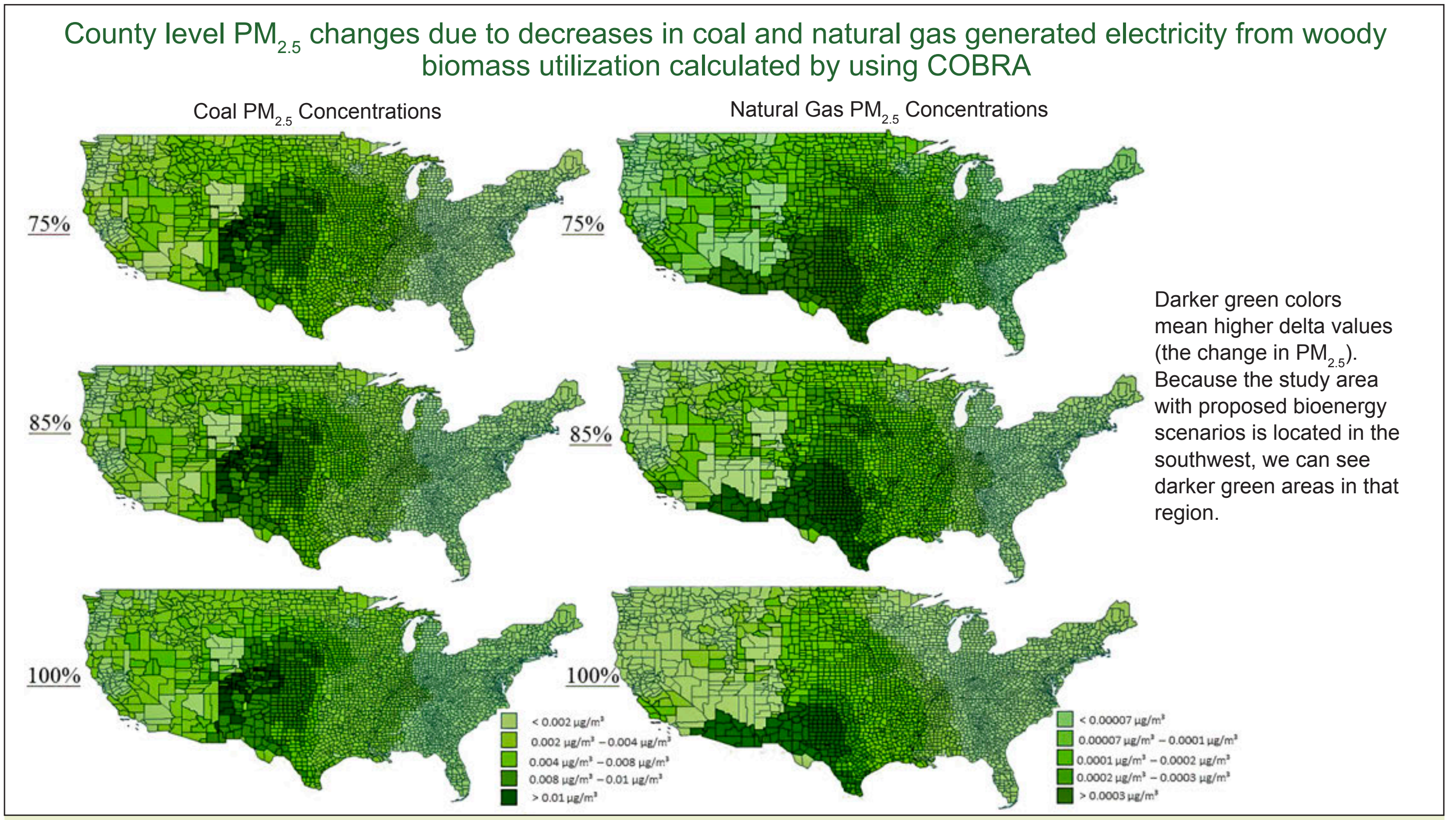
“[These two models] have been utilized to quantify the benefits of renewable energy,” Huang explained. “We were the first study looking into modeling the benefits of using woody biomass from fuel reduction treatments in the southwestern region.”

Huang and Hedgepeth worked with the model developers extensively to determine what data they needed to run the bioenergy scenarios. They generated data not only from their study area but also at the national level, which provided valuable information to help policymakers understand the complex cause-and-effect relationship between biomass energy development and public health.

By displacing fossil fuels with biomass energy, “overall the air quality in those areas is significantly improved, especially for higher population cities,” Hedgepeth says. Yet when looking at specific locales and their sources of electricity, local air quality may decrease when switching from natural gas to biomass. Natural gas is well known as a clean-burning fuel when it comes to stack emissions, with especially low particulates. Natural gas being a cleaner fuel has a caveat though: As a fossil fuel there are social costs of greenhouse gases from natural gas combustion contributing to climate change. The team didn’t account for the social cost of the extraction process of natural gas.

For Huang, it was encouraging to see the effects of displacing fossil fuels with bioenergy extend well beyond the Southwest. “For our research purpose, our focus is on a certain area, but in reality, there are no boundaries,” she says. “The pollution goes everywhere. The impacts are beyond what we imagined when we started the study.”

When looking at the economic outcomes: the scenarios calculated the monetary benefits by summarizing avoided mortalities, hospitalizations, and workdays lost. These benefits were achieved by adopting a woody biomass-based bioenergy to improve air quality. For researchers studying the adverse health effects of air pollution,



Using the CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) tool, Huang and Hedgepeth calculated the county level particulate matter ($PM_{2.5}$) changes due to decreases in coal and natural gas generated electricity from woody biomass utilization. Sources of particulate matter can include soot, metals, dust, and organic chemicals. The reason for caring about this size of $PM_{2.5}$ is because these particles can negatively affect people's health. The COBRA model was developed by the United States Environmental Protection Agency and calculates benefits from reducing air pollutants by applying different policy scenarios. The process model selected was the environmental Benefits Mapping and Analysis Program Community Edition (BenMAP-CE version v.1.4.8) developed by the EPA to estimate economic value of environmental and health impacts caused by changes in air quality. Image courtesy of Ching-Hsun Huang (Virginia Tech) and McKenna Hedgepeth (New Mexico Environment Department).

these metrics are known as "health endpoints." The next step, Hedgepeth says, is looking at "how these interactions change the amount of health endpoints we're seeing, the changes in health endpoints or the changes in hospitalizations and the monetary benefits." In other words, improvements in health and productivity metrics can have real economic value.

Though switching to biomass energy can have net benefits over broad areas, the costs and benefits are not evenly or equally distributed. The northern counties of Arizona, where the biomass plants would be hypothetically located, potentially on Tribal lands, don't receive the same health benefits as more distant locales; they actually would experience an increase in local power plant emissions which are associated with negative health effects. This is compounded by the fact that these communities are already marginalized. Where a bioenergy plant is located will matter a lot—local health effects, proximity to populations, and environmental justice are important aspects of expanding bioenergy production.

Looking ahead, Hedgepeth sees their work as being useful to several stakeholders beyond the Southwest. "California foresters are going to be interested in this because of extreme wildfires there, and areas that are proposing biomass plants will have more incentives for their stakeholders as this is going to be a profitable endeavor," she explains. "Maybe

MANAGEMENT IMPLICATIONS

- Treated timber stands still showed a reduction in crown fire potential 5 to 10 years after treatment. Their more park-like structures also make it easier for firefighters to suppress fires that do start, which reduces suppression costs.
- Pairing mechanical treatments with prescribed burning that reintroduces periodic, low-intensity fires to these forests will help maintain their resilient condition.
- When locating new biomass plants, discussions related to equity are necessary because the communities adjacent to the plants experience different costs and benefits than more distant communities.

not due to financial gains, but they would improve the air quality of the communities in the region and the overall quality of life."

Challenges Faced by Land Managers—In Their Own Words

For her master's thesis, Mary-Ellen Reyna took a qualitative perspective on what's needed to develop sustainable biomass utilization in the Southwest. She interviewed Forest Service staff who worked on the thinning projects or managed the ranger districts where the project was conducted.

One key takeaway was that "biomass utilization had a positive effect where there were nearby markets," says Reyna. "Contractors could sell the biomass to the biomass energy facility for a profit or at least break even on some of the treatments." Staff also emphasized that it was a game-changer when contractors could sell the biomass for revenue because it incentivized the removal of the biomass from the project site.

Where there was a lack of markets, such as in New Mexico, managers disposed of the biomass through prescribed burning, including pile burning.

Just as Anderson and Dodson found that high trucking costs and long hauling distances were barriers to selling the biomass to biomass energy facilities, managers observed the same. "Hauling distances limited how much biomass could be treated or taken to mills because it is so expensive to haul it out," she says, adding that everything is project dependent.

Looking ahead to what is needed to develop markets, Reyna heard that collaboration and greater economic incentives are necessary. All the players—private industry, nonprofits, and government agencies—have a role in developing biomass utilization infrastructure. Additionally, she says, "there is also a need for better long-term funding to really grow biomass utilization so it can better compete with things like solar and wind energy."

Though these sources of renewable electricity generally have lower production costs and lower lifecycle greenhouse gas emissions than biomass power, they do not provide any forest management or wildfire risk benefits, so are not linked to values like watershed protection, recreation, biodiversity, and other ecosystem services. Providing financial incentives for biomass utilization tied to thinning helps protect and enhance these values.

However, accompanying this long-term funding must be a message regarding the long-term supply of biomass. While Reyna conducted her interviews, the Mexican spotted owl injunction was handed down. "The effect that the Mexican spotted owl injunction had on people's perceptions of things like supply guarantees could affect stakeholders wanting to invest in the industry," she says. "Having an injunction close the forest doesn't sound appealing to investors who want to come into the area and build capacity."

Another component that must be developed is the contractor capacity. "The contractor workforce is limiting capacity and what treatments they can do because the workforce is getting old and retiring," Reyna explains. "There's just not enough people learning the trade to replace them."

Despite these barriers, Reyna found that there is an appetite for a sustainable biomass industry in the Southwest. "Everyone said that's what they need," she said. "Although there is apprehension of the realities of growing the industry and its long-term future, if they can remove the small-diameter biomass that is just sitting there waiting to burn, anything helps."

FURTHER READING

Townsend, L.; Dodson, E.; Anderson, N.; Worley-Hood, G.; Goodburn, J. 2019. Harvesting forest biomass in the U.S. southern Rocky Mountains: cost and production rates of five ground-based forest operations. International Journal of Forest Engineering. DOI: 10.1080/14942119.2018.1563851.

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The following individuals were instrumental in the creation of this Bulletin.

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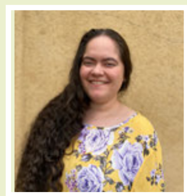
JOHN GOODBURN is an associate professor of silviculture with the University of Montana. His research interests are uneven-aged silviculture, regeneration ecology, and modeling forest dynamics.



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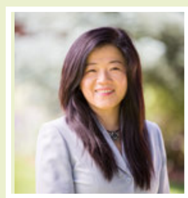

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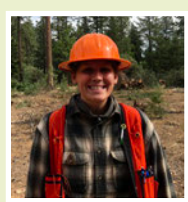

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