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ScienceDirect
Biomass and Bioenergy 31 (2007) 638–645
BIOMASS & BIOENERGY
www.elsevier.com/locate/biombioe

Forest bioenergy system to reduce the hazard of wildfires: White Mountains, Arizona

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Received 11 August 2006; accepted 17 June 2007
Available online 20 August 2007

Abstract

In an innovative effort, the USDA Forest Service is planning to reduce the long-term threat of catastrophic wildfires by inaugurating a series of forest thinnings for bioenergy. The start-up project is in the Nutrioso area of the Alpine Ranger District, Apache-Sitgreaves National Forest. "The Nutrioso Wildland/Urban Interface Fuels Reduction Project", under the authority of the Healthy Forest Restoration Act of 2003, addresses the existing condition of the forest, defines the desired condition of the forest, and proposes actions that will result in a healthier forest and a reduced risk from wildfire. This project is part of larger-scale, small-diameter tree thinning covering an area of 607 km^2 over a 10-yr period. Although the Nutrioso Project encompasses 213 km^2 of mixed ownerships, only National Forest lands (79%) will be treated. A variety of thinning and fire prescriptions have been established depending on slopes, road access, and distance from private land. The mostly small-diameter (<12 cm) trees in ponderosa pine and mixed conifer stands are being removed under a "Stewardship Contract" for utilization in small power plants (<3 MW), and a wood-heating pellet manufacturing facility. The outlet for the wood fuel pellets is the growing market for house and business heating, and co-generation fuel in a 615 MW coal-fired power station. This paper examines the scope, costs, and environmental trade-offs of this pioneering and remarkably successful effort in forest bioenergy in the southwestern USA.
Published by Elsevier Ltd.

Keywords: Thinning; Wildland–urban interface; *Pinus ponderosa*; Stewardship contracts; Fuels treatments; USDA Forest Service; Arizona

1. Introduction

1.1. Background

After a series of large wildfires (<200 km^2) on the Mogollon Rim of Arizona (34°22′N latitude, 110°37′W longitude), a partnership of federal, state, local, and private organizations began fire risk reduction programs in 1997. The objective was to restore overstocked conifer forests around wildland–urban interface (WUI) zones [1–4]. These forests make up the largest contiguous portion of the 162,000 km^2 of ponderosa pine (*Pinus ponderosa*) forest in North America. Prior to European settlement in the 1860s, the ponderosa pine forest consisted of relatively open stands of large-diameter ponderosa pine with a significant grass-forb understory. Tree numbers averaged 75–125 trees ha^{-1}, arranged mostly in small groups. Light surface fires occurred on the landscape at an average interval of 2–7 yr. These low-severity fires consumed forest floor material, burned most of the young regeneration, and promoted growth of a dense, grassy understory. Catastrophic crown fires were rare due to the lack of ladder fuels, and the clumpy widely spaced ponderosa pine canopy [5–7].

Heavy sheep and cattle grazing followed by modern forest fire control for most of the 20th century stopped forest and grass fires in ecosystems that were fire-adapted [8]. This resulted in the development of dense, overstocked stands that have created the current wildfire crisis. These stands typically have tree numbers ranging from 500 to 5000 ha^{-1} with canopy closures that range from 50% to 70% but often approach 100%. An occasional juniper (*Juniperus* spp.), pinyon pine (*Pinus edulis*), Douglas fir

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0961-9534/$ - see front matter Published by Elsevier Ltd.
doi:10.1016/j.biombioe.2007.06.028

(*Pseudotsuga menziesii*), white fir (*Abies concolor*), Gambel oak (*Quercus gambelii*), limber pine (*Pinus flexilis*) or aspen (*Populus tremuloides*) are scattered among the pine stands. Insect and disease problems include dwarf mistletoe (*Arceuthobium* spp.) and periodic episodes of various bark beetles. Forest floor fuel loads that were 0.4–4.5 t ha^{-1} prior to 1870 increased by nearly two orders of magnitude to an average of 49 t ha^{-1} with some stands accumulating up to 112 t ha^{-1} [9]. Many ponderosa pine stands reached a critical ecological point late in the 20th century so that wildfires frequently consumed 4–5 times the area burned in the period from 1910 to 1990, greatly increasing damage to watersheds [10–12].

1.2. Rodeo–Chediski wildfire 2002

The Rodeo–Chediski Fire was actually two fires that ignited on the White Mountain Apache Reservation and merged into one. In the afternoon of June 18th, 2002, an arson fire northeast of Cibeque near the Rodeo Fairgrounds on the Reservation burned between 40 and 120 ha by nightfall. By mid-morning on the 20th, the Rodeo Fire had expanded to 121 km^2. Meanwhile, a second blaze was ignited near Chediski Peak northwest of Cibeque when a lost hiker started a signal fire. At that point of time, the two fires were about 24 km apart. Two days later, the fires merged to encompass more than 951 km^2. Over the next 2 weeks, the fire burned another 810 km^2 ha, becoming the largest and most severe fire in Arizona's history. The Rodeo–Chediski Fire burned across the northern portion of the White Mountain Apache Nation, into the Apache-Sitgreaves National Forest, and into communities scattered along the Mogollon Rim from Heber to Show Low. Over 30,000 local people were eventually forced to flee the inferno.

By the time that most of the multi-agency team of firefighters left the area on July 13th, the Rodeo–Chediski Fire suppression cost was almost 43 M$ but other costs and losses increased the total to 153 M$. Nearly 500 buildings were destroyed, with over one-half of the burned structures being the houses of local residents or second-homes of summer visitors. Watershed rehabilitation efforts began immediately after the fire was controlled and it was declared safe to enter into the burned area. The rehabilitation costs totaled another 20 M$.

Harvesting of fire-damaged trees of commercial value that were not expected to survive began on Apache lands in late fall, 2002. Fire-salvage logging was delayed 2 yr on National Forest lands due to National Environmental Protection Act (NEPA) and Endangered Species Act considerations, challenges, and litigations. The Forest finally sold 897,000 m^3 in fire-salvage sales. Over 849,500 m^3 of salvageable, mostly ponderosa pine, timber was harvested on White Mountain Apache Tribal lands in this emergency operation by the early summer of 2003. In a normal year, about 94,392 m^3 of timber is harvested from these forests. Because of the fire, future timber sales on White Mountain Apache lands will be comparatively small.

The environmental cost of this wildfire includes damage to the forests, watersheds, and wildlife of the White Mountains. In addition to the 153 M$, the Federal government's fire-related expenditures, over 500 structures were lost with a value of over 50 M$. The foregone wood volume on just the White Mountain Apache land alone is over 14 Mm^3, a significant economic impact.

1.3. White Mountains wildland–urban interface situation

The loss of 500 homes and other structures in the Rodeo–Chediski Fire was a wake-up call for local communities that have a continuous cover of pine from the Apache-Sitgreaves National Forest, White Mountain Apache Tribe, State of Arizona, and private lands. Local communities and four county governments pooled their money to complete community fire plans that seamlessly span the WUI across the White Mountains. These plans addressed not only the WUI boundaries and priorities for hazardous fuels treatments, but also identified community watersheds at risk and evacuation needs. While some groups have suggested that the WUI boundaries are as narrow as 200 m around private land and structures, the real WUI boundaries are often 5–8 km deep due the risk of fast-moving crown fires and heavy fuel continuities. Community input also suggested treatment prescriptions, which gave the Apache-Sitgreaves National Forest a large head start in conducting NEPA analyses and public involvement. The community plans proposed ordinances, which are now being enacted, which would require landowners to reduce the risk of fire on their property. After completing the community fire plans, one of the counties received 1 M$ in Rural Community Assistance Grants to cost-share the private land thinning.

The White Mountain Apache Tribe had already accelerated their thinning and burning programs around the communities. Based on the WUI boundaries and priorities contained in the plan, the Apache-Sitgreaves National Forest determined that there were 607 km^2 of ponderosa pine forests in the WUI that were seriously overstocked and vulnerable to fire and insect attacks. Thus, the Forest offered a 10-yr stewardship contract to thin at least 607–3035 km^2. This action broke the wood supply log jam that had hindered full development of a forest-based bioenergy program in Arizona.

2. White Mountain stewardship contract

2.1. Stewardship contracts

The Authority for the White Mountains Stewardship Contract is the Omnibus Appropriations Act for Fiscal Year 2003 [13]. This act authorized the USDA Forest Service and the USDI Bureau of Land Management (BLM) to undertake stewardship contracting projects, also known as stewardship contracting, for a period of up to 10 yr. The stewardship end-result contracting provision

was passed on February 20, 2003, and authorized by section 323 of Public Law 108-7. This Law defines stewardship contracting as: "….those activities used to accomplish the goals set forward in Section 323 of Public Law 108-7 whereby the Forest Service and the BLM would enter into contract or agreement, including consideration of source under public and private contracts, for services to achieve land management goals and meet local and rural community needs. In addition, the contract or agreement is awarded on a best-value basis." Federal Agency direction provides that stewardship contracts must include at least one of the new authorities granted by the legislation where (1) the value of timber and other forest products is applied as an offset against the cost of services received or (2) a multi-year contract authority greater than 5 yr but not to exceed 10 yr is used. A notice of interim guidelines on stewardship contracting, with opportunity for public comment, was published in the Federal Register on June 27, 2003, jointly by the USDA Forest Service and the BLM. Public input was accepted in writing until July 28, 2003.

Stewardship contracting emphasizes on-the-ground results and up-front collaboration with States, Tribes, local communities, and other interested parties. It also emphasizes identifying and maintaining strong relationships of trusts with the public. To comply with existing laws and policies, Stewardship Contracting Projects are directed to meet the intent of the Forest Service's land use plans and management policies relating to existing special designations (e.g., Wilderness). The projects are further directed to comply with the NEPA and other laws such as Endangered Species Act, Clean Water Act, and Clean Air Act.

2.2. White Mountains project goals and benefits

The purpose of the White Mountains Stewardship Contract is to procure a long-term (10-yr) complete set of services to accomplish landscape stand treatments for the variety of Forest Health issues. The goals of the contract are to treat all the ponderosa pine WUI in Forest Service lands in the White Mountains, support local economies, reduce the costs of treatment, and encourage new wood fiber industries, including bioenergy, by providing a commitment of wood for 10 yr. This is the first long-term stewardship contract in effect in the United States, so many problems and authorities had to be worked out prior to awarding the contract in September.

One advantage of the contract is that neighboring national forests can offer wood for utilization with no upper limit, except budget limitations, on how much can be offered. If at the end of the year, other National Forests or regions have money left and fuels targets left, the Forest is allowed to obligate the surplus money and targets instantly. Another advantage is that the cost of treatments under the contract are 30–50% lower than they were prior to the contract and there are several new fiber industries interested in locating in the area, which would further reduce costs. Another major advantage of this type of contract is that it combines separate operations into one Stewardship Contract, thereby taking advantage of the efficiencies of having one larger operation to meet multiple objectives and provide for a healthier forest. The contract also has the ability to procure a long-term (10 yr) complete set of services to accomplish landscape stand treatments for the variety of forest health issues as well as accomplishing the goal of reducing the effects of wildfire in and around the White Mountains WUI.

The contract specifically states that the awarded contractors shall provide services to perform biomass management that may include tree removal, treatment of existing slash and dead trees, erosion control, resource protection, and haul road maintenance for a period of 10 yr from date of award under the Stewardship Authority. The contract is estimated to cost the Forest service 4 M$ the 1st year and 60 M$ over the 10-yr life of the project. The total project cost estimate is 27% of the costs of the Rodeo–Chediski Fire.

2.3. Partnership and collaboration

A Multi-Party Community Monitoring Board has been established for the project. An existing citizens' Natural Resources Working Group has been active for 7 yr, providing collaborative input to forest management. The Multi-Party Community Monitoring Board represents a broad group of interests that makes recommendations to the Apache-Sitgreaves National Forest on environmental, social and economic goals relating to the stewardship contract and other healthy forest projects. These recommendations are considered by the forest in adaptive management of future projects and monitoring of those projects.

The ecological, economic, and social goals include definitions of indicators, status, responsible parties, and methods for determination. The main goals are displayed in Tables 1–3. Table 4 lists the indicators for just Ecological Goal Number 1 to give a representative list of indicators used for just one of the goals.

The National Forests/Community Partnership for Restoration (NF/CPR) has helped establish excellent working relationships between the Eastern Arizona Counties and the Apache-Sitgreaves National Forest. The highest priority for forest restoration has been agreed upon by all parties as thinning forests in the White Mountains WUI. In Arizona, NF/CPR has been involved with the Natural Resources Working Group in Eastern Arizona, which includes community members from diverse backgrounds who meet monthly to discuss and help plan for improvement projects on 69 km^2 near the towns of Pinetop and Lakeside. Several different treatment prescriptions have been applied on the ground and NF/CPR and Northern Arizona University have been involved with the planning and monitoring of results.

Table 1
White Mountain Stewardship Contract, Multi-Party Community Monitoring Board categories and goals: 1—ecological

Category	Goal
Ecological 1	Reduce the threat of large, high-severity wildfire, improve the ability to control fires near communities and restore the role of fire in the ecosystem
Ecological 2	To improve and maintain habitat quality and vegetative structure for diverse species populations
Ecological 3	To improve and maintain watershed function
Ecological 4	To maintain or increase long-term soil productivity
Ecological 5	To quantify invasive plant populations, both spread of existing and new populations
Ecological 6	To improve understanding of unanticipated consequences of treatments
Ecological 7	Measure changes in air quality due to changes in prescribed burning or wildfires

Table 2
White Mountain Stewardship Contract, Multi-Party Community Monitoring Board categories and goals: 2—economic

Category	Goal
Economic 1	To decrease the cost per acre of forest treatment
Economic 2	To increase the local industrial capacity to utilize the wood fiber generated by the stewardship contract
Economic 3	To increase local stability
Economic 4	To track and report costs and benefits of various treatments
Economic 5	To increase local economic activity related to forest-based tourism and recreation
Economic 6	To increase property values both regionally and in wildland urban interface (WUI) areas
Economic 7	Evaluate efficiency and effectiveness of the 10-yr contract
Economic 8	To track the transfer and use of the latest and most appropriate technologies and best practices in forest treatment and utilization of the resulting wood fiber
Economic 9	To increase local economic development
Economic 10	Develop and use a number of standard, longitudinal economic measures that can apply to most stewardship contracts

Table 3
White Mountain Stewardship Contract, Multi-Party Community Monitoring Board categories and goals: 3—social

Category	Goal
Social 1	Do people feel that the threat of high-intensity fire near or within communities has decreased due to treatments?
Social 2	Do people understand, accept and support active ecosystem management at the landscape scale?
Social 3	To insure that forest restoration/fuels reduction treatments meet local community expectations and desired future conditions
Social 4	To measure the change in public awareness, knowledge, education, and outreach
Social 5	Measure whether collaboration is occurring, and the public perception of the value and effectiveness of collaboration
Social 6	Measure broad-based understanding, support and acceptance of the Community Wildfire Plan, and how they are implemented through stewardship contracting
Social 7	Are we meeting the expectation and needs of tribal government and tribal members?
Social 8	How should the Monitoring Board keep the public informed about the project?

Table 4
White Mountain Stewardship Contract, Multi-Party Community Monitoring Board categories and goals: examples of indicators for Ecological Goal 1

Category	Goals	Indicators
Ecological 1	Reduce the threat of large, high-intensity wildfire, improve our ability to control fires near communities and restore the role of fire in the ecosystem	Ecological/forest models: change in FVS, Fire Regime Condition Class (FRCC), tons of biomass left in the woods
		Change in canopy cover and crown bulk density
		Change in density and size of trees, old growth characteristics, dbh
		Change in openings (grasslands) and meadow restoration
		Health of the residual trees
		Change in fuel loading
		Change in fire behavior
		Change in fire effects
		Maintenance of stand structure over time

2.4. Using healthy forest restoration act tools

The Apache-Sitgreaves National Forest is using the Healthy Forest Restoration Act (HFRA) NEPA tools to streamline environmental analysis [13]. Environmental organizations are supporting the contract. The forest had about 336 km^2 of fuel treatment projects that were finished with the NEPA analysis, but burned in the Rodeo–Chediski Fire. There are currently 126 km^2 remaining that have been through NEPA analysis and will cover about 2 yr of contract treatments. That leaves 486 km^2 that require additional NEPA analysis coverage.

One alternative to the NEPA analysis problem was to prepare one large Environmental Impact Statement (EIS) to cover the entire 486 km^2 of projects (spanning closer to 1010 km^2 of analysis area). This alternative was rejected because it would be difficult to make such a large EIS site-specific, and the EIS would probably not have a 10 yr "shelf life". The new cumulative effects (CE) and streamlined fuels environmental analysis (EA) tools created by HFRA offer the perfect solution.

The strategy employed in the White Mountains Stewardship Contract is to use the CE authorities for smaller, more isolated projects that are 4 km^2 or less. Many of the

projects will have 40–121 km^2 analysis areas, and the streamlined fuels EA template will be used [13]. Environmental effects will be analyzed on two levels, project level and landscape level, across the entire forest. The thinning projects are fairly uniform, so it will be easier to generalize some effects. Since the fuels EA allows the Apache-Sitgreaves National Forest to reference other documents and summarize impacts, white papers have been prepared for landscape level topics such as the broad-scale cumulative effects of thinning 607 km^2, the effects of thinning on threatened, endangered and management indicator species habitats, the benefits of thinning pine forests to reduce fire hazard, and the social and economic effects of the White Mountains project. The EAs contain site-specific cumulative and project effects, and reference other NEPA documents, white papers and scientific reports, making the NEPA documents brief. The Forest signed the 121 km^2 Greer, Arizona, WUI Streamlined EA with no objections filed, and has started two more analyses of similar-sized areas. So far there are 16 projects in progress using HFRA NEPA analysis tools [13]. The Apache-Sitgreaves National Forest completed 283 km^2 of new NEPA analyses with only one challenge, a substantial achievement.

The new direction in the HFRA has been beneficial because it limits the range of alternatives and further focuses the NEPA analysis to fuels treatments to reduce the hazard to communities. The first step in the process was the completion of the Community Fire Plans across the Apache-Sitgreaves National Forest, following HFRA guidance, which defines the WUI boundaries through a collaborative process. All the counties, tribes, and communities subsequently worked together to prioritize and coordinate the WUI project needs across ownership lines.

2.5. Current status

The White Mountain Stewardship Contract amounts to 19–90 M$, depending on treatment methods and final areas (202–607 km^2) chosen over the 10-yr term of the contract. It was awarded to two companies that have worked together for over 5 yr on other projects. These companies make up Future Forests LLC (Limited Liability Corporation). Future Forests consists of WB Contracting, based in Eagar, Arizona, and Forest Energy Products based in Show Low, Arizona. WB Contracting has more than 18 yr of experience specializing in forest landscape restoration, thinning, piling, chipping, transporting and marketing of wood fiber, seeding, water bar construction, and contour falling. Forest Energy Products has operated for 13 yr in as a pellet manufacturer producing high-density wood pellets used for fuel, animal bedding and litter, absorbents, re-vegetation material, and high-density wood logs for use in wood stoves and campfires. It currently utilizes over current consumption 90.72 Gg (green wood at 50% moisture).

In 2004, the Apache-Sitgreaves National Forest released almost 49 km^2 to the Stewardship Contract prime contractor for thinning. On-the-ground work was initiated on an additional 49 km^2 of task orders in Fiscal Year 2004. NEPA analyses were completed on the Greer WUI, approving (with no challenges) 81 km^2 of treatment, and NEPA analyses are under way for two other WUI areas (Nutrioso, Fig. 1; and Nagel) at about 81 km^2 each. The forest offered over 61 km^2 of task orders in fiscal year 2005 and it was able to conduct extensive prescribed fires. About 20 km^2 of task orders were covered at \$61,800/km^2 per the Stewardship agreement. The contract allows a price that averages \$86,400/km^2.

On October 20, 2004, Mark Rey, Under Secretary for the USDA, Harv Forsgren, Regional Forester, Southwestern Region, USDA Forest Service, Elaine Zieroth, Apache-Sitgreaves National Forest Supervisor, along with local, county and state dignitaries attended a ceremony commemorating the beginning of work on the White Mountain Stewardship project. Arizona Governor Janet Napolitano also praised the Stewardship efforts at the Western Governors' Conference.

3. Forest bioenergy options

3.1. Overview

Neary et al. [6] examined the major market opportunities for biomass removed from ponderosa pine forest restoration operations relative to bioenergy use. The major opportunity in the late 1990s appeared to be local firewood sales, pelletized chunkwood production, specialty fire log production, and ethanol synthesis. The keys to success in the development of a mature bioenergy market with a wider variety of products, including electrical generation, were identified as new processing technologies and the long-term availability of a wood residue supply. The latter was a fairly intractable problem since the majority of the woody biomass potentially available for bioenergy was on Federal land, mostly USDA Forest Service. The White Mountains Stewardship Contract solved the problem and instantly created many new opportunities for utilization of small-diameter woody biomass.

3.2. Small bioenergy power plants—3 MW

One 3 MW biomass power plant is currently in operation using woody biomass removed from White Mountains Stewardship Contract projects. This plant, the Stone Forest Biomass Project, located at Eager, Arizona, was built in 2003 with the assistance of Arizona Public Service Company (APS) and is operated by Western Renewable Energy [14]. It utilizes the output of fuels treatments on 11 km^2 of National Forest lands within the White Mountains Stewardship Contract area. The biomass power plant burns 87 $t\,d^{-1}$ of woody biomass, providing the energy for up to 3000 homes in the region. APS expects to reduce greenhouse gas emissions by up to 13,605 $t\,yr^{-1}$ for each power plant by generating power from woody

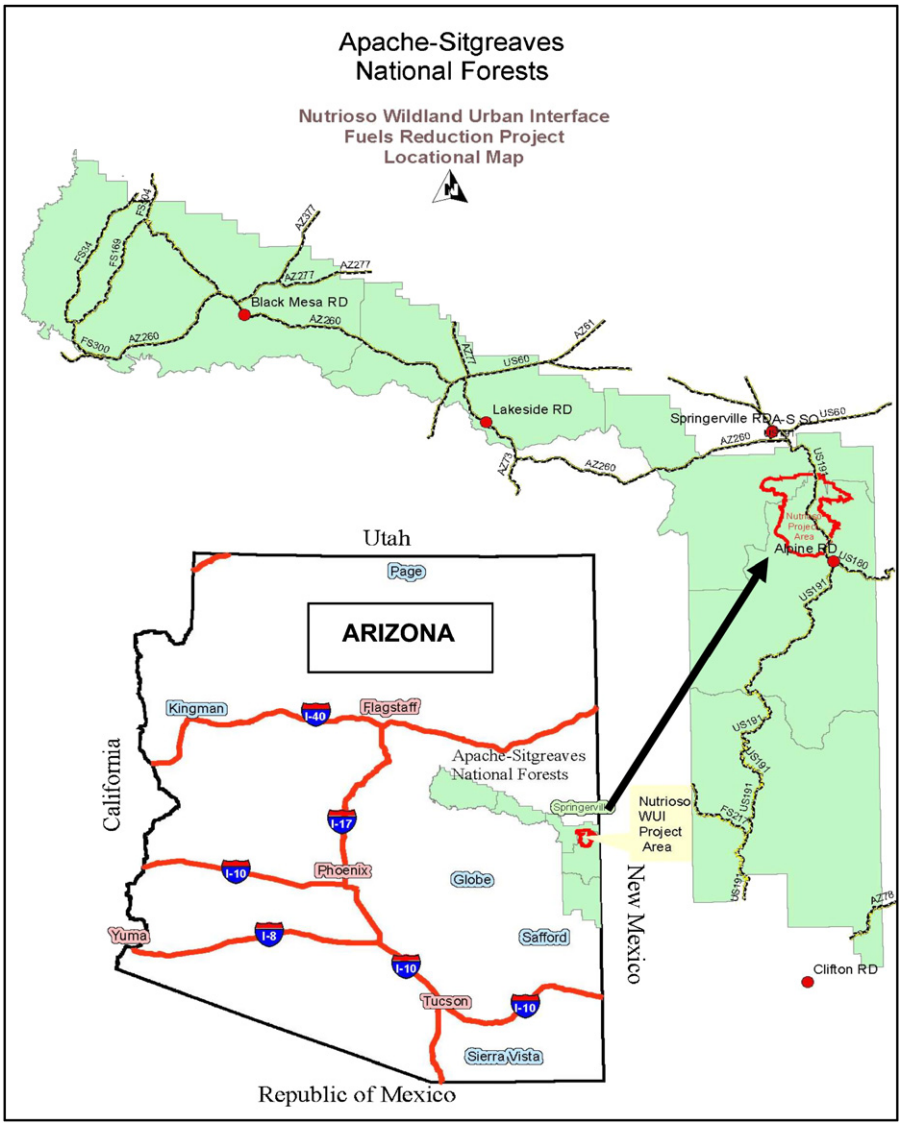

Fig. 1. Nutrioso WUI fuels reduction project, Apache-Sitgreaves National Forest, Arizona, 2005.

biomass. Other 3 MW plants are being evaluated elsewhere in the region.

3.3. *Wood pellets for large buildings and co-fueling existing coal-fired power plants*

Forest Energy Products currently produces wood pellets for home and business heating. It utilizes 90,700 t yr^{-1} of green fuel from the Rodeo–Chediski Fire, the White Mountain Apache Tribe thinning operations and fire salvage, and the White Mountain Stewardship Contract. The company has considerable capacity for increased production, and is currently in the process of increasing its production. Forest Energy Products has produced wood pellets for wood stoves and other uses for over 13 yr. The company expanded from the residential energy market into business and municipal building heating in the past few years. It is working with APS on a proposal to 25% co-fuel the 615 MW coal-fired Cholla Power Station at Joseph City, Arizona, with 25% wood pellets. The estimate of the woody fuel need of a 615 MW station operating 8000 h yr^{-1} is over 800 kt yr^{-1} (Overend, R.P., pers. comm.). The ponderosa pine area alone of the Apache-Sitgreaves National Forest, the Coconino National Forest, and the White Mountain Apache Nation could supply over 37 yr of wood fuel [15]. This does not include other supply sources such as ponderosa pine slash, pinyon–juniper fuels, or additional salvage from the Rodeo–Chediski Fire. This effort would contribute greatly to utilization of small diameter woody biomass, improve the bioenergy portfolio in Arizona, and reduce emissions from the coal-fired plants in the State.

3.4. *Abitibi mill 20 MW bioenergy power station*

A feasibility study is under way to develop the largest biomass energy plant in the United States in 15 yr. The Snowflake White Mountain Power (SWMP) Project is an

effort to construct and operate a 20 MW (net) biomass-fueled power plant on the site of Abitibi Consolidated's paper mill outside Snowflake, Arizona. The plant will be fueled by a combination of paper fiber unusable in Abitibi's paper recycling operation and wood residues from forest management and milling activity in the White Mountains of Arizona.

The key pieces of the project will be used equipment. The boiler selected for use is a 87 t h^{-1} Babcock & Wilcox bubbling fluidized bed unit from a closed Abitibi mill in Sheldon, Texas. Until 2002, this boiler burned a mixture of paper fiber and wood residue. The turbine-generator will be either a unit from the Sheldon mill matched to this boiler or another used unit, of which three are currently under consideration. The balance of plant equipment will be either new equipment or good used equipment matched to this service. The plant will feature a wet cooling tower, with makeup water being supplied from Abitibi's existing well field.

Power output from the facility will be sold via two long-term (10-yr primary term) power purchase agreements to Salt River Project (SRP) and APS, both located in Phoenix, Arizona. Each contract will be for approximately 10 MW on a full time basis, with the SRP contract containing the further requirement that 80% of the fuel come from forest management activities. The SWMP will interconnect to the two utilities through Abitibi's existing 69 kV substation on the APS system.

The SWMP plant will be located on the Abitibi site at Snowflake. It will be operated by Abitibi personnel and receive a bundle of utility services that will not need to be duplicated in the design of the plant. Abitibi will also be responsible for wastewater and ash disposal through its existing systems. The Abitibi paper mill plant is located in a rural area of northeastern Arizona at an elevation of 1829 m in an area that is already in compliance with all ambient air quality standards. The SWMP boiler will be equipped with a multiclone and baghouse for particulate control, urea injection for nitrogen oxides control, and will be capable of injecting limestone into the fluidized bed for sulfur dioxide control, though this is not expected due to the alkaline nature of the paper fiber ash. Each single-criteria pollutant will be emitted at less than 227 t y^{-1}, so an air quality review is not required.

The fuel plan for SWMP anticipates combusting 227 t of dry paper fiber from the Abitibi mill plus 90,700 t of bone dry wood residue to produce 20 MW of power. The annual quantity of wood residue required was calculated using data from the Abitibi paper fiber residue production, the boiler output parameters, and wood residue heating value and moisture content. Forest fuels needed for the 20 MW SWMP power station adds another 3% to the fuel needs calculated for 25% co-fueling the 615 MW coal-fired Cholla Power Station at Joseph City, Arizona (Overend, R.P., pers. comm.).

4. Summary and conclusions

Starting in the early 1990s, large, high-severity wildfires began breaking out in the Southwest of the United States due to significant build-up of small-diameter fuels in ponderosa pine and other forest types. These fires were completely out of the normal range of variability for forest fires experienced in the 20th century. There has been a general consensus that prevention of large wildfires rested on programs to remove woody biomass from the forests and restore natural fire regimes. One of the problems has always been utilization of this resource on the 23,000 km^2 of overstocked forests in the Southwest. The key to the success of this endeavor was identified as providing a long-term, local supply of wood for forest processing industries. This would allow development of economically viable, small-dimension forest products and markets. In light of the developing energy situation in the United States, bioenergy products were recognized as having a strong future in this endeavor.

The innovative White Mountains Stewardship Contract has provided the leverage for rapid advancements in the field of bioenergy in Arizona and the Southwest. The guarantee of wood supply made possible by the Contract has completely changed the economic picture and allowed development of plans for small 3 MW biomass power plants as well as a larger 20 MW plant. The latter will be the largest bioenergy power plant to be constructed in the United States in 15 yr. Other plans include expansion of wood pellet use for commercial properties as well as co-firing coal power plants.

The cooperation of federal government agencies, state agencies, local governments, Native American tribes, and private enterprises in development of the White Mountains Stewardship Contract is a model that can be applied elsewhere. The groups involved in this effort have engaged in a national leadership role. This cooperation has led to an environmentally sound solution that has produced a tool to mitigate a serious wildfire problem as well as advance alternative energy production for the country.

Acknowledgments

We thank Future Forests LLC, Carlson Small Energy Consultants, Arizona Public Service Company, and the staff of the Apache-Sitgreaves National Forest for providing information for this paper.

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